SPECIES ACCOUNT: *Antrolana lira* (Madison Cave isopod)

Species Taxonomic and Listing Information

Listing Status: Threatened; 10/04/1982; Northeast Region (R5)

Physical Description

Albinistic; eyeless. Body flattened with anterior margin of head projecting as shelf beyond bases of both antennae. Pereiopods 1-3 prehensile, 4-7 ambulatory; exopod of pleopod 2, and endopods of pleopod 3-5 1-segmented. 1 cm in length (NatureServe, 2015).

Taxonomy

Thismonotypic genusis the only member of the family Cirolanidae found north of Texas (USFWS, 1996).

Historical Range

It is endemic to the Shenandoah Valley in Virginia. Until 1990, A. lira was known only from two sites, Madison Saltpetre Cave and a fissure near the cave (USFWS, 1996).

Current Range

The northernmost of the seven sites where A. lira occurs is Front Royal Caverns in Warren County, Virginia. Ranging from north to south, the other sites are 3-D Maze Cave, Devils Hole Cave, Linville Quarry Cave No. 3 and Massanutten Caverns in Rockingham County, and the Cave Hill sites, Steger's Fissure and Madison Saltpetre Cave, in Augusta County (USFWS, 1996).

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: Probably sifts sediments and is a general opportunistic feeder; detritivore. Lives in permanent darkness. Presumably rhythms more keyed to seasonal inputs of energy into habitat (NatureServe, 2015). Other than the fact that A. lira is attracted to and will readily consume the shrimp used as bait, and that insect parts were detected in the gut content of some individuals from Steger's Fissure (J.R Holsinger pers. comm. 1995), its feeding habit is also unknown (USFWS, 1996).

Reproduction Narrative

Adult: How A. lira reproduces is unknown. The Madison Cave isopod appears to have low reproductive potential. The female-biased sex ratios were 2.2 females to male at Madison Saltpetre Cave, 3.5 at Steger's Fissure, and 3.7 at all other sites combined. The apparently adult-dominated population structure of A. lira suggests that it has a lengthy life span (USFWS, 1996).

Environmental Specificity

Adult: Very narrow (inferred from NatureServe, 2015)

Habitat Narrative

Adult: Inhabits deep, subterranean lakes with silt and talus bottoms (NatureServe, 2015). The small population size at most of its sites indicates that it is highly sensitive to disturbance. The species is known only from areas where fissures descend to the groundwater table, thus allowing access to the surface of underground lakes, or deep karst aquifers. L (USFWS, 1996).

Dispersal/Migration

Motility/Mobility

Adult: Moderate (NatureServe, 2015)

Dispersal/Migration Narrative

Adult: Mostly benthic walkers, but strong swimmers when disturbed (NatureServe, 2015).

Population Information and Trends

Population Trends:

Not available

Number of Populations:

2 - 6 (USFWS, 1996)

Population Narrative:

Although specimens from all seven sites are morphologically identical, they probably represent more than one but less than seven genetic populations (USFWS, 1996).

Threats and Stressors

Stressor: Pollution (USFWS, 1996)
Exposure:
Response:
Consequence:
Narrative: Expanding urban development, especially in the northern part of the range of A. lira, has increased the probability of pollutants entering the groundwater. Pollution from agricultural runoff is a real threat because of extensive agriculture in the Shenandoah Valley. Of special concern is the rapid expansion of intensive poultry farming practices in karst regions (Berryhill 1994) (USFWS, 1996).

Stressor: Development (USFWS, 1996)
Exposure:
Response:
Consequence:
Narrative: One entrance to Front Royal Caverns was destroyed by the widening of U.S. Highway 340; a second entrance is in a sinkhole less than 10 m west of Highway 340 just south of the city of Front Royal. On the east side of the highway opposite the cave entrance is a busy street that leads into a large housing development. Within the last decade, approximately 14 homes, the new entrance to Shenandoah National Park, and a large church have been constructed in the immediate recharge area of the Front Royal Caverns aquifer (USFWS, 1996).

Recovery

Reclassification Criteria:
Not available

Recovery Priority Number: 4

Delisting Criteria:
1. Populations of Antrolana lira and groundwater quality at Front Royal Caverns, Linville Quarry Cave No. 3, and Madison Saltpetre Cave/Steger's Fissure are shown to be stable over a ten-year monitoring period (USFWS, 1996).

2. The recharge zone of the deep karst aquifer at each of the population sites identified in criterion I is protected from all significant contamination sources (USFWS, 1996).

3. Sufficient population sites are protected to maintain the genetic diversity of the species (USFWS, 1996).

Recovery Actions:
- Determine the number of genetic populations of A. lira (USFWS, 1996).
- Search for additional populations (USFWS, 1996).
- Identify potential sources and entry points of contamination of their deep karst aquifer habitat (USFWS, 1996).
- Protect known populations and habitats, taking a watershed perspective (USFWS, 1996).
- Collect baseline ecological data relevant to management and recovery (USFWS, 1996).
- Implement a program to monitor progress of the recovery plan (USFWS, 1996).
- Madison Saltpetre Cave, the type locality of Antrolana lira, is protected through cooperation between the property owner and cave conservation organizations (USFWS, 1996).
- In 1994, the federal Nonpoint Source Program funded a Virginia Department of Conservation and Recreation multi-year demonstration project to delineate groundwater basin boundaries with the deep aquifer habitat of Antrolana lira in Front Royal Caverns (T. Brown in litt. 1996). The data resulting from this project should help in setting protection priorities for the species (USFWS, 1996).

References

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SPECIES ACCOUNT: *Branchinecta conservatio* (Conservancy fairy shrimp)

Species Taxonomic and Listing Information

Listing Status: Endangered; 9/19/1994; Pacific Southwest (R8) (USFWS, 2016)

Physical Description

A tiny freshwater crustacean with delicate elongate body, large stalked compound eyes, and 11 pairs of phyllopods (swimming legs that also function as gills). Conservancy fairy shrimp do not have a hard shell, a characteristic of the order Anostraca to which they belong. This species can be differentiated from other branchinectids by the flattened portions of its antennae (USFWS, 2012).

Taxonomy

In the order Anostraca (USFWS, 2012)

Historical Range

Conservancy fairy shrimp are endemic to vernal pools in California (USFWS, 2012).

Current Range

Restricted to the California Great Central Valley with one outlying population in Ventura County in the Interior Coast Ranges (Erikson and Belk, 1999) (NatureServe, 2015).

Critical Habitat Designated

Yes; 8/6/2003.

Legal Description

The Fish and Wildlife Service (Service), designated approximately 858,846 acres (ac) (347,563 hectares (ha)) of critical habitat for 4 vernal pool crustaceans and 11 vernal pool plants in 34 counties in California and 1 county in southern Oregon in a final rule of August 11, 2005 (70 FR 46924). That rule designated critical habitat for the 15 vernal pool species collectively. Pursuant to that rule, on February 10, 2006, the Service published species-specific unit descriptions and maps for the 15 species. This rule specifically identifies the critical habitat for each individual species identified in the August 11, 2005, final rule.

Critical Habitat Designation

Critical habitat is designated in 8 units totaling 161,786.

Unit 1 Tehama County, California. Unit 1A: Tehama County, California. From USGS 1:24,000 topographic quadrangles Richardson Springs, and Acorn Hollow. Unit 1B: Tehama County, California. From USGS 1:24,000 topographic quadrangle Richardson Springs NW. Unit 1C: Tehama County, California. From USGS 1:24,000 topographic quadrangle Richardson Springs NW. Unit 1D: Tehama County, and Butte County, California. From USGS 1:24,000 topographic quadrangles Richardson Springs NW, Campbell Mound, Richardson Springs. Unit 1E: Butte County, California. From USGS 1:24,000 topographic quadrangles Richardson Springs.

Unit 3: Solano County, California. From USGS 1:24,000 topographic quadrangles Elmira, and Denverton.

Unit 5: Stanislaus County, California. From USGS 1:24,000 topographic quadrangle Ripon.

Unit 6: Merced County, and Mariposa County, California. From USGS 1:24,000 topographic quadrangles Snelling, Merced Falls, Winton, Yosemite Lake, Haystack Mtn. Indian Gulch, Merced, Planada, Owens Reservoir, Illinois Hill, Plainsburg, Le Grand, and Raynor Creek.

Unit 7: Merced County, California. Unit 7A: Merced County, California. From USGS 1:24,000 topographic quadrangles Gustine, Stevinson, San Luis Ranch. Unit 7B: Merced County, California. From USGS 1:24,000 topographic quadrangles Stevinson, San Luis Ranch. Unit 7C: Merced County, California. From USGS 1:24,000 topographic quadrangles Stevinson, Arena, San Luis Ranch, Turner Ranch. Unit 7D: Merced County, California. From USGS 1:24,000 scale quadrangles Arena, Turner Ranch. Unit 7E: Merced County, California. From USGS 1:24,000 scale quadrangles Turner Ranch, Sandy Mush. Unit 7F: Merced County, California. From USGS 1:24,000 scale quadrangles Turner Ranch, Sandy Mush.

Unit 8: Ventura County, California. From USGS 1:24,000 scale quadrangles San Guillermo, Lockwood Valley, Alamo Mountain, Lion Canyon, Topatopa Mountains.

Primary Constituent Elements/Physical or Biological Features

Critical habitat units are designated for Butte, Colusa, Mariposa, Merced, Solano, Stanislaus, Tehama, and Ventura Counties, California. The primary constituent elements of critical habitat for Conservancy fairy shrimp (Branchinecta conservatio) are the habitat components that provide:

(i) Topographic features characterized by mounds and swales and depressions within a matrix of surrounding uplands that result in complexes of continuously, or intermittently, flowing surface water in the swales connecting the pools described below in paragraph (2)(ii), providing for dispersal and promoting hydroperiods of adequate length in the pools;

(ii) Depressional features including isolated vernal pools with underlying restrictive soil layers that become inundated during winter rains and that continuously hold water for a minimum of 19 days, in all but the driest years; thereby providing adequate water for incubation, maturation, and reproduction. As these features are inundated on a seasonal basis, they do not promote the development of obligate wetland vegetation habitats typical of permanently flooded emergent wetlands;

(iii) Sources of food, expected to be detritus occurring in the pools, contributed by overland flow from the pools' watershed, or the results of biological processes within the pools themselves, such as single-celled bacteria, algae, and dead organic matter, to provide for feeding; and

(iv) Structure within the pools described above in paragraph (2)(ii), consisting of organic and inorganic materials, such as living and dead plants from plant species adapted to seasonally inundated environments, rocks, and other inorganic debris that may be washed, blown, or otherwise transported into the pools, that provide shelter.

Special Management Considerations or Protections

Existing manmade features and structures, such as buildings, roads, railroads, airports, runways, other paved areas, lawns, and other urban landscaped areas do not contain one or more of the primary constituent elements. Federal actions limited to those areas, therefore, would not trigger a consultation under section 7 of the Act unless they may affect the species and/ or primary constituent elements in adjacent critical habitat.

Life History

Feeding Narrative

Adult: This species is a detritivore and an invertivore (NatureServe, 2015)

Reproduction Narrative

Adult: The eggs are dropped from the brooding female to the benthos. The eggs hatch when the vernal pools and swales fill with rainwater and the immature stages rapidly develop into adults. Other life history characteristics include mean days to mature (36.5), mean days to reproduce (46.2), mean population longevity in days (113.9) (Helm, 1998) (NatureServe, 2015). Conservancy fairy shrimp hatch out of tiny cysts within the soil during the first winter rains, and complete their entire life cycle by early summer (USFWS, 2012).

Geographic or Habitat Restraints or Barriers

Adult: 16 - 5,577 ft. elevation (USFWs, 2005)

Environmental Specificity

Adult: Very narrow (NatureServe, 2015)

Habitat Narrative

Adult: The species is typically associated with large, clay-bottomed vernal pool playas with turbid water (Vollmar, 2002); however, three pools in Butte Co. and two pools in Solano Co. at the Montezuma wetlands are atypical, because they are relatively small in area and have very low turbidity (Vollmar, 2002). Occupies clay-bottomed vernal pools and vernal lakes Tuscan and Merhten geological formations and on Basin Rim landforms. The environmental specificity is very narrow; it is ecologically dependent on the presence or absence and duration of water during specific times of the year, as well as water chemistry (USFWS, 1992) (NatureServe, 2015). They have been observed in vernal pools ranging in size from 30 to 356,253 square meters (323 to 3,834,675 square feet) (Helm 1998). Conservancy fairy shrimp have been found at elevations ranging from 5 to 1,700 meters (16 to 5,577 feet) (Eriksen and Belk 1999). The species has been found at sites that are low in alkalinity (16 to 47 parts per million) and total dissolved solids (20 to 60 parts per million), with pH near 7 (Barclay and Knight 1981, Syrdahl 1993, Eriksen and Belk 1999) (USFWS, 2005).

Dispersal/Migration

Dispersal/Migration Narrative

Adult: Not available

Population Information and Trends

Population Trends:

Decline of <30% to increase of 25% (NatureServe, 2015)

Species Trends:

Stable (NatureServe, 2015)

Number of Populations:

10 (USFWS, 2024)

Population Narrative:

This species has experienced a long term population trend of a decline < 30% to an increase of 25%. The short term population trend is stable. It is known areas spanning a north-south distance of 300 km, but disjunct within this range (NatureServe, 2015). This species is only known to occur in ten disjunct populations (USFWS, 2012). At the time of listing in 1994, the Conservancy fairy shrimp's distribution was described as consisting of six disjunct populations spanning the Central Valley and southern California (Figure 4). Some of these "populations" represent geographic clusters of occurrences, and some represent single vernal pools. However, one of these populations is described as being "south of Chico, Tehama County." Tehama County is actually north of Chico, and this population is not discussed in the Recovery Plan or 5-year reviews, other than to note this mistake, and the Diversity Database has no documented occurrences in the vicinity of the city of Chico. Therefore, this population will not be addressed further in this document. By the time of the first 5-year review in 2007, three additional populations had been discovered, and by the time of the second 5-year review in 2012, two more populations had been discovered, for a total of 10 disjunct populations distributed across six vernal pool regions. This information does not indicate that the species is expanding its current range, but simply that greater study and surveys related to permitting pursuant to the Act increased our knowledge of where the species can be found. (USFWS, 2024)

Threats and Stressors

Stressor: Loss and degradation of vernal pools (NatureServe, 2015 and USFWS, 2012)
Exposure:
Response:
Consequence:
Narrative: The primary threats are elimination and degradation of vernal pool habitat in the Central Valley area by urban development, water supply and flood control activities, and conversion of wildlands to agricultural use (USFWS, 1992). Continued threats are summarized in USFWS (2005; 2007): The U.C. Merced population is threatened by habitat fragmentation and degradation from increased development pressures in the region (NatureServe, 2015). Even in areas where habitat is protected, the urbanization of surrounding lands can reduce the suitability of protected habitats, and hinders the dispersal of the Conservancy fairy shrimp within and between populations, as well as causing increased edge effects to pool complexes (USFWS, 2012).

Stressor: Climate change (NatureServe, 2015)
Exposure:
Response:
Consequence:

Narrative: Climate change is expected to have an effect on vernal pool hydrology through changes in the amount and timing of precipitation inputs to vernal pools and the rate of loss through evaporation and evapotranspiration (Pyke, 2004; Pyke and Marty, 2005); and these changes in hydrology will likely affect fairy shrimp species because they are obligate aquatic organisms with life histories dependent on certain hydrologic conditions. It is unknown at this time if climate change in California will result in a localized, relatively small cooling and drying trend, or a warmer trend with higher precipitation events (Pyke, 2005a); however, it is possible that either scenario would result in negative effects to vernal pool invertebrate species (Pyke, 2004; Pyke and Marty, 2005). Pyke (2004; 2005b) postulated that climate change in the future may result in changes in hydrology that would adversely affect populations at sites that are currently preserved for this species (NatureServe, 2015).

Stressor: Non-native vegetation (NatureServe, 2015)
Exposure:
Response:
Consequence:
Narrative: Non-native herbaceous species occur commonly in vernal pool complexes and have become a threat to native vernal pool species through their capacity to change pool hydrology (Marty, 2005). It is likely that the lack of fires, coupled with the lack of adequate grazing, has increased the densities of non-native herbaceous vegetation surrounding vernal pools, degrading the habitat (Wells et al., 1997) (NatureServe, 2015).

Stressor: Pesticides (NatureServe, 2015 and USFWS, 2012)
Exposure:
Response:
Consequence:
Narrative: It is likely that vernal pools containing Conservancy fairy shrimp have been exposed to harmful pesticides to some degree, but the current effects of contaminants on this species are not known at this time (NatureServe, 2015). Pesticides, herbicides, and other chemicals can be conveyed into the vernal pool habitats by overland run-off during rain events, or they may enter vernal pools by drift or direct over-spray (Johnson 2005). In addition, pesticides applied to agricultural fields and orchards in the Central Valley can volatize to the atmosphere (USFWS, 2012).

Stressor: Stochastic events (USFWS, 2012)
Exposure:
Response:
Consequence:
Narrative: The combination of highly specialized pool type and soil characteristics makes the Conservancy fairy shrimp exceedingly rare (Vollmar 2002). This species is only known to occur in ten disjunct populations, with some populations being comprised of a single vernal pool. Such populations may be highly susceptible to extirpation due to chance events or additional environmental disturbance (Gilpin and Soule 1988; Goodman 1987), such as adverse effects from changes in hydrology or temperatures due to climate change, invasive plant species, and inappropriate grazing regimes. If an extirpation event occurs in an isolated population, the opportunities for recolonization will be greatly reduced due to physical isolation from other source populations (USFWS, 2012).

Stressor: Grazing (USFWS, 2012)
Exposure:
Response:
Consequence:
Narrative: Inappropriate grazing practices include complete elimination of grazing in areas where nonnative grasses dominate the uplands surrounding vernal pools, and inappropriate timing or intensity of grazing. Appropriate grazing practices utilize a grazing regime to ensure proper function of hydrology in vernal pools (Marty 2005). In particular, an appropriate grazing regime ensures that non-native weedy plants such as Italian ryegrass and waxy mannagrass, which increase thatch buildup, decrease ponding durations, and decrease the aquatic habitat available to Conservancy fairy shrimp. The majority of localities for this species are grazed by cattle, although not all are grazed for the benefit of vernal pool species. Management and monitoring plans that do not include an adaptive management approach and do not facilitate natural processes and functions may not result in conservation of Conservancy fairy shrimp. Similarly, lack of funding to implement grazing management and monitoring activities may contribute to a decline of habitat conditions and species baseline (Service 2005a) (USFWS, 2012).

Stressor: Agricultural Conversions (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Conversion of vernal pool grasslands to agricultural uses is by far the most significant factor driving the loss of vernal pool habitat, at least in the Central Valley where this has been most closely studied. Vernal pool grasslands are generally located in areas that are well suited to agriculture. Agricultural conversions resulted in the loss of 70,878 acres of vernal pool grasslands in the Central Valley between 2005 and 2018, accounting for 93% of all losses (Witham 2021, p. 8). Madera, San Joaquin, and Merced Counties have all experienced losses of over 10,000 acres from 2005 to 2018 due to agricultural conversions. Even the vernal pool region with the most losses due to urban development, the Southeastern Sacramento Valley region, still had over four times more losses due to agricultural conversion. In particular, conversion to orchards, vineyards, and eucalyptus plantations has been the largest driver of vernal pool habitat loss over the past 40 years. It accounted for almost 30% of losses from the late 20th century through 2005 (Holland 2009, p. 4), and 56% of losses from 2005 to 2018 (Witham 2021, p. 8). From 2005 to 2012 the largest losses were due to conversion of vernal pool grasslands to bare plowed ground (Witham et al. 2014, p. 8), but most of these areas had been fully converted to orchards by 2018 (Witham 2021, p. 8). Agricultural conversion of vernal pool habitat is expected to continue in the future. Most agricultural conversions occur outside of normal regulatory processes. In most instances, these losses have gone unmitigated, either proceeding without required authorization(s) such as a Clean Water Act Section 404 permit and associated section 7(a)(2) consultation, or in instances where direct filling of waters of the United States has been avoided, thus not triggering the Clean Water Act permitting process or the Act’s section 7 process. Researchers have consistently recommended increased enforcement of the Act and the Clean Water Act to deter this unauthorized loss of vernal pool habitat, or to provide compensation to offset the loss of habitat to the same extent that is required of projects that go through the appropriate regulatory channels (USFWS, 2024).

Stressor: Urban Development (USFWS, 2024)
Exposure:

Response:
Consequence:
Narrative: Although not as extensive as agricultural conversions, urban development has contributed to losses of vernal pool grasslands throughout California. Vernal pool grasslands are often located in fairly flat areas that are well suited to urban development. From the end of the 20th century through 2005, approximately 25,965 acres of vernal pool grassland in the Central Valley was lost due to urban development (Holland 2009, p. 10), and an additional 5,056 acres was lost from 2005 to 2018 (Witham 2021, geodatabase). This represents approximately 19% of all losses from the end of the 20th century through 2005 (Holland 2009, p. 19) and only 7% of all losses from 2005 to 2018 (Witham 2021, p. 8). The decrease in the rate of loss due to urban development since 2005 can likely be attributed to the economic downturn caused by the Great Recession in 2008 and other factors that have made urban development more difficult or costly in recent years. However, pressure to convert vernal pool grasslands to urban development is expected to continue as the population of California and southern Oregon continues to grow. Even when vernal pool habitat is avoided during urban development, the urbanization of surrounding lands leads to greater habitat fragmentation. Urban development has not been evenly distributed across the range of the three shrimp species. At the end of the 20th century, losses due to urban development were very significant in Placer County (15,368 acres, 59.2% of all losses) and fairly significant in Sacramento County (3,267 acres, 12.6% of all losses) (Holland 2009, p. 10). From 2005 to 2018, losses due to urban development continued to remain highest in Placer (1,842 acres) and Sacramento (933 acres) Counties, representing 39.2% and 21.8% of losses in each county, respectively (Witham 2021, p. 9). The Greater Sacramento area (the six-county area surrounding the city of Sacramento) had a population of approximately 2,578,590 in 2020, up 11.3% from 2010 (SACOG 2022, p. 1). The population is expected to continue growing over the next 20 years, with a projected population of 2,996,832 in 2040 (16.2% increase over 20 years) (SACOG 2020, p. 15), so urbanization will likely continue to be a significant cause of habitat loss for the vernal pool fairy shrimp within this region. Although vernal pool grasslands have not been as extensively researched outside of the Central Valley, it is likely that urban development is a greater threat to vernal pool grasslands in the Central Coast (Ferren and Pritchett 1988, p. 4) and Southern California (Dudek and Associates 2003, entire). The terrain and climate of these areas is not as conducive to agriculture as the Central Valley, and urban development has been particularly extensive in Southern California. The Klamath Mountains Vernal Pool Region in Oregon is not heavily urbanized, with a population of 223,259 in 2020, a 10% increase from 2010 (U.S. Census Bureau 2022, p. 1). Urban development is much more closely regulated than agricultural conversions, and therefore the Service almost always conducts an interagency consultation with the Corps when an applicant is seeking a Clean Water Act Section 404 permit to fill vernal pools. The Corps generally requires mitigation for destroyed vernal pools in the form of vernal pool creation at a 1:1 ratio. In many parts of California, project applicants will also incorporate conservation measures that include preserving existing vernal pool habitat that is occupied by the shrimp species (often at a 2:1 ratio) and ensuring that the created vernal pools will also provide habitat for the shrimp species. These projects may still result in a net loss of vernal pool grassland acreage (pools may be created within existing vernal pool grasslands, and created pools are often more densely concentrated than natural pools), but the mitigation acquired and conservation measures implemented through regulatory channels has been an important source of vernal pool preservation throughout the range of the three shrimp species (USFWS, 2024).

Stressor: Infrastructure (USFWS, 2024)

Exposure:
Response:
Consequence:
Narrative: Road construction and widening threatens occurrences of the three shrimp species that are in construction boundaries and within road rights-of-way. Although not examined specifically, road infrastructure was likely included within Holland's (2009, p. 4), Witham et al.'s (2014, p. 8), and Witham's (2021, p. 8) urban development category, and thus represents a small portion of total vernal pool grassland losses. Besides direct loss of vernal pools, roads can create barriers to dispersal and hydrologic connectivity, and disturbance along the road edge can be a source of introduction for invasive plants. Unlike the habitat loss and fragmentation of most urban development, which is by definition mostly in urban or urbanizing areas, some roads and highways may cause fragmentation in more rural or isolated areas. Other infrastructure projects that threaten the three shrimp species include energy infrastructure such as substations, pipelines, and solar panels, as well as other utilities infrastructure like sewer, water lines, and telephone lines. Besides direct loss due to grading or excavation during construction of the infrastructure, ongoing maintenance of infrastructure placed within vernal pool grasslands may subject the pools to repeated disturbance from off-road vehicles, management activities like vegetation removal or firebreak creation, and the introduction of invasive plants (USFWS, 2024).

Stressor: Altered Hydrology (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Altered hydrology caused by nearby development, agriculture, or other land uses can sometimes result in vernal pools that no longer function as habitat for the three shrimp species. The greater watershed can supply 25–60% of the water needed to fill vernal pools to the margin (Williamson et al. 2005, p.10), so changes to surrounding lands such as urban development that influence a pool's watershed may indirectly cause habitat loss even if the pool itself is left intact. Altered hydrology is not as significant a threat as direct losses of vernal pools from agricultural conversion, urban development, and infrastructure. Still, it is likely that this threat has increased along with direct losses since remaining vernal pools adjacent to the direct losses may have their hydrology altered, although this threat has not been studied as closely as direct loss of vernal pool grasslands. Small changes in local land use may have adverse impacts on vernal pools, although the degree to which such changes affect pools is poorly understood because the fundamental hydrogeological characteristics of perched aquifers remain relatively unexplored (Rains et al. 2006, p. 1173). It is possible that remnant vernal pools within altered landscapes, or higher densities of created vernal pools, may not have adequate surface and/or subsurface flows to adequately function as shrimp habitat. Alternatively, the abiotic habitat components such as water chemistry, which are mediated by transport through subsurface and surface flows, may alter the suitability of the habitat to support the three shrimp species if anthropogenic activities significantly affect upland watersheds (Rains et al. 2008, p. 348). The change in surface permeability, from permeable grasslands and semipermeable old-terrace geologic formations to impermeable roads, residential and commercial rooftops, and concrete reduces and prevents natural percolation through the soils and significantly increases runoff and storm flows. Excessive urban runoff or agricultural discharge can change the hydroperiod of vernal pools, so that they become inundated during hot summer months when they would naturally have remained dry. When the hydrologic regime is altered, the biota of vernal pools and swales is expected to change and the new hydroperiod or ecological community may not support the lifecycle of the

three shrimp species. Ground disturbing activities within the watershed of vernal pools may result in siltation when pools fill during the wet season following construction. Besides negative changes to a pool's hydroperiod caused by silt deposition, siltation can also impact the plant and invertebrate communities more directly. In general, increased amounts of sediment in freshwater wetlands can reduce the richness and density of invertebrates and alter their species composition (Sheldon et al. 2003, 4-26–4-28). Based on these general findings, it is anticipated that siltation in vernal pools could bury shrimp cysts, clog filter feeding apparatuses, change the aquatic community species composition, and decrease availability of food sources like plant matter and detritus due to burial or decreased light availability. Although vernal pool tadpole shrimp in particular are known to occur in turbid wetlands, they may be adversely affected by increased siltation if sediment levels increase above the levels they are locally adapted to in a particular pool or vernal pool complex (USFWS, 2024).

Recovery

Reclassification Criteria:
100% of occurrences are protected (USFWS, 2005).

Recovery Priority Number: 8

Delisting Criteria:
100% of newly discovered/ reintroduced populations are protected (USFWS, 2005).

Recovery Actions:

- Conduct research and use results to refine recovery actions and criteria, and guide overall recovery and long-term conservation efforts (USFWS, 2005).
- Develop and implement participation programs (USFWS, 2005).
- Protect vernal pool habitat in the largest blocks possible from loss, fragmentation, degradation, and incompatible uses (USFWS, 2005).
- Manage, restore, and monitor vernal pool habitat to promote the recovery of listed species and the long-term conservation of the species of concern (USFWS, 2005).
- Conduct range-wide status surveys and status reviews for all species addressed in this recovery plan to determine species status and progress toward achieving recovery of listed species and long-term conservation of species of concern (USFWS, 2005).
- Preservation of Zone 1 and 2 core areas should be pursued to preserve known localities that are currently not protected. Core Areas that are within Zone 1 include Vina Plains, Caswell, Grasslands, Jepson Prairie, Sacramento NWR, Collinsville, and Madera. Zone 2 core areas include the Ventura and Western Placer County Core Areas (USFWS, 2012).
- Develop standardized monitoring for species status at areas with known localities throughout the range of this species. Conduct additional research at these sites to incorporate research recommendations outlined in the Recovery Plan. Results from monitoring and research should be included in the management plans for these areas (USFWS, 2012).
- Encourage researchers and project proponents to complete surveys for vernal pool crustaceans statewide in an effort to detect additional Conservancy fairy shrimp localities and populations (USFWS, 2012).

- Conduct surveys at Mapes Ranch to determine if this population is extant. This will require landowner permission for access (USFWS, 2012).
- Acquire conservation easements or fee title for properties with unprotected populations of Conservancy fairy shrimp to ensure these populations continue to persist (USFWS, 2012).

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SPECIES ACCOUNT: *Branchinecta longiantenna* (Longhorn fairy shrimp)

Species Taxonomic and Listing Information

Listing Status: Endangered; September 19, 1994 (59 FR 48136).

Physical Description

The longhorn fairy shrimp (Branchinecta longiantenna) is a small crustacean in the Branchinectidae family and Anostraca order. Mature males have been measured between 12 and 21 millimeters (mm) (0.5 to 0.8 inch [in.]) in length, and females range from 13.3 to 19.8 mm (0.5 to 0.8 in.) in length. They have delicate elongate bodies, large stalked compound eyes, no carapaces, and 11 pairs of swimming legs. They glide gracefully upside down, swimming by beating their legs in a complex, wavelike movement that passes from front to back (USFWS 2015). This species is easily identified by the male's very long second antennae, which is about twice as long, relative to its body, as the second antennae of other species of Branchinecta. Longhorn fairy shrimp antennae range from 6.7 to 10.4 mm (0.3 to 0.4 in.) in length (Eriksen and Belk 1999). Females can be recognized by their cylindrical brood pouch, which extends to below abdominal segments six or seven (USFWS 2005).

Taxonomy

The longhorn fairy shrimp, named for its relatively long antennae, was first collected in 1937 but not formally described until 1990. The type specimen was collected from a sandstone outcrop pool on the Souza Ranch in Contra Costa County, California. Longhorn fairy shrimp are easily distinguished from other fairy shrimp by the male’s extremely long second antennae. Female longhorn fairy shrimp may be confused with alkali fairy shrimp (Branchinecta mackini), although female longhorn fairy shrimp lack the dorsal outgrowths found on the thoracic segments of female alkali fairy shrimp (USFWS 2005).

Historical Range

The extent of the historical range or variation in vernal pool habitats in which the species occurs is not known (USFWS 2012). The distribution of the longhorn fairy shrimp may never have extended into the northern portion of the Central Valley or into southern California. Extensive surveying of vernal pool habitats in southern California has never revealed populations of longhorn fairy shrimp. However, it is likely that the longhorn fairy shrimp was once more widespread in the regions where it is currently known to occur, and in adjacent areas such as the San Joaquin and Southern Sierra Foothill Vernal Pool Regions, where habitat loss has been extensive (USFWS 2007; USFWS 2012). Longhorn fairy shrimp are restricted to the Central Valley (USFWS 2012).

Current Range

Longhorn fairy shrimp are extremely rare. The longhorn fairy shrimp is known from only a small number of widely separated populations (USFWS 2005). The five known populations of longhorn fairy shrimp include: (1) areas in and adjacent to the Carrizo Plain National Monument, San Luis Obispo County; (2) areas in the San Luis National Wildlife Refuge (NWR) Complex, Merced County; (3) areas in the Brushy Peak Preserve, Alameda County; (4) areas in the Vasco Caves Preserve, near the town of Byron in Contra Costa County; and (5) areas in the proposed Alkali

Sink Conservation Bank east of Mendota in Fresno County (USFWS 2012). This species was also detected in 2003 in a roadside ditch 2 miles north of Los Baños, in Merced County. Only one individual was detected in the ditch; this occurrence is considered to be an anomaly and not a sustainable population (USFWS 2012).

Distinct Population Segments Defined

No

Critical Habitat Designated

Yes; 8/6/2003.

Legal Description

On August 11, 2005, the Fish and Wildlife Service (Service), re-evaluated the economic exclusions made to the previous final rule (68 FR 46683; August 6, 2003), which designated critical habitat pursuant to the Endangered Species Act of 1973, as amended (Act), for 4 vernal pool crustaceans and 11 vernal pool plants. A total of approximately 858,846 acres (ac) (347,563 hectares (ha)) of land are now designated critical habitat. This reflects exclusion of lands from the final designation for economic reasons, pursuant to section 4(b)(2) of the Act. This designation also reflects the lands previously confirmed for exclusion under 4(b)(2) of the Act for noneconomic reasons (70 FR 11140; March 8, 2005). The non-economic exclusions include the boundaries of various Habitat Conservation Plans, National Wildlife Refuges and National fish hatchery lands (33,097 ac (13,394 ha)), State lands within ecological reserves and wildlife management areas (20,933 ac (8,471 ha)), Department of Defense lands within Beale and Travis Air Force Bases as well as Fort Hunter Liggett and Camp Roberts Army installations (64,259 ac (26,005 ha)), Tribal lands managed by the Mechoopda Tribe (644 ac (261 ha)), and the Santa Rosa Plateau Ecological Reserve (10,200 ac (4,128 ha)) from the final designation.

Critical Habitat Designation

Critical habitat for longhorn fairy shrimp (Branchinecta longiantenna) consists of the following areas:

(1) Subunit 1A; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Shady Cove.

(2) Subunit 1B; Jackson County, Oregon.

(3) Subunit 1C; Jackson County, Oregon.

(4) Subunit 1D; Jackson County, Oregon.

(5) Subunit 1E; Jackson County, Oregon.

(6) Subunit 1F; Jackson County, Oregon.

(7) Subunit 1G; Jackson County, Oregon.

(8) Subunit 2A; Jackson County, Oregon.

(9) Subunit 2B; Jackson County, Oregon.

(10) Subunit 2C; Jackson County, Oregon.

(11) Subunit 2D; Jackson County, Oregon.

(12) Subunit 2E; Jackson County, Oregon.

(13) Subunit 3A; Jackson County, Oregon.

(14) Subunit 3B; Jackson County, Oregon.

(15) Subunit 3C; Jackson County, Oregon.

(16) Subunit 4A; Jackson County, Oregon.

(17) Subunit 4B; Jackson County, Oregon.

(18) Subunit 5A; Siskiyou County, California.

(19) Subunit 5B; Modoc and Shasta County, California.

(20) Subunit 5C; Shasta County, California.

(21) Subunit 5D; Shasta County, California.

(22) Subunit 5E; Shasta County, California.

(23) Subunit 5F; Shasta County, California.

(24) Subunit 5G; Shasta County, California.

(25) Subunit 5H; Lassen County, California.

(26) Subunit 5I; Lassen and Shasta County, California.

(27) Subunit 5J; Lassen County, California.

(28) Subunit 5K; Shasta County, California.

(29) Subunit 5L; Plumas County, California.

(30) Subunit 6A; Shasta County, California.

(31) Subunit 6B; Shasta County, California.

(32) Subunit 6C; Shasta County, California.

(33) Subunit 6D; Shasta County, California.

(34) Subunit 6E; Tehama County, California.

(35) Subunit 6F; Glenn and Tehama Counties, California.

(36) Subunit 7A; Shasta County, Tehama County, California.

(37) Subunit 7B; Shasta and Tehama County, California.

(38) Subunit 7C; Butte County, Tehama County, California.

(39) Subunit 7D; Butte County, California.

(40) Subunit 7E; Butte County, California.

(41) Subunit 7F; Butte County, California.

(42) Subunit 7G; Butte County, California.

(43) Subunit 7H; Butte County, California.

(44) Subunit 7I; Butte County, California.

(45) Subunit 7J; Butte County, California.

(46) Subunit 7K; Butte County, California.

(47) Subunit 7L; Butte County, California.

(48) Subunit 7M; Butte County, California.

(49) Subunit 7N; Butte County, California.

(50) Subunit 8A; Mendocino County, California.

(51) Subunit 9A; Lake County, California.

(52) Subunit 9B; Lake County, California.

(53) Subunit 9C; Napa County, California.

(54) Subunit 10A; Colusa County, California.

(55) Subunit 10B; Yolo County, California.

(56) Subunit 10C; Solano County, California.

(57) Subunit 10D; Solano County, California.

(58) Subunit 10E; Solano County, California.

(59) Subunit 10F; Solano County, California.

(60) Subunit 10G; Solano County, California.

(61) Subunit 10H; Solano County, California.

(62) Subunit 11A; Yuba County, California.

(63) Subunit 11B; Placer County, California.

(64) Subunit 11C; Placer County, California.

(65) Subunit 11D; Sacramento County, California.

(66) Subunit 11E; Sacramento County, California.

(67) Subunit 11F; Sacramento County, California.

(68) Subunit 11G; Amador County, Sacramento County, California.

(69) Subunit 11H; Sacramento, San Joaquin County, California.

(70) Subunit 12A; Napa County, California.

(71) Subunit 12B; Napa County, California.

(72) Subunit 12C; Contra Costa County, California.

(73) Subunit 13A; Contra Costa County, California.

(74) Subunit 13B; Contra Costa County, California.

(75) Subunit 13C; Contra Costa County, California.

(76) Subunit 13D; Alameda County, California.

(77) Subunit 13E; Alameda County, California.

(78) Subunit 14A; Stanislaus County, California.

(79) Subunit 14B; Merced County, California. From USGS 1:24,000 scale quadrangles Gustine, San Luis Ranch, and Stevinson.

(80) Subunit 14C; Merced County, California. From USGS 1:24,000 scale quadrangles San Luis Ranch, and Stevinson.

(81) Subunit 14D; Merced County, California. From USGS 1:24,000 scale quadrangles Arena, San Luis Ranch, Stevinson, and Turner Ranch.

(82) Subunit 14E; Merced County, California. From USGS 1:24,000 scale quadrangles Arena, and Turner Ranch.

(83) Subunit 14F; Merced County, California. From USGS 1:24,000 scale quadrangles Sandy Mush, and Turner Ranch.

(84) Subunit 14G; Merced County, California. From USGS 1:24,000 scale quadrangles Sandy Mush and Turner Ranch.

(85) Subunit 14H; Merced County, California. From USGS 1:24,000 scale quadrangle Sandy Mush.

(86) Subunit 14I; Merced County, California. From USGS 1:24,000 scale quadrangles El Nido, and Sandy Mush.

(87) Subunit 14J; Merced County, California. From USGS 1:24,000 scale quadrangle Sandy Mush.

(88) Subunit 14K; Merced County, California. From USGS 1:24,000 scale quadrangle El Nido.

[(89) Excluded] (90) Subunit 14L; Merced County, California. From USGS 1:24,000 scale quadrangles El Nido, and Plainsburg.

(91) Subunit 14M; Kings County and Tulare County, California. From USGS 1:24,000 scale quadrangles Burris Park, Monson, Remnoy, and Traver.

(92) Subunit 14N; Tulare County, California. From USGS 1:24,000 scale quadrangles Alpaugh, Cocoran, and Taylor Weir.

(93) Subunit 14O; Tulare County, California. From USGS 1:24,000 scale quadrangles Alpaugh, and Pixley.

(94) Subunit 14P; Tulare County, California. From USGS 1:24,000 scale quadrangles Alpaugh, and Pixley.

(95) Subunit 14Q; Tulare County, California. From USGS 1:24,000 scale quadrangle Delano West.

(96) Subunit 15A; San Joaquin County, California. From USGS 1:24,000 scale quadrangle Peters, Farmington, Linden, Valley Springs SW.

(97) Subunit 15B; Tuolumne and Stanislaus County, California. From USGS 1:24,000 scale quadrangle Keystone, Knights Ferry.

(98) Subunit 15C; Stanislaus County, California. From USGS 1:24,000 scale quadrangles Paulsell, and Waterford.

(99) Subunit 15D; Stanislaus County, California. From USGS 1:24,000 scale quadrangle Paulsell.

(100) Subunit 15E; Stanislaus County, Tuolumne County, California. From USGS 1:24,000 scale quadrangles Cooperstown, Keystone, La Grange, and Paulsell.

(101) Subunit 15F; Stanislaus County, California. From USGS 1:24,000 scale quadrangle Paulsell.

(102) Subunit 15G; Stanislaus County, California. From USGS 1:24,000 scale quadrangles Montpelier, and Paulsell.

(103) Subunit 15H; Merced County, Stanislaus County, California. From USGS 1:24,000 scale quadrangles Cooperstown, La Grange, Merced Falls, Montpelier, Paulsell, and Turlock Lake.

(104) Subunit 15I; Merced County, California. From USGS 1:24,000 scale quadrangle Turlock Lake.

(105) Subunit 15J; Madera County, Mariposa County, Merced County, California. From USGS 1:24,000 scale quadrangles Haystack Mountain, Illinois Hill, Indian Gulch, Le Grand, Merced, Merced Falls, Owens Reservoir, Plainsburg, Planada, Raynor Creek, Snelling, Winton, and Yosemite Lake.

(106) Subunit 15K; Madera County, California. From USGS 1:24,000 scale quadrangle Kismet.

(107) Subunit 15L; Fresno County, and Madera County, California. From USGS 1:24,000 scale quadrangles Daulton, Friant, Gregg, Lanes Bridge, Little Table Mountain, and Millerton Lake West.

(108) Subunit 15M; Madera County, California. From USGS 1:24,000 scale quadrangles Millerton Lake East, and North Fork.

(109) Subunit 15N; Fresno County, California. From USGS 1:24,000 scale quadrangles Academy, and Millerton Lake East.

(110) Subunit 15O; Fresno County, California. From USGS 1:24,000 scale quadrangles Academy, Friant, and Round Mountain.

(111) Subunit 15P; Fresno County, California. From USGS 1:24,000 scale quadrangle Clovis.

(112) Subunit 15Q; Fresno County, California. From USGS 1:24,000 scale quadrangle Clovis.

(113) Subunit 15R; Tulare County, California. From USGS 1:24,000 scale quadrangles Ivanhoe, and Stokes Mountain.

(114) Subunit 15S; Tulare County, California. From USGS 1:24,000 scale quadrangles Auckland, Ivanhoe, Stokes Mountain, and Woodlake.

(115) Subunit 15T; Tulare County, California. From USGS 1:24,000 scale quadrangle Woodlake.

(116) Subunit 15U; Tulare County, California. From USGS 1:24,000 scale quadrangle Monson.

(117) Subunit 15V; Tulare County, California. From USGS 1:24,000 scale quadrangle Monson.

(118) Subunit 15W; Tulare County, California. From USGS 1:24,000 scale quadrangle Monson.

(119) Subunit 16B; Alameda County, California. From USGS 1:24,000 scale quadrangle Niles, Milpitas.

(120) Subunit 17A; San Benito, Monterey Counties, California. From USGS 1:24,000 scale quadrangle Llanada, San Benito, Hernandez Reservoir, Rock Springs Peak, Topo Valley, Hepsedam Peak, Lonoak, Pinalito Canyon, Monarch Peak, Nattrass Valley.

(121) Subunit 18A; Monterey County, California. From USGS 1:24,000 scale quadrangle Williams Hill, Jolon, Valleton, Bradley, San Miguel, Wunpost.

(122) Subunit 19A; Monterey County, California. From USGS 1:24,000 scale quadrangle Bradley, San Miguel, Wunpost, Valleton.

(123) Subunit 19B; Monterey, San Luis Obispo Counties, California. From USGS 1:24,000 scale quadrangle Bradley.

(124) Subunit 19C; Monterey, San Luis Obispo Counties, California. From USGS 1:24,000 scale quadrangle San Miguel.

(125) Subunit 19D; San Luis Obispo County, California. From USGS 1:24,000 scale quadrangle San Miguel.

(126) Subunit 19E; San Luis Obispo County, California. From USGS 1:24,000 scale quadrangle Paso Robles, and San Miguel.

(127) Subunit 19F; San Luis Obispo County, California. From USGS 1:24,000 scale quadrangle Paso Robles, Adelaida.

(128) Subunit 19G; Monterey and San Luis Obispo Counties, California. From USGS 1:24,000 scale quadrangle Creston, Paso Robles, Estrella, Ranchito Canyon, Cholame Hills.

(129) Subunit 20A; San Luis Obispo, California. From USGS 1:24,000 scale quadrangle Simmler.

(130) Subunit 21A; Santa Barbara County, California. From USGS 1:24,000 scale quadrangle Santa Ynez, Lake Cachuma, Los Olivos, Figueroa Mtn.

(131) Subunit 22A; Ventura County, California. From USGS 1:24,000 scale quadrangles Alamo Mountain, Lion Canyon, Lockwood Valley, San Guillermo, and Topatopa Mountains.

Primary Constituent Elements/Physical or Biological Features

The primary constituent elements of critical habitat for longhorn fairy shrimp (Branchinecta longiantenna) are the habitat components that provide:

(i) Topographic features characterized by mounds and swales and depressions within a matrix of surrounding uplands that result in complexes of continuously, or intermittently, flowing surface water in the swales connecting the pools described in paragraph (c)(2)(ii) of this section, providing for dispersal and promoting hydroperiods of adequate length in the pools;

(ii) Depressional features including isolated vernal pools with underlying restrictive soil layers that become inundated during winter rains and that continuously hold water for a minimum of 23 days, in all but the driest years; thereby providing adequate water for incubation, maturation, and reproduction. As these features are inundated on a seasonal basis, they do not promote the development of obligate wetland vegetation habitats typical of permanently flooded emergent wetlands;

(iii) Sources of food, expected to be detritus occurring in the pools, contributed by overland flow from the pools' watershed, or the results of biological processes within the pools themselves, such as single-celled bacteria, algae, and dead organic matter, to provide for feeding; and

(iv) Structure within the pools described in paragraph (c)(2)(ii) of this section, consisting of organic and inorganic materials, such as living and dead plants from plant species adapted to seasonally inundated environments, rocks, and other inorganic debris that may be washed, blown, or otherwise transported into the pools, that provide shelter.

Special Management Considerations or Protections

Once a vernal pool habitat has been protected from direct filling, it is still necessary to ensure that the habitat is not rendered unsuitable for vernal pool species because of factors such as altered hydrology, contamination, nonnative species invasions, or other incompatible land uses. Many of the factors that cause the decline and localized extirpation of vernal pool species can be avoided. Actions that should be avoided include the following: (1) Actions that increase competition from invasive species as many of the species addressed in this rule are threatened by invasion of nonnative species (CNDDB 2001). (2) Alteration of natural hydrology such as construction of dams or other structures that artificially increase the length of vernal pool inundation or construction of ditches that artificially drain vernal pools. (3) Human degradation of vernal pools such as off-road vehicle use, dumping, and vandalism that threatens many of the species addressed in this rule.

Life History

Feeding Narrative

Adult: Longhorn fairy shrimp are opportunistic filter feeders, and need algae, bacteria, protozoa, rotifers, and bits of detritus present in their environments for feeding (USFWS 2015). They can face competition from other fairy shrimp species present in their environments, although competition is limited (Eriksen and Belk 1999). Active adult longhorn fairy shrimp have been observed from the same vernal pool as versatile fairy shrimp (Branchinecta lindahli) and spadefoot toad tadpoles (Mesobatrachia) on the Carrizo Plain (USFWS 2007).

Reproduction Narrative

Adult: Female fairy shrimp carry their eggs in a ventral brood sac. The eggs either are dropped to the pool bottom or remain in the brood sac until the mother dies and sinks. When the pool dries out, so do the eggs. Resting fairy shrimp eggs are known as cysts. The cysts remain in the dry pool bed until hatching begins in response to rains and other environmental stimuli such as vernal pool filling up (USFWS 2015). The cyst bank in the soil may contain cysts from several years of breeding. Cysts can withstand extreme environmental conditions because of their protective coatings. Unless they are smashed or punctured, cysts are not digested when moved down the intestines of animals. When fairy shrimp cyst dry up, they are even more tolerant of extreme conditions and can be subjected to temperatures of up to 65 degrees Celsius (°C)(150 degrees Fahrenheit [°F]), or can be frozen for months. Cysts can also withstand near-vacuum conditions for 10 years without damage to the embryo. The cysts do not hatch until they receive proper environmental signals such as rain (Eriksen and Belk 1999). Hatching can begin in the same week that a pool starts to fill (typically in winter). Larvae of longhorn fairy shrimp hatch soon after rains fill the pools and water reaches around 10 °C (50 °F) (Eriksen and Belk 1999) The minimum time to maturity for longhorn fairy shrimp is 23 days, with an average of 43 days (USFWS 2005; USFWS 2015).Longhorn fairy shrimp have been collected from December to late April and complete their entire life cycle by early summer (USFWS 2007). Because only one cohort of eggs is produced each year, longhorn fairy shrimp disappear before their native pools dry. Males die first and appear to be less tolerant of stressful conditions than females (Eriksen and Belk 1999).

Geographic or Habitat Restraints or Barriers

Adult: Limited to their home pool. Cysts can be dispersed from dried-up pools, but survival is limited to areas where vernal pools are created. Habitat destruction can remove known vernal pools occurrences.

Spatial Arrangements of the Population

Adult: Clumped according to resources.

Environmental Specificity

Adult: Moderate

Tolerance Ranges/Thresholds

Adult: Low

Site Fidelity

Adult: High

Habitat Narrative

Adult: The longhorn fairy shrimp is highly adapted to the unpredictable conditions of vernal pool ecosystems. Although the longhorn fairy shrimp is only known from a few localities, these sites contain very different types of vernal pool habitats. Longhorn fairy shrimp in the Livermore Vernal Pool Region in Contra Costa and Alameda counties live in small, clear, sandstone outcrop vernal pools. These sandstone pools are sometimes no larger than 1 m (3.3 ft.) in diameter, have a pH near neutral, and very low alkalinity and conductivity. Water temperatures in these vernal pools have been measured between 10 to 17.8 °C (50 to 64 °F). In the San Joaquin, Fresno County and Carrizo Vernal Pool regions, the longhorn fairy shrimp is found in clear to turbid grassland pools. These grassland pools may be as large as 62 m (203.4 ft.) in diameter. Water temperatures in the grassland vernal pools are also warmer, between 10 to 28 °C (50 to 82 °F). There is some evidence that temperatures may not be warm enough for the species to mature in the northern portions of the Central Valley. The species was most recently observed in a disturbed roadside ditch near Los Baños. Longhorn fairy shrimp have been found at elevations ranging from 23 m (75.5 ft.) in the San Joaquin Vernal Pool Region to 880.5 m (2,887 ft.) in the Carrizo Vernal Pool Region (USFWS 2007; USFWS 2012).Although longhorn fairy shrimp are adapted to variable vernal pool habitats, longhorn fairy shrimp presumably have evolved to persist under a range of variation in climatic conditions such as rainfall and drought. For population maintenance, vernal pools must last longer, on average, than the time needed for a species to reach maturity and produce viable eggs, and relatively small changes in the timing or amount of precipitation can affect population dynamics. Based on existing data, weather conditions in which vernal pool flooding promotes hatching—but in which pools dry (or become too warm) before embryos are fully developed—are expected to have the greatest negative effect on the resistance and resilience of vernal pool fairy shrimp populations as cyst banks are depleted (USFWS 2007; USFWS 2012).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: Nonmigratory

Dispersal

Adult: Aquatic birds are the most likely agents of dispersal. Large mammals are also known distributors (Eriksen and Belk 1999). Environmental requirements, rather than the ability or inability to disperse, are the likely limiting factor in the distribution of fairy shrimp (59 FR 48136).

Immigration/Emigration

Adult: No

Dispersal/Migration Narrative

Adult: Longhorn fairy shrimp are nonmigratory and have relatively little ability to disperse on their own. Aquatic birds are the most likely agents of dispersal of longhorn fairy shrimp. Large mammals are also known to act as distributors by wallowing in dirt, getting caught in their fur, and transporting the cysts to another wallow. Also, because cysts can pass through the digestive systems, they can be ingested and then deposited in new habitats when the animal urinates. Less commonly, usual flooding and wind can also transport cysts. Certain fairy shrimp species are restricted in distribution, and adjacent soils may have different or no fairy shrimp. Pools observed after years seem to have the same species and structural and genetic diversity (Eriksen and Belk 1999).

Population Information and Trends

Population Trends:

The short-term population trend is stable, the long-term population trend varied from a decline of 30 percent to an increase of 25 percent (NatureServe 2015). Monitoring has not been sufficient to quantify abundance and identify trends (USFWS 2012).

Species Trends:

Declining (NatureServe 2015)

Population Growth Rate:

Stable

Number of Populations:

Five (USFWS 2022).

Population Size:

Unknown (NatureServe 2015)

Resistance to Disease:

Unknown (USFWS 2012)

Adaptability:

Low

Additional Population-level Information:

Monitoring has not been sufficient to quantify abundance and identify trends, but rather just presence of the species in surveyed pools (USFWS 2012).

Population Narrative:

Population dynamics for longhorn fairy shrimp have not been investigated, and USFWS does not know of any studies that have assessed the status of cyst banks in isolated or connected pools. Monitoring has not been sufficient to quantify abundance and identify trends, but rather just presence of the species in surveyed pools. Because of the small population size of longhorn fairy shrimp, they are very susceptible to stochastic events (USFWS 2012). The current population trend is stable, but the population trend has historically varied, from a decline of 30 percent to an increase of 25 percent (NatureServe 2015). Currently, there are five known populations of longhorn fairy shrimp: (1) areas in and adjacent to the Carrizo Plain National Monument, San Luis Obispo County; (2) areas in the San Luis NWR Complex, Merced County; (3) areas in the Brushy Peak Preserve, Alameda County; (4) areas in the Vasco Caves Preserve, near the town of Byron in Contra Costa County; and (5) areas in the proposed Alkali Sink Conservation Bank east of Mendota in Fresno County (USFWS 2012). Longhorn fairy shrimp occur in five geographically disjunct populations in different counties in California (refer to Figure 1 below). From the time of listing to the first 5-year review in 2007, four populations were known in Brushy Peak Preserve, Vasco Caves Preserve, San Luis National Wildlife Refuge Complex, and Carrizo Plain National Monument (Service 1994, p. 48137; Service 2007b, p. 3). A fifth population was discovered in the Alkali Sink Conservation Bank prior to the 2012 status review (Service 2012, p. 2). For the purpose of this 5-year review, a “population” is a cluster of individual longhorn fairy shrimp locality records that are in close proximity and within a few miles of each other. Populations are defined by entire vernal pool complexes, rather than individual pools (Service 2012, p. 3). “Locality” does not necessarily coincide with a single vernal pool, nor do we think a locality necessarily represents a biological population. Rather, localities are convenient for reference to various parts of a population. Four of the five populations are on public land and are protected. The Carrizo Plain population has 19 localities protected on public lands and 20 localities not protected - Private land (USFWS, 2022).

Threats and Stressors

Stressor: Habitat destruction
Exposure: Development
Response: Elimination of habitat.
Consequence: Direct mortality.
Narrative: Urban development and conversion of native habitats to agriculture were noted as major threats for the longhorn fairy shrimp when it was listed as endangered in 1994. At the time of listing, the majority of known populations of this species were protected on public lands. Since the time of listing, additional localities have been detected that are in the same populations as those previously known, but not all of them are on protected land. A new population was detected in Fresno County in an area that is currently being proposed as a conservation bank for vernal pool species. The number of unprotected localities has increased considerably since the previous 5-year review. At this time, there are 20 unprotected localities of longhorn fairy shrimp within portions of the Carrizo Plain population (USFWS 2012). These localities occur on privately owned parcels that are about 20 acres in size. The population at Alkali Sink in Fresno County, discovered in 2009, has yet to be protected, because decisions are still pending about the area's status as a conservation bank. Until the area is finalized as a conservation bank and easements are put in place, this population remains threatened by development or other habitat modification. In the Livermore area in Alameda County, wind energy leases may potentially threaten longhorn fairy shrimp. Wind energy developers approach landowners to obtain use of the property for wind energy facilities. These leases are long-term, 20 to 30 years, and may be floating (the locations of the wind power equipment can be moved around on a given percentage of a person's property). However, if wind leases exist on these parcels and were to be developed, the longhorn fairy shrimp populations in those vernal pools could be subject to direct and indirect effects of site preparation and placement of wind generation equipment (e.g., altered hydrology, sedimentation, and placement of fill), construction of access roads or fencing (altered hydrology, sedimentation, and placement of fill), and vegetation management (chemical runoff or drift). In addition, access for monitoring and adaptive management could be limited (USFWS 2012).

Stressor: Stochastic events
Exposure: Random or unpredictable disturbances, and altered hydrology.
Response:
Consequence: Direct mortality; extirpation.
Narrative: Stochastic extinction occurs as a result of random or unpredictable disturbances, and is a continued threat to the longhorn fairy shrimp, due to the rarity of the species. Localities or entire populations may be highly susceptible to extirpation due to stochastic events, such as a series of prolonged catastrophic droughts; or additional environmental disturbances, such as adverse effects from adjacent development or agriculture activities, altered hydrology due to climate change, invasive plant species, or inappropriate grazing regimes. If a catastrophic extirpation event occurs in any locality, the opportunities for re-colonization from other source localities within that population may be reduced, with long-term impacts to the abundance and sustainability of longhorn fairy shrimp in that population. More importantly, populations with a limited number of localities could be extirpated entirely. The U.S. Fish and Wildlife Service (USFWS) considers the loss of long-term viability in any one of the five extant populations a serious threat the species' recovery (USFWS 2012).

Stressor: Nonnative plants
Exposure: Spread of nonnative plants to vernal pool.
Response: Sequestering light and soil moisture and increasing thatch buildup, oxygen depletion in pools, and shortening of inundation periods.
Consequence: Negative effects on species: direct mortality; reduced populations, and extirpation.
Narrative: Nonnative invasive plant species are known to adversely affect vernal pool habitat throughout California. Nonnative herbaceous species occur commonly in vernal pool complexes and have become a threat to native vernal pool species through their capacity to change pool hydrology. It is likely that the lack of fires, coupled with the lack of adequate grazing, has increased the densities of nonnative herbaceous vegetation surrounding vernal pools, degrading the habitat. Nonnative grasses maintain dominance at pool edges, sequestering light and soil moisture. In addition, Italian ryegrass (Lolium multiflorum) and waxy mannagrass (Glyceria declinata) increase thatch buildup, which can lead to oxygen depletion in the pools, and contribute to the shortening of inundation periods through increased evapotranspiration in the vernal pools and reduction in the amount of water entering the system through surface and subsurface flows. This negatively affects vernal pool crustaceans through a decrease in available aquatic habitat both spatially and temporally (USFWS 2012).

Stressor: Climate change and drought
Exposure: Climate change affecting factors such as precipitation, warming climate, and drought.
Response: Shortened inundation period, and more predators.
Consequence: Direct mortality; population extirpation.
Narrative: Longhorn fairy shrimp are dependent on vernal pools that have sufficient water to remain wet throughout the annual reproductive phase of the species. Climate change is expected to change hydrologic conditions in some parts of California. In addition, climate change is expected to influence the amount and timing of precipitation inputs to vernal pools and the rate of loss through evaporation and evapotranspiration, which may result in negative effects to vernal pool crustacean species through altered vernal pool hydrology. In addition, protected areas could become unusable to the longhorn fairy shrimp if climatic conditions do not allow the necessary hydrological conditions to persist. Monitoring of vernal pool ecosystems to determine effects from drought and altered hydrology due to climate change is necessary to determine what adaptive land management practices would be the most appropriate to ensure the sustainability of vernal pool species, including longhorn fairy shrimp. Vernal pool crustaceans have developed life-history strategies to survive drought periods. They are, however, adapted to complete their life cycles within limited temperature ranges, and require a minimum length of inundation to reach maturity and reproduce. Climate change is expected to lead to increased variability in precipitation and to increased loss of soil moisture due to evaporation and transpiration of water from plants, which may exacerbate effects due to drought. Drought decreases in water depth and inundation period could increase the frequency at which pools dry before shrimp have completed their life cycle, or cause pool temperatures to more often exceed temperatures suitable for hatching and persistence of the species. Increased inundation periods associated with a warming trend could negatively affect the species by facilitating the increased abundance of predator species that require more permanent water sources in vernal pools such as dragonflies, aquatic beetles, and amphibians (including the nonnative bullfrog, [Rana catesbiana]) (USFWS 2012).

Recovery

Reclassification Criteria:
Accomplish habitat protection that promotes vernal pool ecosystem function sufficient to contribute to the population viability of the species, including: a. Protection of suitable vernal pool habitat in each prioritized core area for the species. To downlist the longhorn fairy shrimp, the Recovery plan recommends that 100 percent of occurrences be protected, and 95 percent of habitat in zone 1 and 2 (North Carrizo Plain, Southern Carrizo Plain, Altamont Hill, and Grasslands Ecological Area) be protected; b. Protection of species localities distributed across the species geographic range and genetic range. Protection of extreme edges of populations protects the genetic differences that occur there. c. Reintroduction and introductions must be carried out and meet success criteria. d. Additional localities should be permanently protected, if determined essential to recovery goals; e. Habitat protection results in protection of hydrology essential to vernal pool ecosystem function, and monitoring indicates that hydrology that contributes to population viability has been maintained through at least one multi-year period that includes above-average, average, and below-average local rainfall as defined above, a multi-year drought, and a minimum of 5 years of post-drought monitoring (USFWS 2005; USFWS 2012).

Adaptive Habitat Management and Monitoring, including: a. Habitat management and monitoring plans that facilitate maintenance of vernal pool ecosystem function and population viability have been developed and implemented for all habitat protected, as previously discussed above. b. Mechanisms are in place to provide for management in perpetuity and long-term monitoring of items presented above, as previously discussed (funding, personnel, etc.). c. Monitoring indicates that ecosystem function has been maintained in the areas protected under items presented above for at least one multi-year period that includes above-average, average, and below-average local rainfall, a multi-year drought, and a minimum of 5 years of post-drought monitoring (USFWS 2005; USFWS 2012).

Status surveys, including a. Status surveys, 5-Year status reviews, and population monitoring show that populations in each vernal pool region where the species occur are viable (e.g., evidence of reproduction and recruitment) and have been maintained (stable or increasing) for at least one multi-year period that includes above-average, average, and below-average local rainfall, a multi-year drought, and a minimum of 5 years of post-drought monitoring. b. Status surveys, status reviews, and habitat monitoring show that threats identified during and since the listing process have been ameliorated or eliminated. Site-specific threats identified through standardized site assessments and habitat management planning also must be ameliorated or eliminated (USFWS 2005; USFWS 2012).

Research, including: a. Research actions necessary for recovery and conservation of the covered species have been identified (these are research actions that have not been specifically identified in the recovery actions but for which a process to develop them has been identified). Research actions (both specifically identified in the recovery actions and determined through the process) on species biology and ecology, habitat management and restoration, and methods to eliminate or ameliorate threats, have been completed and incorporated into habitat protection, habitat management and monitoring, and species monitoring plans, and refinement of recovery criteria and actions. b. Research on genetic structure has been completed (for species where necessary—for reintroduction and introduction, seed banking) and results incorporated into habitat protection plans to ensure that in and among population, genetic variation is fully representative by protected populations. c. Research necessary to determine appropriate parameters to measure population viability for each species has been completed (USFWS 2005; USFWS 2012).

Participation and outreach, including: a. Recovery Implementation Team is established and functioning to oversee range-wide recovery efforts. b. Vernal Pool Regional working groups are established and functioning to oversee regional recovery efforts. c. Participation plans for each vernal pool region have been completed and implemented. d. Vernal Pool Regional working groups have developed and implemented outreach and incentive programs that develop partnerships (USFWS 2005; USFWS 2012).

Recovery Priority Number: 8

Delisting Criteria:
The recovery plan for this species uses an ecosystem-level approach because many of the listed species and species of concern co-occur in the same natural ecosystem and share the same threats. Major gaps in knowledge and understanding of vernal pool species and ecosystems hinder development of definitive recovery criteria. The preliminary recovery criteria in the recovery plan were designed to address these uncertainties, and strategies were developed to refine recovery criteria as recovery actions are implemented. Vernal pool branchiopod species reclassification/downlisting and delisting criteria are generalized (USFWS 2005). In addition to the reclassification criteria, delisting criteria recommend reintroduction of the species to vernal pool regions and soil types from which status surveys indicate the species has been extirpated, and recommends protection of 100 percent of newly discovered or reintroduced populations. Additional populations must be discovered or established in order to delist. (USFWS 2005; USFWS 2007; USFWS 2012).

Recovery Actions:
- Protect vernal pool habitat in the largest blocks possible from loss, fragmentation, degradation, and incompatible uses (USFWS 2005).
- Develop standardized, species-specific guidance for conducting range-wide status surveys for all species addressed in the 2005 Recovery Plan for Vernal Pool Ecosystems of California (USFWS 2005).
- Manage, restore, and monitor vernal pool habitat to promote the recovery of listed species and the long-term conservation of the species of concern (USFWS 2005).
- Conduct research on species addressed in the 2005 Recovery Plan for Vernal Pool Ecosystems of California (USFWS 2005).
- Develop and implement participation programs (USFWS 2005).
- Protection of the known occurrences on private lands in the Carrizo Plain core areas and the currently unprotected Alkali Sink population should be a priority for this species (USFWS 2007, 2012).
- Develop a standardized monitoring method to identify threats and management needs, and to monitor species status and population trends at the Carrizo Plain, San Luis NWR, Vasco Caves Preserve, and Brushy Peak Preserve populations (USFWS 2007, 2012).
- Management and monitoring plans should be prepared for the San Luis NWR Complex and developed for the Alkali Sink conservation bank, the only longhorn fairy shrimp locations

remaining without completed management plans. Results from standardized monitoring discussed above, above, should be included in the management plans for all five populations (USFWS 2007, 2012).

- In addition, the following research should be prioritized over the next 5 years: a. Conduct surveys on private lands with a high potential for supporting longhorn fairy shrimp, particularly in areas south of the Brushy Peak and Vasco Caves Preserves and north of the Carrizo Plain, along the western side of the Central Valley; b. Conduct surveys in the area of the Alkali Sink conservation bank; c. Conduct surveys, in the vicinity of Miller Road, north of Los Baños, Merced County, to determine whether or not the single longhorn fairy shrimp found in a road-side ditch represents a self-sustaining population, or represents an anomaly; and, d. Conduct research on vernal pool habitat restoration and longhorn fairy shrimp reintroduction methods to determine the feasibility of introducing longhorn fairy shrimp to biologically appropriate vernal pool regions and soil types (USFWS 2007, 2012).
- Regional vernal pool working groups should be created in regions where longhorn fairy shrimp are known to occur (USFWS 2007, 2012).
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Conservation Measures and Best Management Practices:

- RECOMMENDATIONS FOR FUTURE ACTIONS: Here we propose several habitat conservation and ecological research recommendations which will aid in the recovery and conservation of longhorn fairy shrimp. Some of these recommendations have already been discussed in previous status reviews (Service 2007b, pp. 21–22; Service 2012, pp. 25–26) and remain valid. 1. Acquire and manage habitat. All populations of longhorn fairy shrimp should be protected. Resource agencies and private partner groups should work to ensure protection of localities on private lands in the Carrizo Plain population through acquisition or conservation easement. 2. Determine population status and implement regular population monitoring. Develop a standardized monitoring method to monitor the status and trend of occurrences to (a) track any threats, (b) estimate current population sizes and the number and distribution of populations, and (c) determine whether the species is stable, increasing, or declining. The monitoring method should account for all important population metrics, which may include presence, abundance of fairy shrimp and eggs, and number of generations present (i.e., instars, juveniles, and breeding adults). Work with landowners and managers to implement multi-year monitoring programs. Survey for additional localities within the five known populations. 3. Explore the effect of climate change on vernal pool hydrology and species viability. Assess how climate change, including increase in temperature and frequency of extreme weather events, will impact vernal pool hydrology through modeling. Determine how these impacts differ among pool types, i.e., rock outcrop pools versus soil-bottom pools. Work with partners to model current hydrology and vernal pool connectivity. Assess how future climate conditions will impact reproduction and, consequently, population dynamics. Determine which populations are most vulnerable to climate change to prioritize conservation actions. 4. Designate a suitable unit of assessment. Consult with species experts and land managers to develop a geographically and ecologically appropriate unit of assessment to describe a longhorn fairy shrimp population subcategory. Currently, the use of “locality” or “occurrence” is not standardized. Defining a unit of assessment will aid in more precise assessments of recovery criteria. 5. Develop habitat suitability criteria. Determine the role of microhabitat characteristics and local community structure in habitat suitability for longhorn fairy shrimp. Determine range of suitable abiotic conditions (e.g., turbidity, nutrient concentration, oxygen concentration, light availability, pool depth, hydroperiod) for the species. Model pool characteristics in relation to landscape and abundance. Work with partners to apply information towards (a) restoring and creating suitable habitat and (b) predicting vulnerability of localities as habitat conditions change due to climate change. 6. Develop research needs and actions. Support ongoing longhorn fairy shrimp research at Brushy Peak and Vasco Caves Preserves, and support other studies to fulfill research needs, including: • Genetic diversity within and among populations. • Whether genetic diversification occurs due to highly variable habitat features. • The use of environmental DNA, or eDNA, as a complementary survey tool to the use of dip nets and soil samples. • Biotic and abiotic parameters for species occurrence. 7. Assess recovery criteria. Consider reassessing longhorn fairy shrimp's recovery criteria to account for climate change impacts. Additionally, to continue tracking progress towards meeting recovery criteria, we need additional information about the species and its habitat, including: • Species characteristics, including environmental stimuli that trigger hatching of eggs, length of cyst viability, and stratification of cysts. • Percentage of protected land within identified core areas. • Survey of localities on private lands. • An assessment of the effectiveness of current habitat management plans. (USFWS, 2022).

Additional Threshold Information:

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SPECIES ACCOUNT: *Branchinecta lynchi* (Vernal pool fairy shrimp)

Species Taxonomic and Listing Information

Listing Status: Threatened; September 19, 1994 (59 FR 48136).

Physical Description

The vernal pool fairy shrimp (Branchinecta lynchi) is a small freshwater crustacean, varying in size from 3 to 38 millimeters (0.12 to 1.5 inches [in.] long) and belonging to an ancient order of branchiopods, the Anostraca. Like other anostracans, it has stalked compound eyes and eleven pairs of phyllopods (swimming legs that also function as gills). The vernal pool fairy shrimp is genetically distinct from other Branchinecta species, and is distinguished by the morphology of the male's second antenna and the female's third thoracic segment (on the middle part of its body) (USFWS 2007).

Taxonomy

The vernal pool fairy shrimp was first collected between 1874 and 1941, when it was described incorrectly as Colorado fairy shrimp (Branchinecta coloradensis). Its identity as a separate species was resolved in 1990. Subsequent genetic analysis has confirmed that the vernal pool fairy shrimp is a distinct species (USFWS 2007). The species was named in honor of James B. Lynch, a systematist of North American fairy shrimp (USFWS 2005). Vernal pool fairy shrimp closely resemble Colorado fairy shrimp (Branchinecta coloradensis). However, there are differences in the shape of a small mound-like feature at the base of the male's antennae, called the pulvillus. The Colorado fairy shrimp has a round pulvillus, while the vernal pool fairy shrimp's pulvillus is elongate. The vernal pool fairy shrimp can also be identified by the shape of a bulge on the distal, or more distant end, of the antennae. This bulge is smaller and less spiny on the vernal pool fairy shrimp. The female Colorado fairy shrimp's brood pouch is longer and more cylindrical than the vernal pool fairy shrimp's. Female vernal pool fairy shrimp also closely resemble female midvalley fairy shrimp. These two species can be distinguished by the number and placement of lobes on their backs, called dorsolateral thoracic protuberances. Vernal pool fairy shrimp have paired dorsolateral thoracic protuberances on the third thoracic segment that are not found in the midvalley fairy shrimp (USFWS 2005).

Historical Range

At the time of listing in 1994, the vernal pool fairy shrimp was known from 32 loosely described populations in a range that extended from the Redding and Stillwater Plains area in Shasta County, California, south through the Central Valley to Pixley in Tulare County, and along the central coast range from northern Solano County to Pinnacles in San Benito County, California. These populations were distributed within eleven vernal pool regions (Northeastern Sacramento Valley, Northwestern Sacramento Valley, Southeastern Sacramento Valley, Solano-Colusa, Livermore, Southern Sierra Foothills, San Joaquin Valley, Central Coast, Carrizo, Santa Barbara, and Western Riverside County vernal pool regions), and included a total of 178 occurrence records. Of this total number of extant populations, four disjunct populations were known from San Luis Obispo, Santa Barbara, and Riverside counties in Central and Southern California. Three of these four isolated "populations" were known only from single pools occupied by the species (USFWS 2007).

Current Range

Since the vernal pool fairy shrimp's listing, surveys of vernal pools and other temporary waters throughout the western United States have resulted in an increase in the shrimp's known range. In 1998, the shrimp was discovered in two distinct vernal pool habitats in Jackson County, Oregon. The known range of the vernal pool fairy shrimp was also extended due to its detection in one pool at the Napa Airport at the southeastern edge of the Lake-Napa Vernal Pool Region (USFWS 2007). The vernal pool fairy shrimp is currently found in 28 counties across the Central Valley and coast ranges of California, and in Jackson County in southern Oregon. The species occupies a variety of vernal pool habitats, and occurs in 11 of the 17 vernal pool regions and 45 of the 85 core recovery areas identified in California (USFWS 2005).

Distinct Population Segments Defined

No

Critical Habitat Designated

Yes; 8/6/2003.

Legal Description

The Fish and Wildlife Service (Service), designated approximately 858,846 acres (ac) (347,563 hectares (ha)) of critical habitat for 4 vernal pool crustaceans and 11 vernal pool plants in 34 counties in California and 1 county in southern Oregon in a final rule of August 11, 2005 (70 FR 46924). That rule designated critical habitat for the 15 vernal pool species collectively. Pursuant to that rule, on February 10, 2006, the Service published species-specific unit descriptions and maps for the 15 species. This rule specifically identifies the critical habitat for each individual species identified in the August 11, 2005, final rule.

Critical Habitat Designation

35 units are designated as critical habitat, totaling 597,821 acres.

Unit 1: Jackson County, Oregon. Unit 1A: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Shady Grove. Unit 1B: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Shady Grove. Unit 1C: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Shady Grove. Unit 1D: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point. Unit 1E: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Shady Grove. Unit 1F: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Shady Grove. Unit 1G: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point.

Unit 2: Jackson County, Oregon. Unit 2A: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point. Unit 2B: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point. Unit 2C: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point. Unit 2D. Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point. Unit 2E: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point. Unit 2E: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point.

Unit 3: Jackson County, Oregon. Unit 3A: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point. Unit 3B: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point, Sams Valley. Unit 3C: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Sams Valley.

Unit 4: Jackson County, Oregon. Unit 4A: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Sams Valley. Unit 4B: Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Sams Valley.

Unit 5: Shasta County, California. From USGS 1:24,000 scale quadrangle Palo Cedro, Enterprise, Balls Ferry, Cottonwood.

Unit 6: Tehama County, California. From USGS 1:24,000 scale quadrangle Red Bluff East, Red Bluff West, Gerber, West of Gerber, Corning, Henleyville.

Unit 7: Tehama County, California. Unit 7A: Tehama County, California. From USGS 1:24,000 scale quadrangle Acorn Hollow and Richardson Springs NW. Unit 7B: Tehama County, California. From USGS 1:24,000 scale quadrangle Sloughhouse. Unit 7C: Tehama County, California. From USGS 1:24,000 scale quadrangle Richard Springs NW. Unit 7D: Tehama and Butte Counties, California. From USGS 1:24,000 scale quadrangle Campbell Mound, Richardson Springs, and Richardson Springs NW. Unit 7E: Butte County, California. From USGS 1:24,000 scale quadrangle Richardson Springs. Unit 7F: Butte County, California, California. From USGS 1:24,000 scale quadrangle Richardson Springs.

Unit 8: Tehama and Glenn Counties, California. From USGS 1:24,000 scale quadrangle Kirkwood and Black Butte Dam.

Unit 9: Butte County, California. From USGS 1:24,000 scale quadrangle Chico.

Unit 11: Yuba County, California. From USGS 1:24,000 scale quadrangle Browns Valley and Wheatland.

Unit 12: Placer County, California. Unit 12A: Placer County, California. From USGS 1:24,000 scale quadrangle Lincoln. Unit 12B: Placer County, California. From USGS 1:24,000 scale quadrangle Lincoln.

Unit 13: Sacramento County, California. From USGS 1:24,000 scale quadrangle Carmichael.

Unit 14: Sacramento and Amador County, California. Unit 14A: Sacramento and Amador County, California. From USGS 1:24,000 scale quadrangle Carbondale, Sloughhouse, Goose Creek, and Clay. Unit 14B: Sacramento County, California. From USGS 1:24,000 scale quadrangle Sloughhouse.

Unit 16: Solano County, California. Unit 16A: Solano County, California. From USGS 1:24,000 scale quadrangle Elmira, Denverton, and Fairfield South. Unit 16B: Solano County, California. From USGS 1:24,000 scale quadrangle Elmira and Denverton. Unit 16C: Solano County, California. From USGS 1:24,000 scale quadrangle Elmira. Unit 16D: Solano County, California. From USGS 1:24,000 scale quadrangle Dozier.

Unit 17: Napa County, California. From USGS 1:24,000 scale quadrangle Cuttings Wharf.

Unit 18: San Joaquin County, California. From USGS 1:24,000 scale quadrangle Valley Springs SW, Linden, Farmington, and Peters.

Unit 19: Contra Costa County, California. Unit 19A: Contra Costa County, California. From USGS 1:24,000 scale quadrangle Brentwood and Antioch South. Unit 19B: Contra Costa County, California. From USGS 1:24,000 scale quadrangle Clifton Court Forebay and Byron Hot Springs. Unit 19C: Alameda County, California. From USGS 1:24,000 scale quadrangle Altamont and Livermore.

Unit 20: Stanislaus County, California. From USGS 1:24,000 scale quadrangle Ripon.

Unit 21: Stanislaus County, California. Unit 21A: Stanislaus County, California. From USGS 1:24,000 scale quadrangle Paulsell and Montpelier. Unit 21B: Stanislaus, Merced, and Mariposa Counties, California. From USGS 1:24,000 scale quadrangle La Grange, Cooperstown, Paulsell, Turlock Lake, Snelling, Montpelier and Merced Falls. Unit 21C: Merced County, California. From USGS 1:24,000 scale quadrangle Turlock Lake.

Unit 22: Merced County, California. From USGS 1:24,000 scale quadrangle Merced Falls, Snelling, Indian Gulch, Haystack Mtn., Yosemite Lake, Winton, Owens Reservoir, Planada, Le Grand, Plainsburg, and Merced.

Primary Constituent Elements/Physical or Biological Features

Critical habitat units are designated for Jackson County, Oregon, and Alameda, Amador, Butte, Contra Costa, Fresno, Kings, Madera, Mariposa, Merced, Monterey, Napa, Placer, Sacramento, San Benito, San Joaquin, San Luis Obispo, Santa Barbara, Shasta, Solano, Stanislaus, Tehama, Tulare, Ventura, and Yuba Counties, California. The primary constituent elements of critical habitat for vernal pool fairy shrimp (Branchinecta lynchi) are the habitat components that provide:

(i) Topographic features characterized by mounds and swales and depressions within a matrix of surrounding uplands that result in complexes of continuously, or intermittently, flowing surface water in the swales connecting the pools described below in paragraph (2)(ii), providing for dispersal and promoting hydroperiods of adequate length in the pools;

(ii) Depressional features including isolated vernal pools with underlying restrictive soil layers that become inundated during winter rains and that continuously hold water for a minimum of 18 days, in all but the driest years; thereby providing adequate water for incubation, maturation, and reproduction. As these features are inundated on a seasonal basis, they do not promote the development of obligate wetland vegetation habitats typical of permanently flooded emergent wetlands;

(iii) Sources of food, expected to be detritus occurring in the pools, contributed by overland flow from the pools' watershed, or the results of biological processes within the pools themselves, such as single-celled bacteria, algae, and dead organic matter, to provide for feeding; and

(iv) Structure within the pools described above in paragraph (3)(ii), consisting of organic and inorganic materials, such as living and dead plants from plant species adapted to seasonally inundated environments, rocks, and other inorganic debris that may be washed, blown, or otherwise transported into the pools, that provide shelter.

Special Management Considerations or Protections

Existing manmade features and structures, such as buildings, roads, railroads, airports, runways, other paved areas, lawns, and other urban landscaped areas do not contain one or more of the primary constituent elements. Federal actions limited to those areas, therefore, would not trigger a consultation under section 7 of the Act unless they may affect the species and/ or primary constituent elements in adjacent critical habitat.

Life History

Feeding Narrative

Adult: Vernal pool fairy shrimp are opportunistic filter feeders, and need algae, bacteria, protozoa, rotifers, and bits of detritus present in their environments for feeding. Given the apparently wide distribution of this species and its tolerance for a wide range of conditions, it is possible that the absence of the vernal pool fairy shrimp in certain habitats is explained by competitive exclusion by other fairy shrimp (Eriksen and Belk 1999; USFWS 2005).

Reproduction Narrative

Adult: Female fairy shrimp carry their eggs in a ventral brood sac. The eggs either are dropped to the pool bottom or remain in the brood sac, sinking with the mother when she dies (NatureServe 2015; USFWS 2005). Resting fairy shrimp eggs are known as cysts. The cyst bank in the soil may contain cysts from several years of breeding (USFWS 2005). Cysts can withstand extreme environmental conditions because of their protective coatings. Unless they are smashed or punctured, cysts are not digested when moved down the intestines of animals. When fairy shrimp cysts dry up, they are even more tolerant of extreme conditions and can be subjected to temperatures of up to 65 °C (150 °F), or can be frozen for months. Cysts can also withstand near-vacuum conditions for 10 years without damage to the embryo. The cysts do not hatch until they receive proper environmental signals such as rain (Eriksen and Belk 1999). Hatching can begin in the same week that a pool starts to fill (typically in winter). Vernal pool fairy shrimp can reach maturity in 18 days at optimal conditions of 20°C (68°F) (USFWS 2005). However, time to reach maturity is temperature-dependent and varies between 18 and 147 days with a mean of 39.7 days. Vernal pool fairy shrimp live 91 days on average (NatureServe 2015). Vernal pool fairy shrimp complete their entire life cycle by early summer, and immature and adult shrimp are known to die off when water temperatures rise to approximately 24°C (75°F) (USFWS 2007). Vernal pool fairy shrimp have been collected from December to early May. Because only one cohort of eggs is produced each year, vernal pool fairy shrimp disappear before their native pools dry. Males die first and appear to be less tolerant of stressful conditions than females (Eriksen and Belk 1999). In years with warm winter rains, vernal pool fairy shrimp apparently do not hatch in at least a portion of their range. In years with low amounts of precipitation or atypical timing of precipitation (or in substandard habitat), vernal pool species may die off before reproducing (Eriksen and Belk 1999). In some cases, vernal pool fairy shrimp will cease to be found in pools where they were formerly found (USFWS 2007).

Geographic or Habitat Restraints or Barriers

Adult: Limited to their home pool. Cysts can be dispersed from dried-up pools, but survival is limited to the areas of vernal pools. Habitat destruction can remove known vernal pool occurrences.

Spatial Arrangements of the Population

Adult: Clumped according to resources.

Environmental Specificity

Adult: Narrow

Tolerance Ranges/Thresholds

Adult: Males have a lower tolerance than females (Eriksen and Belk 1999).

Site Fidelity

Adult: High

Habitat Narrative

Adult: Vernal pool fairy shrimp have an ephemeral life cycle and exist only in vernal pools or vernal pool-like habitats; the species does not occur in riverine, marine, or other permanent bodies of water. The vernal pool fairy shrimp is endemic to California and the Agate Desert of southern Oregon. It has the widest geographic range of the federally listed vernal pool crustaceans, but it is seldom abundant where found, especially where it co-occurs with other species.The vernal pool fairy shrimp occupies a variety of different vernal pool habitats, from small, clear, sandstone rock pools to large, turbid, alkaline, grassland valley floor pools (USFWS 2005). The vernal pool fairy shrimp occurs only in cool-water pools. Whatever the habitat, the wetlands in which this species is found are small (less than 200 square meters [m2] [2,153 square feet (sq. ft.)]) and shallow (mean 5 centimeters [cm] [2 in.]); however, this species occasionally inhabits large (44,534 m2 [478,371 sq. ft.]) and very deep (122 cm [48 in.]) habitats (NatureServe 2015). Although the vernal pool fairy shrimp has been collected from large vernal pools, including one exceeding 10 hectares (ha) (25 acres [ac.]) in area, it tends to occur primarily in smaller pools, and is most frequently found in pools measuring less than 0.02 ha (0.05 ac.) in area. The vernal pool fairy shrimp typically occurs at elevations from 10 meters (m) (33 feet [ft.]) to 1,220 m (4,003 ft.), although two sites in the Los Padres National Forest have been found to contain the species at an elevation of 1,700 m (5,600 ft.).The vernal pool fairy shrimp has been collected at water temperatures as low as 4.5°C (40°F), and has not been found in water temperatures above about 24°C (75°F). The species is typically found in pools with low to moderate amounts of salinity or total dissolved solids. Vernal pools are mostly rain-fed, resulting in low nutrient levels and dramatic daily fluctuations in pH, dissolved oxygen, and carbon dioxide. Although there are many observations of the environmental conditions where vernal pool fairy shrimp have been found, there have been no experimental studies investigating the specific habitat requirements of this species. In Oregon, the vernal pool fairy shrimp is found in two distinct vernal pool habitats. The species occurs on alluvial fan terraces associated with Agate-Winlo soils on the Agate Desert, and in the Table Rocks area on Randcore-Shoat soils underlain by lava bedrock. These vernal pool habitats represent the northern extent of the vernal pool fairy shrimp. In the Western Riverside County and Santa Barbara vernal pool regions, the vernal pool fairy shrimp occurs on inland mesas and valleys, on weak to strongly alkaline soils. In the Los Padres National Forest in Ventura County, it is known to occur in atypical habitats that consist of vernal pools located under a Jeffrey pine (Pinus jeffreyi) canopy that does not possess a grass understory.In general, the vernal pool fairy shrimp has a sporadic distribution in the vernal pool complexes, with most pools being uninhabited by the species (USFWS 2007). The thermal and chemical properties of vernal pool waters are two of the primary factors affecting the distributions of specific fairy shrimp species (including the vernal pool fairy shrimp), or their appearance from year to year. Different species may appear in pools from one year to the next, depending on whether the pools fill at a different time of the year. In years with warm winter rains, vernal pool fairy shrimp do not hatch in at least a portion of their range. In years with low amounts of precipitation or atypical timing of precipitation (or in substandard habitat), vernal pool species may die off before reproducing (Eriksen and Belk 1999). In some cases, vernal pool fairy shrimp will cease to be found in pools where they were formerly found (USFWS 2007).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: Nonmigratory

Dispersal

Adult: Aquatic birds are the most likely agents of dispersal. Large mammals are also known distributors (Eriksen and Belk 1999). Environmental requirements, rather than the ability or inability to disperse, are the likely limiting factor in the distribution of fairy shrimp (59 FR 48136).

Immigration/Emigration

Adult: No

Dispersal/Migration Narrative

Adult: Vernal pool fairy shrimp are nonmigratory and have relatively little ability to disperse on their own. Aquatic birds are the most likely agents of dispersal. Large mammals are also known to act as distributors by wallowing in dirt, getting caught in their fur, and transporting the cysts to another wallow. Also, because cysts can pass through the digestive systems, they can be ingested and then deposited in new habitats when the animal urinates (Eriksen and Belk 1999). Because the cysts are dispersed by other animals, they can be dispersed into locations that will never provide suitable habitat, or into waters that provide conditions allowing individuals to hatch in some years, but where conditions are not suitable for maintaining viable populations (USFWS 2007). Less commonly, usual flooding and wind can also transport cyst. Certain fairy shrimp species are restricted in distribution, and adjacent soils may have different or no fairy shrimp. Pools observed after years seem to have the same species and structural and genetic diversity (Eriksen and Belk 1999). Both flooding and the movement of wildlife in vernal pool complexes allow fairy shrimp to disperse between individual pools. These movement patterns, as well as genetic evidence, indicate that vernal pool fairy shrimp populations are defined by entire vernal pool complexes, rather than individual pools (USFWS 2007).

Population Information and Trends

Population Trends:

Short-term trend: decline of 50 to 70 percent. Long-term trend: unknown. (NatureServe 2015).

Species Trends:

Declining

Population Growth Rate:

Declining (NatureServe 2015)

Number of Populations:

At the time of listing, 178 extant occurrences were known from 32 putative populations, based on proximity of known occurrences. There are currently 400 recorded occurrences (USFWS 2007).

Population Size:

Unknown (NatureServe 2015)

Adaptability:

Moderate

Additional Population-level Information:

There are 13 vernal pool regions in which vernal pool fairy shrimp is found (USFWS 2007).

Population Narrative:

The vernal pool fairy shrimp is much less restricted in range than other species of fairy shrimp; however, it is not abundant at any site (NatureServe 2015). Surveys (and monitoring) of vernal pool fairy shrimp generally only record presence/absence in pools and do not provide information on shrimp abundance in pools. At the time of listing in 1994, the populations represented either geographic clusters of occurrence records or single occurrences from areas with extant vernal pool habitat. The 32 extant populations were described for the following counties, with the number of populations in parentheses: Shasta County (1), Tehama County (4), Glenn County (1), Butte County (1), Yuba County (1), Placer County (1), El Dorado County (1), Sacramento County (2), Solano County (1), Contra Costs County (1), Alameda County (1), Merced County (4), Madera County (2), Fresno County (2), San Benito County (1), Tulare County (4), San Luis Obispo County (1), Santa Barbara County (1), and Riverside County (2)(USFWS 2007). Currently, the vernal pool fairy shrimp is known from 13 pool regions. At the time of listing, 178 extant occurrences were known from 32 putative populations, based on proximity of known occurrences. There are currently 400 recorded occurrences (USFWS 2007).The USFWS has information to indicate that the shrimp is still extant in most of the putative populations, although loss and fragmentation of vernal pool habitat has occurred in and around most of the 1994 populations, potentially decreasing their viability. Without species specific monitoring, the USFWS does not know whether populations of vernal pool fairy shrimp are declining (USFWS 2007). At the time of listing in 1994, the vernal pool fairy shrimp's distribution was described as consisting of 32 loosely defined populations (clusters of occurrences or single occurrences within extant vernal pool habitat) identified by Sugnet & Associates' (1993, entire) surveys, as well as 4 additional populations in southern California (Figure 2). These occurrences were distributed across 11 vernal pool regions. By the time of the first 5-year review in 2007, the known range of the vernal pool fairy shrimp had been filled in throughout the Central Valley, as well as expanded along the borders of the range. In addition to the numerous new occurrences in the Central Valley, the known range was expanded to include southern Oregon, much more of the Central Coast, and new locations in southern California. This information does not indicate that the species is expanding its current range, but simply that greater study and surveys related to permitting pursuant to the Act have increased our knowledge of where the species can be found. In 1998, the vernal pool fairy shrimp was documented in the Agate Desert region of southern Oregon near Medford in the Klamath Mountains Vernal Pool Region, and in 2000–2003 the species was repeatedly documented in a single pool at the Napa Airport at the southeastern edge of the Lake-Napa Vernal Pool Region. This brings the total number of vernal pool regions containing the vernal pool fairy shrimp to 13. Note that a previous Diversity Database record incorrectly identified the vernal pool fairy shrimp in the San Diego Vernal Pool Region, but this record was not discussed in the previous 5-year review and has since been corrected (E. Luciani, Service, in litt. 2021, p. 1). Since the last 5-year review, occurrences have been documented in several new locations in the San Joaquin Valley and in the Central Coast south to Los Angeles County. None of these new locations are within a new vernal pool region for the species, though several are outside of the vernal pool regions defined by Keeler-Wolf et al. (1998, pp. 12–14) and the Recovery Plan (Service 2005a, pp. I-9–I-10). Some of these are just slightly outside of the borders of the vernal pool regions, but others may be isolated pockets of suitable vernal pool habitat that are not within a greater matrix of connected vernal pool complexes (USFWS, 2024).

Threats and Stressors

Stressor: Habitat destruction specific to vernal pool fairy shrimp
Exposure: Conversion of habitat to agriculture, water conveyance, storage projects, population growth, and urbanization.
Response: Habitat elimination and degradation.
Consequence: Reduction in population numbers, extirpation, and decreased dispersal.
Narrative: The loss and modification of vernal pool habitat continues to be the primary threat to the vernal pool fairy shrimp. In areas with extant habitat, loss of vernal pool habitat is expected to continue as urban boundaries expand further, especially through high and low terrace formations on the eastern side of the valley. Even in areas where habitat is protected, the urbanization of lands surrounding conserved areas results in the fragmentation of protected habitats, likely preventing dispersal of the shrimp in and between populations, as well as causing increased edge effects to pool complexes. Protection of vernal pool habitat through the purchase of land and conservation easements has resulted in the preservation of habitat for the shrimp, but the trend of loss of vernal pool habitat has continued. Remnant habitat that has been protected in small parcels is often subject to changed hydrological conditions, invasion by nonnative plants and other species, increased vegetation growth, and other conditions (such as cessation of grazing or overgrazing) that serve to make habitat less suitable for the shrimp. This threat is expected to continue as expected population increases result in urban growth in areas of remaining vernal pool habitat. Studies have not been conducted to determine the minimum area (upland and wetland) needed to sustain vernal pool species in the long term (USFWS 2007).

Stressor: Altered hydrology
Exposure: Physical barriers, such as roads and canals that dam vernal pools; changes to patterns of surface and subsurface flow; and increased runoff.
Response: Habitat becomes unsuitable or degraded.
Consequence: Reduction in population numbers.
Narrative: In addition to direct habitat loss, vernal pool crustaceans have declined because of a variety of activities that render existing vernal pools unsuitable for the species. Vernal pool hydrology can be altered directly when swale systems connected to vernal pools are dammed by physical barriers, such as roads and canals. These barriers can alter vernal pool hydrology both

upstream and downstream of the barrier by truncating connectivity and flow. Vernal pool hydrology also may be altered by changes to patterns of surface and subsurface flow, depending on topography, precipitation, and soil types. The increased runoff and nuisance flows associated with urban development and impervious surfaces may result in altered hydrology of seasonal wetlands on and off site. For example, stormwater drains, or the coverage of land surfaces with concrete, asphalt, or irrigated lawns, can alter the duration, volume discharge, and frequency of surface flows through increased flooding and runoff (USFWS 2005). All vernal pools may appear to be similar, yet each pool may exhibit different hydrological behavior: in some vernal pool habitats, clay soils keep most water on or near the surface, so vernal pools receive nearly all of their water due to direct precipitation and are maintained by surface flows. Vernal pool hydrology can also be altered by the nonnative grasses that occur commonly in vernal pool complexes. Nonnative grasses maintain dominance at pool edges, sequestering light and soil moisture, promoting thatch build-up, and shortening inundation periods. Although the mechanism responsible for the change in inundation is not documented, reduction in inundation period is thought to be due to increased evapotranspiration at the vernal pools. In most vernal pool regions, some vernal pool fairy shrimp occurrences are located on remnant vernal pool habitat adjacent to residential, industrial, or commercial development; to infrastructure; or to deep-ripped vineyards or orchards. Development can result in the loss of hydrological connections that sustain the remnant vernal pools, resulting in premature drying of pools before the life cycle of the shrimp is completed. Alternatively, in remnant habitat parcels, vernal pools can be subject to increased periods of inundation due to nearby irrigation, outfall discharge, or runoff from development. Increased periods of inundation can reduce habitat suitability. In addition, use of off-road vehicles (ORVs) poses an unquantified threat to the vernal pool fairy shrimp at specific locations. ORVs cut deep ruts, compact soil, destroy native vegetation, and alter vernal pool hydrology. Various ORV uses have cumulatively damaged vernal pool habitats within the shrimp’s range (USFWS 2007).

Stressor: Invasive plant species
Exposure: Invasion of native and nonnative species; grazing cessation.
Response: Change in hydrology.
Consequence: Reduction in population numbers.
Narrative: Exotic, weedy nonnative and invasive native wetland plants are a threat to natural vernal pool hydrology in a number of lands under public or private conservation management. Nonnative plant species occur commonly in vernal pool complexes and have become a threat to native vernal pool species through their capacity to change pool hydrology. Invasive nonnative plants are a threat to natural vernal pool hydrology in a number of lands under public or private conservation management. In areas near the urban boundary, cattle grazing is often discontinued in anticipation of land use changes. Cessation of cattle grazing has been found to exacerbate the negative effects of invasive nonnative plants on vernal pool inundation period, presumably due to the positive effects of grazing on evapotranspiration rates. Use of prescribed fire is being employed at some sites to reduce invasive plants; however, its use is problematic in urban and suburban areas due to air quality and wildfire concerns. In vernal pools where vegetative material is relatively sparse, fairy shrimp cysts do not appear to be negatively affected by fire, but in regions where thatch has built up or vegetative material is dense, fire may have deleterious effects on cyst viability. Without treatment, the density of nonnative herbaceous vegetation surrounding pools is expected to increase degradation of vernal pool habitat through contamination and loss of water (USFWS 2007).

Stressor: Predation
Exposure: Introduced and nonnative predators.
Response: See narrative.
Consequence: Direct mortality.
Narrative: The final rule noted that predation of vernal pool crustaceans by nonnative bullfrogs (Rana catesbeiana) potentially increased the threat of predation beyond that found naturally. Opportunities for bullfrog dispersal into vernal pool ecosystems have increased because additional permanent-water habitat has been created in canals, in streams augmented by urban runoff and irrigated agriculture, and in stock ponds and other impoundments. However, the effect of such predation on the prey populations in these pools has not been determined. Vernal pool crustaceans lack predator-avoidance mechanisms and are continuously moving their phyllopods, so they may be particularly susceptible to predation by bullfrogs and other visual predators. The use of mosquitofish (Gambusia affinis) to control mosquito larvae may be an emerging threat for the vernal pool fairy shrimp. Mosquitofish have also dispersed into vernal pools from nearby permanent waters. Mosquitofish have been shown to significantly reduce fairy shrimp abundance when introduced to pools with active shrimp. In summary, two introduced predators are known to disperse into vernal pool habitat during the time of year when the vernal pool fairy shrimp is active. The threat from bullfrogs was noted in the final listing rule, and mosquitofish are a newly recognized threat. These predators are good dispersers and are found throughout the range of the shrimp. The permanent-water habitat for these species is known to be increasing in the state due to impoundments, irrigation canals, and augmented stream flows due to urban runoff. Both introduced species pose a potential threat to the vernal pool fairy shrimp, but the magnitude of the threat is unknown at this time (USFWS 2007).

Stressor: Inadequate regulatory mechanisms.
Exposure: Mismanaged areas, lack of regulations, and few laws protecting vernal pool fairy shrimp.
Response: See narrative.
Consequence: Reduction in protection and population numbers.
Narrative: Without protection under the Endangered Species Act (ESA), regulatory mechanisms to protect the vernal pool fairy shrimp continue to be inadequate. State regulations do not protect the shrimp. Changes in implementation of the Clean Water Act may result in greater losses of vernal pool habitat on private lands, because fewer permits are required under Section 404. Other federal regulatory mechanisms provide discretionary protections for the species based on current management direction, but do not guarantee protection for the species absent its status under ESA (USFWS 2007).

Stressor: Habitat fragmentation
Exposure: Fragmentation
Response: See narrative.
Consequence: Unknown
Narrative: The continuing fragmentation of vernal pool fairy shrimp habitat range-wide may result in small, isolated occurrences of this species in some areas. Populations in the Klamath Mountains, West Riverside County, Santa Barbara, Central Coast, and Carrizo vernal pool regions have already been largely fragmented, while populations in the remaining regions are sustaining increasing fragmentation. If an extirpation event, such as a prolonged drought cycle, occurs in a population that has lost substantial habitat and has been fragmented, the opportunities for recolonization will likely be greatly reduced due to physical isolation from other source

populations. Population dynamics for the species have not been studied, and the U.S. Fish and Wildlife Service (USFWS) does not know of any studies that have assessed the status of cyst banks in isolated or connected pools (USFWS 2007).

Stressor: Drought
Exposure: Use of herbicides, fertilizers, and other chemicals; lack of water.
Response: Water contamination, reduction in habitat quality; reduction in habitat.
Consequence: Delayed development, injury, mortality, and reduction in population numbers. No reproductive output, mortality, and reduction in population numbers.
Narrative: The introduction of pesticides and other contaminants into vernal pool waters may threaten occurrences of the vernal pool fairy shrimp. In Oregon, the presence of the shrimp appears to be threatened by unsuitable water quality in vernal pools due to deposition of timber industry wood waste (log deck debris), planting of intermediate wheat grass, accumulation of dead organic matter (including thatch from dead, dry wetland plants), and deposition of biosolids (treated sewage) or other pollutants. Plant decomposition and algal growth can lead to the depletion of dissolved oxygen in natural waters, and can increase sediment toxicity. These factors could contribute to loss of the shrimp and could potentially become limiting in areas where thatch from nonnative grasses accumulates in vernal pool habitat, although the degree of risk is unknown. Water quality in vernal pools may also be degraded over large portions of the Central Valley due to pesticide overspray and residues. Vernal pool crustaceans are highly sensitive to the chemistry of their vernal pool habitats. Use of herbicides, fertilizers, and other chemicals are common in urban and agricultural settings. There is a general lack of specific studies to assess effects of herbicides, fertilizers, and other chemicals on vernal pool species. However, if such chemicals reach seasonal wetlands via storm or nuisance sheet flow, they could have detrimental impacts on these species. Contamination of vernal pools from adjacent areas may injure or kill vernal pool crustaceans and plants either directly or indirectly. Drought is likely to decrease or terminate reproductive output as pools fail to flood, or dry up before reproduction is complete. In a Mediterranean climate such as that of California, the annual season of precipitation (November to March) is relatively predictable, although the amount of precipitation can vary substantially from year to year. For population maintenance, vernal pools must last longer, on average, than the time needed for a species to reach maturity and produce viable eggs; and relatively small changes in the timing or amount of precipitation can affect population dynamics. Based on existing data, weather conditions in which vernal pool flooding promotes hatching—but in which pools dry (or become too warm) before embryos are fully developed—are expected to have the greatest negative effect on the resistance and resilience of vernal pool fairy shrimp populations as depletion of the cyst banks occur (USFWS 2007).

Stressor: Off-road vehicle use
Exposure: Use of off-ORVs.
Response: Compact soil, destroy native vegetation, alter vernal pool hydrology, and crush vernal pool cysts.
Consequence: See narrative.
Narrative: Use of ORVs poses an unquantified threat to the vernal pool fairy shrimp at specific locations. ORVs cut deep ruts, compact soil, destroy native vegetation, and alter vernal pool hydrology. A variety of ORV uses have cumulatively damaged vernal pool habitats within the shrimp's range. On military bases, vernal pools may be subject to various forms of disturbance from military operations, including ORVs, although the effect on vernal pool fairy shrimp is not clear. At Camp Roberts, biologists have reported no evident correlation between shrimp

presence and light to moderate disturbance by grazing sheep and cattle, and vehicle use; however, vehicle use during the wet season was limited. Other studies have reported fewer vernal pool fairy shrimp present in areas with evidence of heavy ORV use. Fairy shrimp cysts appear to be easily crushed, so abundance of the species in affected pools could be reduced by substantial ORV disturbance (USFWS 2007).

Stressor: Stochastic extinction
Exposure: Isolated populations, and random or naturally occurring events.
Response: See narrative.
Consequence: Mortality and reduction in population numbers.
Narrative: Isolated populations continue to be threatened by stochastic extinction in that unforeseen natural and man-caused catastrophic events may eliminate some sites. The status of many occurrences is unknown, so USFWS cannot quantify the extent to which extinction events have occurred or may occur. If an extirpation event, such as a prolonged drought cycle, occurs in a population that has lost substantial habitat and has been fragmented, the opportunities for recolonization will likely be greatly reduced due to physical isolation from other source populations (USFWS 2007).

Stressor: Competitive effects of human disturbance
Exposure: Disturbance that facilitates changes in species composition.
Response: Competition for the vernal pool fairy shrimp.
Consequence: See narrative.
Narrative: Disturbance may also facilitate changes in species composition by allowing species not typically found in specific vernal pools to colonize. Colonizers can sometimes hybridize or replace endemic species. For example, occurrence patterns of the congeneric versatile fairy shrimp (Branchinecta lindahli) suggest that it may out-compete the vernal pool fairy shrimp where the two occur together. The versatile fairy shrimp is a habitat generalist and is a widespread species in the western United States and Canada. Like the vernal pool fairy shrimp, it is a cool-water species, develops quickly, and when found in pools without other fairy shrimp species, typically inhabits small pools. The versatile fairy shrimp has been found in pools with the vernal pool fairy shrimp, including pools in western Riverside County and in the Livermore core recovery area. In such areas, the versatile fairy shrimp greatly outnumbers the vernal pool fairy shrimp. The species could be a threat to persistence of the vernal pool fairy shrimp in areas where they both occur; however, to our knowledge, the interactions between the two species have not been systematically studied (USFWS 2007).

Stressor: Climate change
Exposure: Rising global temperatures.
Response: Habitat degradation and decreased inundation periods.
Consequence: Reduction in population numbers and reduced fitness.
Narrative: Climate change is expected to have an effect on vernal pool hydrology through changes in the amount and timing of precipitation inputs to vernal pools, and the rate of loss through evaporation and evapotranspiration. Cooling and drying trends could adversely affect vernal pool fairy shrimp through decreased inundation periods that do not allow the species sufficient time to complete its life cycle. It is expected that California winters may become warmer and wetter, while El Niño frequency and intensity may increase. Even modest increases in average temperature could result in more runoff in winter, less runoff in spring and summer, more winter flooding, and drier summer soils, thereby altering the seasonality and duration of

vernal pool hydration (USFWS 2007).

Stressor: Agricultural Conversions (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Conversion of vernal pool grasslands to agricultural uses is by far the most significant factor driving the loss of vernal pool habitat, at least in the Central Valley where this has been most closely studied. Vernal pool grasslands are generally located in areas that are well suited to agriculture. Agricultural conversions resulted in the loss of 70,878 acres of vernal pool grasslands in the Central Valley between 2005 and 2018, accounting for 93% of all losses (Witham 2021, p. 8). Madera, San Joaquin, and Merced Counties have all experienced losses of over 10,000 acres from 2005 to 2018 due to agricultural conversions. Even the vernal pool region with the most losses due to urban development, the Southeastern Sacramento Valley region, still had over four times more losses due to agricultural conversion. In particular, conversion to orchards, vineyards, and eucalyptus plantations has been the largest driver of vernal pool habitat loss over the past 40 years. It accounted for almost 30% of losses from the late 20th century through 2005 (Holland 2009, p. 4), and 56% of losses from 2005 to 2018 (Witham 2021, p. 8). From 2005 to 2012 the largest losses were due to conversion of vernal pool grasslands to bare plowed ground (Witham et al. 2014, p. 8), but most of these areas had been fully converted to orchards by 2018 (Witham 2021, p. 8). Agricultural conversion of vernal pool habitat is expected to continue in the future. Most agricultural conversions occur outside of normal regulatory processes. In most instances, these losses have gone unmitigated, either proceeding without required authorization(s) such as a Clean Water Act Section 404 permit and associated section 7(a)(2) consultation, or in instances where direct filling of waters of the United States has been avoided, thus not triggering the Clean Water Act permitting process or the Act's section 7 process. Researchers have consistently recommended increased enforcement of the Act and the Clean Water Act to deter this unauthorized loss of vernal pool habitat, or to provide compensation to offset the loss of habitat to the same extent that is required of projects that go through the appropriate regulatory channels (USFWS, 2024)

Stressor: Urban Development (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Although not as extensive as agricultural conversions, urban development has contributed to losses of vernal pool grasslands throughout California. Vernal pool grasslands are often located in fairly flat areas that are well suited to urban development. From the end of the 20th century through 2005, approximately 25,965 acres of vernal pool grassland in the Central Valley was lost due to urban development (Holland 2009, p. 10), and an additional 5,056 acres was lost from 2005 to 2018 (Witham 2021, geodatabase). This represents approximately 19% of all losses from the end of the 20th century through 2005 (Holland 2009, p. 19) and only 7% of all losses from 2005 to 2018 (Witham 2021, p. 8). The decrease in the rate of loss due to urban development since 2005 can likely be attributed to the economic downturn caused by the Great Recession in 2008 and other factors that have made urban development more difficult or costly in recent years. However, pressure to convert vernal pool grasslands to urban development is expected to continue as the population of California and southern Oregon continues to grow. Even when vernal pool habitat is avoided during urban development, the urbanization of

surrounding lands leads to greater habitat fragmentation. Urban development has not been evenly distributed across the range of the three shrimp species. At the end of the 20th century, losses due to urban development were very significant in Placer County (15,368 acres, 59.2% of all losses) and fairly significant in Sacramento County (3,267 acres, 12.6% of all losses) (Holland 2009, p. 10). From 2005 to 2018, losses due to urban development continued to remain highest in Placer (1,842 acres) and Sacramento (933 acres) Counties, representing 39.2% and 21.8% of losses in each county, respectively (Witham 2021, p. 9). The Greater Sacramento area (the six-county area surrounding the city of Sacramento) had a population of approximately 2,578,590 in 2020, up 11.3% from 2010 (SACOG 2022, p. 1). The population is expected to continue growing over the next 20 years, with a projected population of 2,996,832 in 2040 (16.2% increase over 20 years) (SACOG 2020, p. 15), so urbanization will likely continue to be a significant cause of habitat loss for the vernal pool fairy shrimp within this region. Although vernal pool grasslands have not been as extensively researched outside of the Central Valley, it is likely that urban development is a greater threat to vernal pool grasslands in the Central Coast (Ferren and Pritchett 1988, p. 4) and Southern California (Dudek and Associates 2003, entire). The terrain and climate of these areas is not as conducive to agriculture as the Central Valley, and urban development has been particularly extensive in Southern California. The Klamath Mountains Vernal Pool Region in Oregon is not heavily urbanized, with a population of 223,259 in 2020, a 10% increase from 2010 (U.S. Census Bureau 2022, p. 1). Urban development is much more closely regulated than agricultural conversions, and therefore the Service almost always conducts an interagency consultation with the Corps when an applicant is seeking a Clean Water Act Section 404 permit to fill vernal pools. The Corps generally requires mitigation for destroyed vernal pools in the form of vernal pool creation at a 1:1 ratio. In many parts of California, project applicants will also incorporate conservation measures that include preserving existing vernal pool habitat that is occupied by the shrimp species (often at a 2:1 ratio) and ensuring that the created vernal pools will also provide habitat for the shrimp species. These projects may still result in a net loss of vernal pool grassland acreage (pools may be created within existing vernal pool grasslands, and created pools are often more densely concentrated than natural pools), but the mitigation acquired and conservation measures implemented through regulatory channels has been an important source of vernal pool preservation throughout the range of the three shrimp species (USFWS, 2024).

Stressor: Infrastructure (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Road construction and widening threatens occurrences of the three shrimp species that are in construction boundaries and within road rights-of-way. Although not examined specifically, road infrastructure was likely included within Holland's (2009, p. 4), Witham et al.'s (2014, p. 8), and Witham's (2021, p. 8) urban development category, and thus represents a small portion of total vernal pool grassland losses. Besides direct loss of vernal pools, roads can create barriers to dispersal and hydrologic connectivity, and disturbance along the road edge can be a source of introduction for invasive plants. Unlike the habitat loss and fragmentation of most urban development, which is by definition mostly in urban or urbanizing areas, some roads and highways may cause fragmentation in more rural or isolated areas. Other infrastructure projects that threaten the three shrimp species include energy infrastructure such as substations, pipelines, and solar panels, as well as other utilities infrastructure like sewer, water lines, and telephone lines. Besides direct loss due to grading or excavation during construction of the

infrastructure, ongoing maintenance of infrastructure placed within vernal pool grasslands may subject the pools to repeated disturbance from off-road vehicles, management activities like vegetation removal or firebreak creation, and the introduction of invasive plants (USFWS, 2024).

Stressor: Altered Hydrology (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Altered hydrology caused by nearby development, agriculture, or other land uses can sometimes result in vernal pools that no longer function as habitat for the three shrimp species. The greater watershed can supply 25–60% of the water needed to fill vernal pools to the margin (Williamson et al. 2005, p.10), so changes to surrounding lands such as urban development that influence a pool's watershed may indirectly cause habitat loss even if the pool itself is left intact. Altered hydrology is not as significant a threat as direct losses of vernal pools from agricultural conversion, urban development, and infrastructure. Still, it is likely that this threat has increased along with direct losses since remaining vernal pools adjacent to the direct losses may have their hydrology altered, although this threat has not been studied as closely as direct loss of vernal pool grasslands. Small changes in local land use may have adverse impacts on vernal pools, although the degree to which such changes affect pools is poorly understood because the fundamental hydrogeological characteristics of perched aquifers remain relatively unexplored (Rains et al. 2006, p. 1173). It is possible that remnant vernal pools within altered landscapes, or higher densities of created vernal pools, may not have adequate surface and/or subsurface flows to adequately function as shrimp habitat. Alternatively, the abiotic habitat components such as water chemistry, which are mediated by transport through subsurface and surface flows, may alter the suitability of the habitat to support the three shrimp species if anthropogenic activities significantly affect upland watersheds (Rains et al. 2008, p. 348). The change in surface permeability, from permeable grasslands and semipermeable old-terrace geologic formations to impermeable roads, residential and commercial rooftops, and concrete reduces and prevents natural percolation through the soils and significantly increases runoff and storm flows. Excessive urban runoff or agricultural discharge can change the hydroperiod of vernal pools, so that they become inundated during hot summer months when they would naturally have remained dry. When the hydrologic regime is altered, the biota of vernal pools and swales is expected to change and the new hydroperiod or ecological community may not support the lifecycle of the three shrimp species. Ground disturbing activities within the watershed of vernal pools may result in siltation when pools fill during the wet season following construction. Besides negative changes to a pool's hydroperiod caused by silt deposition, siltation can also impact the plant and invertebrate communities more directly. In general, increased amounts of sediment in freshwater wetlands can reduce the richness and density of invertebrates and alter their species composition (Sheldon et al. 2003, 4-26–4-28). Based on these general findings, it is anticipated that siltation in vernal pools could bury shrimp cysts, clog filter feeding apparatuses, change the aquatic community species composition, and decrease availability of food sources like plant matter and detritus due to burial or decreased light availability. Although vernal pool tadpole shrimp in particular are known to occur in turbid wetlands, they may be adversely affected by increased siltation if sediment levels increase above the levels they are locally adapted to in a particular pool or vernal pool complex (USFWS, 2024).

Recovery

Reclassification Criteria:
The vernal pool fairy shrimp is listed as a threatened species. No reclassification or uplisting criteria have been established for the species.

Recovery Priority Number: 2C

Delisting Criteria:
Accomplish habitat protection that promotes vernal pool ecosystem function sufficient to contribute to population viability of the species, including: a. Protection of suitable vernal pool habitat in each prioritized core area for the species. The delisting criterion for the species requires 85 percent of the range-wide suitable habitat in core areas zone 1 or zone 2 be protected. This total amount of habitat must be represented to some degree in the 38 core areas (within 13 vernal pool regions) in which the shrimp is identified in the Recovery Plan. b. Protection of species localities distributed across the species geographic range and genetic range. Protection of extreme edges of populations protects the genetic differences that occur there. The criterion specifies that 80 percent of the vernal pool fairy shrimp occurrences be protected. c. Reintroduction and introductions must be carried out and meet success criteria. d. Protection of additional occurrences identified through figure site assessments, GIS and other analyses, and status surveys that are determined essential to recovery. Any newly found occurrences may count toward recovery goals if the occurrences are permanently protected as described in the Recovery Plan. e. Habitat protection results in protection of hydrology essential to vernal pool ecosystem function, and monitoring indicates that hydrology that contributes to population viability has been maintained through at least one multi-year period that includes above-average, average, and below-average local rainfall as defined above, a multi-year drought, and a minimum of 5 years of post-drought monitoring. (USFWS 2005; USFWS 2007).

Adaptive Habitat Management and Monitoring, including: a. Habitat management and monitoring plans that facilitate maintenance of vernal pool ecosystem function and population viability have been developed and implemented for all habitat protected, as previously discussed above. b. Mechanisms are in place to provide for management in perpetuity and long-term monitoring of items presented above, as previously discussed (funding, personnel, etc.). c. Monitoring indicates that ecosystem function has been maintained in the areas protected under items presented above for at least one multi-year period that includes above-average, average, and below-average local rainfall, a multi-year drought, and a minimum of 5 years of post-drought monitoring (USFWS 2005, USFWS 2007).

Status surveys, including a. Status surveys, 5-year status reviews, and population monitoring show populations in each vernal pool region where the species occur are viable (e.g., evidence of reproduction and recruitment) and have been maintained (stor increasing) for at least one multi-year period that includes above-average, average, and below-average local rainfall, a multi-year drought, and a minimum of 5 years of post-drought monitoring. b. Status surveys, status reviews, and habitat monitoring show that threats identified during and since the listing process have been ameliorated or eliminated. Site-specific threats identified through standardized site assessments and habitat management planning also must be ameliorated or eliminated (USFWS 2005; USFWS 2007).

Research, including: a. Research actions necessary for recovery and conservation of the covered species have been identified (these are research actions that have not been specifically identified in the recovery actions but for which a process to develop them has been identified). Research actions (both specifically identified in the recovery actions and determined through the process) on species biology and ecology, habitat management and restoration, and methods to eliminate or ameliorate threats have been completed and incorporated into habitat protection, habitat management and monitoring, and species monitoring plans, and refinement of recovery criteria and actions. b. Research on genetic structure has been completed (for species where necessary—for reintroduction and introduction, and seed banking) and results incorporated into habitat protection plans to ensure that in and among population, genetic variation is fully representative by populations protected. c. Research necessary to determine appropriate parameters to measure population viability for each species have been completed (USFWS 2005; USFWS 2007).

Participation and outreach, including: a. Recovery Implementation Team is established and functioning to oversee range-wide recovery efforts. b. Vernal Pool Regional working groups are established and functioning to oversee regional recovery efforts. c. Participation plans for each vernal pool region have been completed and implemented. d. Vernal pool region working groups have developed and implemented outreach and incentive programs that develop partnerships contributing to achieving recovery criteria (USFWS 2005; USFWS 2007).

Recovery Actions:

- Protect vernal pool habitat in the largest blocks possible from loss, fragmentation, degradation, and incompatible uses (USFWS 2005).
- Manage, restore, and monitor vernal pool habitat to promote the recovery of listed species and the long-term conservation of the species of concern (USFWS 2005).
- Conduct range-wide status surveys and status reviews for all species addressed in this recovery plan to determine species status and progress toward achieving recovery of listed species and long-term conservation of species of concern (USFWS 2005).
- Conduct research and use results to refine recovery actions and criteria, and guide overall recovery and long-term conservation efforts (USFWS 2005).
- Develop and implement participation programs (USFWS 2005).
- Research: Conduct coordinated research for the vernal pool fairy shrimp that assesses the number of demographically independent units that are persisting, directly estimates levels of migration between units (to determine likelihood of recolonization), determines long-term trends in population growth, and experimentally measures probabilities of local extinction and recolonization. Research should address egg bank dynamics and trends in egg bank abundance over time. Comparisons between isolated pools, pools in fragmented habitat, pools in intact vernal pool complexes, and a variety of created pools should also be assessed. The long-term effects on the hydrology of vernal pools from development-related alterations to vernal pool sub-watersheds should be assessed. Efforts should lead to determinations of appropriate hydrology (or upland) buffers. Additional research needs include a systematic survey to update the status of known California Natural Diversity Database occurrences. The probability of detecting the species under USFWS' survey guidelines for vernal pool crustaceans should also be conducted (USFWS 2007).
- Recovery: Additional preservation of known extant occurrences is needed to reduce habitat threats and reach recovery goals outlined in the 2005 Recovery Plan. Preservation of large blocks of vernal pool habitat that contain complete or large portions of vernal pool complexes is needed for this species. USFWS should also work with private landowners for

the conservation of habitat for the vernal pool fairy shrimp through conservation easements or other methods (USFWS 2007).

- Monitoring: Develop and implement a standardized formal monitoring program that collects data in sufficient detail to evaluate species status, and examine changes in population dynamics and community composition (USFWS 2007).
- Habitat Management: Develop management indicators for identifying potential problems and assessing ecosystem health as it pertains to vernal pool crustaceans. Establish requirements for appropriate management of vernal pool landscapes. Establish improved guidelines, monitoring protocols, and success criteria for appropriate management of vernal pool landscapes and constructed and restored pools (USFWS 2007).
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Additional Threshold Information:

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SPECIES ACCOUNT: *Branchinecta sandiegonensis* (San Diego fairy shrimp)

Species Taxonomic and Listing Information

Commonly-used Acronym: None

Listing Status: Endangered; February 3, 1997 (62 FR 4925).

Physical Description

The San Diego fairy shrimp (Branchinecta sandiegonensis) is a delicate freshwater shrimp. Mature individuals lack a carapace (hard outer covering of the head and thorax), and have a delicate elongate body, large-stalked compound eyes, and 11 pairs of swimming legs. They swim or glide gracefully upside down by means of complex wave-like beating movements of the legs that pass from front to back. Adult male San Diego fairy shrimp range in size from 9 to 16 millimeters (mm) (0.35 to 0.63 inches [in.]); adult females are 8 to 14 mm (0.31 to 0.55 in.) long. The second pair of antennae in males are greatly enlarged and specialized for clasping the females during copulation, while the second pair of antennae in the females are cylindrical and elongate. The females carry their eggs in an oval or elongate ventral brood sac (62 FR 4925).

Taxonomy

The San Diego fairy shrimp is a small aquatic crustacean in the order Anostraca, first described in 1993 by Michael Fugate (1993), based on collections from Del Mar Mesa in San Diego County (USFWS 2008). Male San Diego fairy shrimp are distinguished from other Branchinecta species males by differences in the distal (i.e., located far from the point of attachment) tip of the second antennae. Females are distinguishable from other Branchinecta species females by the shape and length of the brood sac, length of the ovary, and presence of paired dorsolateral (i.e., located on the sides, toward the back) spines on five of the abdominal segments. The San Diego fairy shrimp is often misidentified with the versatile fairy shrimp (Branchinecta lindahli), which is native to and commonly found throughout western North America (USFWS 2008).

Historical Range

San Diego fairy shrimp were known to inhabit a minimum of 25 vernal pool complexes in coastal areas of San Diego, Orange, and Santa Barbara counties, and northwestern Baja California, Mexico (USFWS 2008).

Current Range

Currently, 137 complexes occupied by San Diego fairy shrimp have been identified in the United States; an additional three complexes that were identified as occupied at listing have since been extirpated. These complexes are in San Diego, Orange, and Santa Barbara counties (USFWS 2008). 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. (USFWS, 2021)

Critical Habitat Designated

Yes; 12/12/2007.

Legal Description

On December 12, 2007, the U.S. Fish and Wildlife Service (Service), designated revised final critical habitat for the San Diego fairy shrimp (Branchinecta sandiegonensis) under the Endangered Species Act of 1973, as amended (Act). Approximately 3,082 acres (ac) (1,248 hectares (ha)) of habitat in Orange and San Diego counties, California, were designated as critical habitat for the San Diego fairy shrimp. The revised final designation constitutes a reduction of 943 ac (382 ha) from the 2000 designation of critical habitat for the San Diego fairy shrimp (72 FR 70648 - 70714).

Critical Habitat Designation

3,082 ac (1,248 ha) of land is designated as critical habitat for San Diego fairy shrimp in 5 units with a total of 29 subunits.

Unit 1: Orange County (15 ac (6 ha)). Unit 1 is located in Orange County, California. The area was occupied at the time of listing and contains the PCEs essential to the conservation of the San Diego fairy shrimp that may require special management considerations or protection. The majority of the vernal pools in Orange County were eliminated prior to 1950 and only a small number of vernal pool complexes remain (Riefner and Pryor 1996, p. 300). This unit represents the northern extent of the species' distribution in southern California and represents the historical distribution of coastal terrace vernal pools in this area. The vernal pools in Orange County are the only pools that form on Alo clay, Calleguas clay loam, Cieneba sandy loam, and Soper gravelly loam that support the San Diego fairy shrimp. This unit contains vernal pools that support San Diego fairy shrimp populations in the ''Group A'' genetic clade (Bohonak 2007, p. 1). For these reasons this unit is essential for recovery of the San Diego fairy shrimp. For more information about Unit 1 please see the proposed rule (68 FR 19888; April 22, 2003). Subunit 1C: Newport-Banning Ranch. The Service designated subunit 1C as critical habitat for the San Diego fairy shrimp. Subunit 1C consists of 15 ac (6 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. It is located south of the Santa Ana River, 2 mi (3 km) inland from the coast. Subunit 1C consists of privately owned land. The vernal pool complex at NewportBanning Ranch is one of only five known vernal pool complexes containing the San Diego fairy shrimp in Orange County. This vernal pool complex and the vernal pool complex at Fairview Park (subunit 1B) represent the only remaining examples of coastal vernal pools in Orange County. Subunit 1C is closed to recreational use; however, this area has been degraded by past activities and may face future impacts from the development of this site and/or its watershed. The PCEs in this critical habitat subunit may require special management considerations or protection to address threats from development activities and nonnative species that may negatively impact the San Diego fairy shrimp, its PCEs, and its habitat.

Unit 2: San Diego, North Coastal Mesa (6 ac (3 ha)). Unit 2 is located in San Diego County, California. The area was occupied at the time of listing and contains the features the Service has identified as essential to the conservation of the San Diego fairy shrimp that may require special management considerations or protection. The vernal pool complexes in this unit occur on Carlsbad gravelly loam sand, Diablo clay, and Salinas clay. As a result of coastal development, most vernal pools supporting the San Diego fairy shrimp on coastal terraces in San Diego County have been lost. Unit 2 represents the largest collection of vernal pools on coastal terraces that remain in San Diego County. Given the rarity of the San Diego fairy shrimp and the limited amount of remaining vernal pool habitat, this unit is essential to the conservation of this species because of the need to conserve vernal pools throughout the range of the species. This unit contains vernal pools that support San Diego fairy shrimp populations in the ‘‘Group B’’ genetic clade (Bohonak 2007, p. 1). This unit is also essential due to its role in maintaining the genetic diversity and population stability of the San Diego fairy shrimp. For more information about Unit 2 please see the proposed rule (68 FR 19888; April 22, 2003). The Service has determined that MCB Camp Pendleton's INRMP provides a benefit to the San Diego fairy shrimp and therefore MCB Camp Pendleton, including the proposed subunits 2A–2F, is exempt from the designation of critical habitat pursuant to section 4(a)(3) of the Act (see Summary of Changes From Previously Designated Critical Habitat and 2003 Proposed Rule and Exemptions and Exclusions sections for more information on this exemption). Subunit 2G: Poinsettia Lane Commuter Station. The Service designated subunit 2G as critical habitat for the San Diego fairy shrimp. Subunit 2G consists of 6 ac (3 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. It is located in Carlsbad, California, north of Poinsettia Lane, 0.25 mi (0.4 km) inland from the coast. Subunit 2G consists of 4 ac (2 ha) of public land owned by the North County Transit District (NCTD) and 2 ac (1 ha) of private land. Lands in this subunit owned by NCTD are in a conservation easement managed by CDFG. However, at this time additional management measures, such as monitoring of water quality and the restoration of native vegetation around the vernal pools, may be needed to conserve the PCEs for San Diego fairy shrimp. The PCEs in this critical habitat subunit may also require special management considerations or protection to address threats from altered hydrology and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat.

Unit 3: San Diego, Inland Valley (725 ac (292 ha)). Unit 3 contains vernal pool complexes within the jurisdiction of the City of San Marcos and the community of Ramona. The area was occupied at the time of listing and contains the features essential to the conservation of the San Diego fairy shrimp that may require special management considerations or protection for the San Diego fairy shrimp. The vernal pool complexes in unit 3 are associated with alluvial or volcanic type soils and include the only vernal pool complexes known to occur on Placentia soils (Service GIS database; soils described by Bowman 1973, pp. 68–69). The vernal pool complexes in San Marcos are associated with a unique plant association of multiple species of Brodiaea (Armstrong 2007, pp. 11–16). The recovery plan specifically identifies these vernal pools as essential for the recovery of the San Diego fairy shrimp. This unit includes vernal pools within the easternmost edge of the geographical distribution of the species and at the highest elevation where this species occurs. This unit contains vernal pools that support San Diego fairy shrimp populations in the ‘‘Group B’’ genetic clade (Bohonak 2004, pp. 3–9). Conservation of vernal pools in this unit will help maintain the diversity of vernal pool habitats and their unique geological substrates, and will retain the genetic diversity of these geographically distinct populations. For more information about Unit 3 please see the proposed rule (68 FR 19888; April 22, 2003). Subunit 3A: San Marcos: Northeast. The Service designated subunit 3A as critical habitat for the San Diego fairy shrimp. Subunit 3A consists of 17 ac (7 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 3A is located north of State Route 78, just south of Palomar Community College, 8 mi (13 km) inland from the coast. Subunit 3A consists of 16 ac (6 ha) of privately owned land and of 1 ac (<1 ha) of land owned by a Special District. This site has been proposed for development, and it is likely that the vernal pools within this subunit will be directly or indirectly impacted by the development. The PCEs within this critical habitat subunit may require special management considerations or protection to address threats from development, off-road vehicles, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 3C: San Marcos: Southwest. The Service designated subunit 3C as critical habitat for the San Diego fairy shrimp. Subunit 3C consists of 63 ac (25 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 3C is located south of State Route 78, to the north of San Marcos Boulevard between South Pacific Street and South Las Posas Road, 8 mi (13 km) inland from the coast. Subunit 3C consists of 11 ac (4 ha) of land owned by the City of San Marcos, 4 ac (2 ha) of land owned by the Water District, and 48 ac (19 ha) of privately owned land. This site is currently not fenced and the vernal pool habitat in this subunit is subject to continuing impacts from off-road vehicles and illegal dumping. The PCEs in this critical habitat subunit may require special management considerations or protection to address threats from development, off-road vehicles, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 3D: San Marcos: Southeast. The Service designated subunit 3D as critical habitat for the San Diego fairy shrimp. Subunit 3D consists of 5 ac (2 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 3D is located south of State Route 78, east of Linda Vista Drive and west of Bent Avenue, 9 mi (14 km) inland from the coast. Subunit 3C is privately owned. The PCEs in this critical habitat subunit may require special management considerations or protection to address threats from altered hydrology and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 3E.1: Ramona Grasslands. The Service designated subunit 3E.1 as critical habitat for the San Diego fairy shrimp. Subunit 3E.1 consists of 382 ac (154 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 3E.1 is located in the western portion of the Santa Maria Valley, north of the Santa Maria Creek and southwest of the Ramona Airport, 20 mi (32 km) inland from the coast. Subunit 3E.1 consists of 1 ac (<1 ha) land owned by the Water District and 381 ac (153 ha) of privately owned land. Various conservation organizations are in the process of acquiring land within this subunit; however, not all of the land is conserved at this point and there is no long-term management plan for the conservation of the San Diego fairy shrimp and its vernal pool habitat. The PCEs in this critical habitat subunit may require special management considerations or protection to address threats from development, off-road vehicles, altered hydrology, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 3E.2: Ramona Airport. The Service designated subunit 3E.2 as critical habitat for the San Diego fairy shrimp. Subunit 3E.2 consists of 191 ac (77 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 3E.2 is located in the central portion of the Santa Maria Valley, north of the Santa Maria Creek and south of the Ramona Airport, 21 mi (34 km) inland from the coast. Subunit 3E.2 consists of 67 ac (27 ha) public land owned by the County of San Diego and 124 ac (50 ha) of privately owned land. Various conservation organizations are in the process of acquiring land within this subunit; however, not all of the land is conserved at this point and there is no long-term management plan for the conservation of the San Diego fairy shrimp. The PCEs in this critical habitat subunit may require special management considerations or protection to address threats from development, off-road vehicles, altered hydrology, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 3E.3: Ramona, Main Street. The Service designated subunit 3E.3 as critical habitat for the San Diego fairy shrimp. Subunit 3E.3 consists of 27 ac (11 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 3E.3 is located along Main Street in Ramona, 23 mi (37 km) inland from the coast. Subunit 3E.3 consists of 1 ac (<1 ha) of land owned by the County of San Diego and 26 ac (10 ha) of private land. This site is privately owned and subject to potential development. In addition, the site is currently not fenced and its vernal pool habitat is subject to continuing impacts from off-road vehicles. The PCEs in this critical habitat subunit may require special management considerations or protection to address threats from development, off-road vehicles, altered hydrology, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 3E.4: Ramona High School. The Service designated subunit 3E.4 as critical habitat for the San Diego fairy shrimp. Subunit 3E.4 consists of 40 ac (16 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 3E.4 is located east of State Route 67, 24 mi (39 km) inland from the coast. Subunit 3E.4 consists of 35 ac (14 ha) of land owned by the Ramona Unified School District and 5 ac (2 ha) of privately owned land. The PCEs in this critical habitat subunit may require special management considerations or protection to address current development threats, and impacts from off-road vehicles, altered hydrology, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat.

Unit 4: San Diego, Central Coastal Mesas (551 ac (225 ha)). Unit 4 is located in San Diego County, California. The area was occupied at the time of listing and contains the features essential to the conservation of the San Diego fairy shrimp. These features may require special management considerations or protection due to threats from development, illegal trash dumping, OHV activity, and nonnative plant species. The occurrences of San Diego fairy shrimp in Unit 4 are associated with coastal terraces and mesas found south of the San Dieguito River to the Sweetwater River. While many of the vernal pool complexes in this unit have been destroyed or fragmented, the complexes being designated represent some of the best remaining vernal pools in San Diego County. Many of the vernal pools in this unit receive conservation protection by virtue of their land ownership; however, they may require additional management to maintain populations of San Diego fairy shrimp. This unit contains vernal pools that support San Diego fairy shrimp populations in both the ‘‘Group A’’ and ‘‘Group B’’ genetic clade (Bohonak 2004, pp. 3–9). This unit includes vernal pools that are within the center of this species’ geographical distribution and retains the genetic diversity of these geographically distinct populations. For more information about Unit 4 please see the proposed rule (68 FR 19888; April 22, 2003). The Service determined that MCAS Miramar’s INRMP provides a benefit to the San Diego fairy shrimp and, therefore, MCAS Miramar is exempt from the designation pursuant to section 4(a)(3) of the Act (see Exemptions and Exclusions section below for a detailed discussion of this exemption). Subunit 4A/B: Del Mar Mesa. The Service designated subunit 4A/B as critical habitat for the San Diego fairy shrimp. Subunit 4A/B consists of 252 ac (102 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4A/B is located south of State Route 56 and north of Los Pen˜ asquitos Canyon, 6 mi (10 km) inland from the coast. Subunit 4A/B consists 51 ac (21 ha) land owned by the City of San Diego, 5 ac (2 ha) land owned by the County of San Diego, 56 ac (23 ha) land owned by the State of California, 41 ac (16 ha) land owned by the Service, and 99 ac (40 ha) is privately owned land. The PCEs in this critical habitat subunit may require special management considerations or protection to address threats from development, off-road vehicles, altered hydrology, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4C: Murphy Canyon Navy Housing. The Service designated subunit 4C as critical habitat for the San Diego fairy shrimp. Subunit 4C consists of 41 ac (17 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4C is located northeast of the junction of Interstate 8 and Interstate 15, 10 mi (16 km) inland from the coast. Subunit 4C consists of 40 ac (16 ha) of DOD land and 1 ac (<1 ha) of public land owned by the City of San Diego. As a result of two section 7 consultations (Service 2002; Service 2003), the vernal pool habitat in this subunit and in subunit 4D were restored to offset project impacts. The Navy has completed a 5-year monitoring and management period as described in the section 7 consultations and is now seeking funds for a long-term management plan for this area (Jacobsen 2007, p. 1). However, at this time additional management measures may be needed for the conservation of San Diego fairy shrimp. The PCEs in this subunit may require special management considerations or protection to address on-going threats from recreational activities, illegal dumping, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4D: Chollas Heights Navy Housing. The Service designated subunit 4D as critical habitat for the San Diego fairy shrimp. Subunit 4D consists of 16 ac (7 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4D is located north of State Route 94 and north Chollas Reservoir, 8 mi (13 km) inland from the coast. Subunit 4D consists entirely of DOD land. As a result of two section 7 consultations (Service 2002; Service 2003), the vernal pool habitat in this subunit and in subunit 4C were restored to offset project impacts. The Navy has completed a 5-year monitoring and management period as described in the section 7 consultations and is now seeking funds for a long-term management plan for this area (Jacobsen 2007, p. 1). However, at this time additional management measures may be needed for the conservation of San Diego fairy shrimp. The PCEs in this subunit may require special management considerations or protection to address on-going threats from nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4E: Carmel Mountain, West. The Service designated subunit 4E as critical habitat for the San Diego fairy shrimp. Subunit 4E consists of 32 ac (13 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4E is located south of State Route 56 and north of Los Pen˜ asquitos Canyon, 3 mi (5 km) inland from the coast. Subunit 4E consists of 31 ac (13 ha) of public land owned by the City of San Diego and 1 ac (<1 ha) of privately owned land. The PCEs in this critical habitat subunit may require special management considerations or protection to address threats from off-road vehicles, altered hydrology, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4F: Carmel Mountain, East. The Service designated subunit 4F as critical habitat for the San Diego fairy shrimp. Subunit 4F consists of 4 ac (2 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. It is located south of State Route 56 and north of Los Peñasquitos Canyon, 3 mi (5 km) inland from the coast. Subunit 4F consists entirely of public land owned by the City of San Diego. The PCEs in this critical habitat subunit may require special management considerations or protection to address threats from off-road vehicles, altered hydrology, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4G: Tierra Alta. The Service designated subunit 4G as critical habitat for the San Diego fairy shrimp. Subunit 4G consists of 5 ac (2 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4G is located north of Calle Cristobal and south of Los Pen˜ asquitos Canyon, 6 mi (10 km) inland from the coast. Subunit 4G consists of 2 ac (1 ha) of public land owned by the City of San Diego and 3 ac (1 ha) of privately owned land. The private land in subunit 4G is conserved and maintained by the Tierra Alta Home Owner’s Association. This subunit is considered to be in the same complex and series as the Lopez Ridge vernal pools to the south (subunit 4H). However, at this time additional management measures may be needed for the conservation of San Diego fairy shrimp. The PCEs in this subunit may require special management considerations or protection to address on-going threats from recreational activities and illegal dumping that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4H: Lopez Ridge. The Service designated subunit 4H as critical habitat for the San Diego fairy shrimp. Subunit 4H consists of 11 ac (4 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4H is located north of Calle Cristobal and south of Los Pen˜ asquitos Canyon, 6 mi (10 km) inland from the coast. Subunit 4H consists of 7 ac (3 ha) of public land owned by the City of San Diego and 4 ac (2 ha) of privately owned land. The private portion of this subunit is zoned for single family residential and it is vulnerable to impacts associated with development. The publicly owned portion of this critical habitat unit is preserved as a mitigation site as a condition of a Service Biological Opinion (1–1–83–F–29R (Service 1983)). However, at this time additional management measures may be needed for the conservation of San Diego fairy shrimp. The PCEs in this critical habitat subunit may require special management considerations or protection to address threats from development, off-road vehicles, altered hydrology, and nonnative species that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4I: Winterwood. The Service designated subunit 4I as critical habitat for the San Diego fairy shrimp. Subunit 4I consists of 17 ac (7 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4I is located to the south of Challenger Middle School in Mira Mesa, 6 mi (10 km) inland from the coast. Subunit 4I consists entirely of public land owned by the City of San Diego. This area is currently owned and managed by the City of San Diego Parks and Recreation Department. The subunit is partially conserved as mitigation as a result of U.S. Environmental Protection Agency compliance order CWA 404– 09a–94–005 (see RECON 1996 for additional information). However, at this time additional management measures may be needed for the conservation of San Diego fairy shrimp. The PCEs in this subunit may require special management considerations or protection to address threats from recreational activities, nonnative weed invasion, illegal dumping, and off-road vehicle use that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4J: Carroll Canyon. The Service designated subunit 4J as critical habitat for the San Diego fairy shrimp. Subunit 4J consists of 14 ac (6 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4J is located at the southern terminus of Parkdale Avenue in Mira Mesa, 6 mi (10 km) inland from the coast. Subunit 4J consists of 14 ac (6 ha) of public land owned by the City of San Diego and 1 ac (<1 ha) of privately owned land. A portion of this subunit was conserved as mitigation pursuant to the requirements of the Service Biological Opinions 1–1–82–F–108 (Service 1982a) and 1–1–82–F–108R (Service 1982b). An additional area within this subunit was purchased by the City of San Diego with money from the City of San Diego's Vernal Pool Preservation Fund. The site has been maintained per the requirements of Service Biological Opinions 1–1–82–F–108 and 1–1–82–F– 108R, and the City of San Diego's Vernal Pool Management Plan (City of San Diego 1996). However, at this time additional management measures may be needed for the conservation of San Diego fairy shrimp. The PCEs in this subunit may require special management considerations or protection to address threats from ongoing recreational activities and illegal dumping that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4K: San Diego Energy Recovery. (SANDER) and Magnatron The Service designated subunit 4K as critical habitat for the San Diego fairy shrimp. Subunit 4K consists of 56 ac (23 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4K is located to the west of the intersection of Magnatron Boulevard and State Route 163 and south of State Route 52, 7 mi (11 km) inland from the coast. Subunit 4K consists of 55 ac (22 ha) of public land owned by the City of San Diego and 1 ac (<1 ha) of privately owned land. Subunit 4K has an ''Industrial Parks'' zoning designation and is not currently conserved or being managed for the San Diego fairy shrimp or its habitat. The PCEs in subunit may require special management considerations or protection to address on-going threats from development, recreational activities, nonnative weed invasion, illegal dumping, and off-road vehicle use that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4L: Cubic. The Service designated subunit 4L as critical habitat for the San Diego fairy shrimp. Subunit 4L consists of 7 ac (3 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4L is located between State Route 52 and State Route 163 at the northeastern terminus of Kearny Mesa Road in Kearny Mesa, 8 mi (13 km) inland from the coast. Subunit 4L consists of privately owned land. Subunit 4L has an ''Industrial Parks'' zoning designation and is not conserved or being managed to protect the San Diego fairy shrimp or its habitat. The PCEs within this subunit may require special management considerations or protection to address on-going threats from development, recreational activities, nonnative weed invasion, illegal trash dumping, and off-road vehicle use that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 4M: Montgomery Field. The Service designated subunit 4M as critical habitat for the San Diego fairy shrimp. Subunit 4M consists of 96 ac (39 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 4M is located north of Aero Drive in Kearny Mesa, 7 mi (11 km) inland from the coast. Subunit 4M is owned and managed by the City of San Diego, Airports Division. The vernal pool complexes within subunit 4M are managed according to the Service Biological Opinion 1–6–94– F–32 (Service 1995, pp. 1–33), the Montgomery Field Final Conceptual Mitigation Plan (P&D Technologies 1994), and the Vernal Pool Management Plan (City of San Diego 1996). The PCEs in this subunit may require special management considerations or protection to address threats from development, on-going operational management for the airport, and nonnative weed invasion that may negatively impact the San Diego fairy shrimp and its habitat.

Unit 5: San Diego, Southern Coastal Mesa (1,785 ac (722 ha)). Unit 5 is located in San Diego County, California. The area was occupied at the time of listing and contains the features essential to the conservation of the San Diego fairy shrimp that may require special management considerations or protection. This southernmost unit of critical habitat is essential to the conservation of the San Diego fairy shrimp because it helps to maintain the ecological distribution and genetic diversity of the species. Due to the rapid urbanization on both sides of the border between the U.S. and Mexico, nearly all vernal pool habitat in this region has been lost. This unit contains vernal pools that support San Diego fairy shrimp populations in the ‘‘Group A’’ genetic clade (Bohonak 2004, pp. 3–9). The conservation of the remaining vernal pools in this unit is essential to maintain continuity in the range between the U.S. and Mexico as well as the genetic diversity of the species. For more information about Unit 5 please see the proposed rule (68 FR 19888; April 22, 2003). The Service determined that the INRMP for Naval Base Coronado, which includes the Navy Outlying Landing Field and Naval Radar Receiving Facility, provides a benefit to the San Diego fairy shrimp and therefore Department of Defense lands that are part of Naval Base Coronado’s INRMP are exempt from critical habitat pursuant to section 4(a)(3) of the Act (see Exemptions and Exclusions section below for a detailed discussion of this exemption). Subunit 5A: Otay Mesa, Northeast. The Service designated subunit 5A as critical habitat for the San Diego fairy shrimp. Subunit 5A consists of 38 ac (16 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 5A is located south of Otay River at the base of Otay Mountain, 12 mi (19 km) inland from the coast. Subunit 5A consists of 8 ac (3 ha) land owned by the County of San Diego, 16 ac (7 ha) land owned by the State of California, 1 ac (<1 ha) land owned by the Water District, and 13 ac (5 ha) privately owned land. The Service excluded land covered by the County of San Diego subarea plan under the MSCP in this subunit because the Service determined that the benefits of exclusion outweigh the benefits of inclusion (see Exemptions and Exclusions section below for a detailed discussion of this exclusion). However, lands within Major/Minor Amendment Areas in this subunit are not covered by the County of San Diego subarea plan under the MSCP. These areas contain sensitive resources that were not addressed during the development of the County of San Diego subarea plan under the MSCP and are to be addressed in a future amendment to the MSCP. The Service designated all lands in subunit 5A that are not covered by the County of San Diego subarea plan under the MSCP, including these future amendment areas. The PCEs in this subunit may require special management considerations or protection to address threats from development, off-road vehicle use, and nonnative weed invasion that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 5B: Otay Mesa, North. The Service designated 304 ac (123 ha) of subunit 5B as critical habitat for the San Diego fairy shrimp. Subunit 5B consists of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 5B is located central Otay Mesa, north of Otay Mesa Road, east of Brown Field, 9 mi (15 km) inland from the coast. Subunit 5B consists of privately owned land. The PCEs in this subunit may require special management considerations or protection to address threats from development, off-road vehicle use, and nonnative weed invasion that may negatively impact the San Diego fairy shrimp and its habitat. The Service excluded land covered by the County of San Diego subarea plan under the MSCP in this subunit because the Service determined that the benefits of excluding this subunit from the final designation outweigh the benefits of including it (see Exemptions and Exclusions section below for a detailed discussion of this exclusion). Subunit 5C: Otay Mesa, East. The Service designated subunit 5C as critical habitat for the San Diego fairy shrimp. Subunit 5C consists of 75 ac (30 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 5C is located on eastern Otay Mesa, northeast of Otay Mesa Road, 12 mi (19 km) inland from the coast. Subunit 5C consists of privately owned land. This vernal pool complex has had relatively little human disturbance compared to most vernal pool complexes on Otay Mesa. However, the PCEs in this subunit may require special management considerations or protection to address threats from development, off-road vehicle use, and nonnative weed invasion that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 5D: Otay Mesa, Southeast. The Service designated subunit 5D as critical habitat for the San Diego fairy shrimp. Subunit 5D consists of 391 ac (158 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 5D is located north of the United States/Mexico border, at the base of Otay Mountain, 13 mi (21 km) inland from the coast. Subunit 5D consists entirely of privately owned land. The vernal pool complexes in this unit have not yet been directly impacted by development or fragmentation. The populations of San Diego fairy shrimp in this subunit are the closest United States population to any of the populations of San Diego fairy shrimp in Mexico. As vernal pool complexes become more fragmented by development in both the United States and Mexico, the preservation of vernal pool complexes near to one another will be increasingly important to these ecosystems to provide continuity in the range between the United States and Mexico. The PCEs in this subunit may require special management considerations or protection to address on-going threats from development, offroad vehicle use, and nonnative weed invasion that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 5F: Otay Mesa, Southwest. The Service designated subunit 5F as critical habitat for the San Diego fairy shrimp. Subunit 5F consists of 621 ac (251 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 5F is located south of Otay Mesa Road and north of the United States/Mexico border on the western portion of Otay Mesa, 7 mi (11 km) inland from the coast. Subunit 5F consists of 11ac (4 ha) of land owned by the U.S. Government, 73 ac (30 ha) of land owned by the City of San Diego, and 537 ac (217 ha) of privately owned land. Some of the land within this subunit has been purchased for conservation; however, these areas may require measures to ensure that the San Diego fairy shrimp is conserved on these lands. Additionally, there are lands in this subunit that are privately owned and may be partially developed. Conservation measures may be required in these areas to ensure that the structure and function of the vernal pool habitat for San Diego fairy shrimp is not altered and that the PCEs are protected. The PCEs in this subunit may require special management considerations or protection to address threats from development, off-road vehicle use, and nonnative weed invasion that may negatively impact the San Diego fairy shrimp and its habitat. The Service excluded DHS-owned land at Arnie’s Point (29 ac (12 ha)) from this subunit because the Service determined that the benefits of exclusion outweigh the benefits of inclusion (see Exemptions and Exclusions section below for a detailed discussion of this exclusion). Subunit 5G: Otay Mesa, Northwest. The Service designated subunit 5G as critical habitat for the San Diego fairy shrimp. Subunit 5G consists of 132 ac (53 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 5G is located north of Otay Mesa Road on the mesa tops around Dennery Canyon, 7 mi (11 km) inland from the coast. Subunit 5G consists of public and private land. Subunit 5G consists of 19 ac (7 ha) of land owned by the City of San Diego and 113 ac (46 ha) of privately owned land. Subunit 5G includes a number of vernal pool complexes. Most of the vernal pool complexes in this unit have been purchased for conservation; however, some of the unprotected areas may be impacted by development. In addition to the threats posed by development to PCEs in some portions of the subunit, the PCEs throughout the subunit may require special management considerations or protection to address threats from offroad vehicle use, and nonnative weed invasion that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 5H: Lower Otay Reservoir. The Service designated subunit 5H as critical habitat for the San Diego fairy shrimp. Subunit 5H consists of 200 ac (81 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. The portion of subunit 5H being designated as critical habitat is located on the south side of Lower Otay Reservoir, 15 mi (24 km) inland from the coast. Subunit 5H is entirely public land owned by the City of San Diego. The Service excluded all of the land covered by the County of San Diego subarea plan under the MSCP in this subunit because the Service determined that the benefits of excluding this subunit from the final designation outweigh the benefits of including it (see Exemptions and Exclusions section below for a detailed discussion of this exclusion). Remaining vernal pool complexes in this subunit are isolated from urbanized areas of San Diego and this subunit may be one of the few places where indirect effects from development have not placed stress on the population of San Diego fairy shrimp. However, the PCEs in this subunit may require special management considerations or protection to address threats from offroad vehicles and nonnative weed invasion that may negatively impact the San Diego fairy shrimp and its habitat. Subunit 5I: Marron Valley. The Service designated subunit 5I as critical habitat for the San Diego fairy shrimp. Subunit 5I consists of 24 ac (10 ha) of habitat occupied by the species at the time of listing and the species continues to occur within this subunit. This subunit contains all of the features essential to the conservation of the species. Subunit 5I is located approximately 25 mi (40 km) east of the coast along the United States/Mexico border. Subunit 5I is entirely public land owned by the City of San Diego. This area is isolated from urbanized areas of San Diego and may be one of the few places where indirect effects from development have not placed stress on the population of San Diego fairy shrimp. Subunit 5I is within the Marron Valley Conservation Bank, which is included in the MSCP Cornerstone Bank Agreement. The PCEs in this subunit may require special management considerations or protection to address threats from offroad vehicles use and nonnative weed invasion that may negatively impact the San Diego fairy shrimp and its habitat.

Primary Constituent Elements/Physical or Biological Features

Critical habitat units are designated for Orange and San Diego counties, California. The primary constituent elements of critical habitat for the San Diego fairy shrimp are:

(i) Vernal pools with shallow to moderate depths (2 in (5 cm) to 12 in (30 cm)) that hold water for sufficient lengths of time (7 to 60 days) necessary for incubation, maturation, and reproduction of the San Diego fairy shrimp, in all but the driest years;

(ii) Topographic features characterized by mounds and swales and depressions within a matrix of surrounding uplands that result in complexes of continuously, or intermittently, flowing surface water in the swales connecting the pools described in paragraph (2)(i) of this entry, providing for dispersal and promoting hydroperiods of adequate length in the pools (i.e., the vernal pool watershed); and

(iii) Flat to gently sloping topography, and any soil type with a clay component and/or an impermeable surface or subsurface layer known to support vernal pool habitat (including Carlsbad, Chesterton, Diablo, Huerhuero, Linne, Olivenhain, Placentia, Redding, and Stockpen soils).

Special Management Considerations or Protections

Critical habitat does not include manmade structures (such as buildings, aqueducts, runways, roads, and other paved areas) and the land on which they are located existing within the legal boundaries on the effective date of this rule.

The most pressing threat to critical habitat for the San Diego fairy shrimp is the loss of habitat. The vernal pool basin (PCE 1) can also be indirectly impacted by development if the vernal pool watershed (PCE 2) is impacted during the development process. Development can also indirectly impact PCE 1 and PCE 2 if the vernal pool soils or topography is altered (PCE 3). Specifically, the following subunits include land that is not protected from development through ownership by a conservation organization or by a conservation easement or other similar legal mechanisms: 1C; 3A; 3C; 3E.1; 3E.2; 3E.3; 3E.4; 4A/B; 4H; 4J–4M; 5A–5D; 5F; and 5G. These lands require special management considerations or protections from negative impacts associated with development.

Special management may be necessary to prevent and reduce incursion of nonnative invasive plant species that alter PCE 1. Nonnative plant species can impact the duration of ponding in a vernal pool basin. Nonnative plant species can also impact the vernal pool watershed (PCE 2) by reducing the inundation period through an over-abundance of vegetation within the watershed (Marty 2005, p. 1630). Special management actions can be taken to reduce the negative effects of such invasions. Removal of weed species by hand, increased planting of vernal pool species, mowing, restoration of native species in the upland areas, and prescribed burns may be potential tools to manage this threat. Nonnative species threaten the following subunits: 1C; 2G; 3A; 3C; 3D; 3E.1; 3E.2; 3E.3; 3E.4; 4I–4M; 5A–5D; 5F; 5G; and 5I.

Special management considerations or protections may be necessary to protect and restore vernal pool hydrology (PCE 1 and PCE 2). Alteration of natural hydrology directly threatens San Diego fairy shrimp, and the invasion of nonnative species may be facilitated by alterations in the natural vernal pool hydrology. Runoff from adjacent developments should be monitored to ensure that a pool’s hydrology has not been altered, either through changes in ponding duration or changes to water temperature or chemistry. Discing, grading and digging in ways that impact the topography and soils near vernal pool complexes (PCE 3) can also indirectly impact the hydrology (PCE 1 and PCE 2). Altered hydrology threatens the following subunits: 1C; 2G; 3A; 3C; 3D; 3E.1; 3E.2; 3E.3; 3E.4; 4A/B; 4I–4M; 5A–5D; 5F; 5G and 5I.

Special management considerations or protection may be necessary to reduce degradation of vernal pools. Management actions such as fencing, trail building, and sign posting can help to reduce human activities that threaten San Diego fairy shrimp habitat. Vehicular traffic can impact to adult and juvenile San Diego fairy shrimp, and may crush cysts during the wet season (Hathaway et al. 1996, p. 451). Motorized and non-motorized off-road vehicle use, illegal trash dumping, and trampling can: (1) Affect the ponding duration in the vernal pool by increasing or decreasing the amount of water in the basin (PCE 1) or move soils and alter the topography, and (2) divert water or compact the soil such that the water does not saturate the soils (PCE 2). Degradation associated with human activities threatens the following subunits: 1C; 2G; 3A; 3C;

3D; 3E.1; 3E.2; 3E.3; 3E.4; 4A/B; 4C–4F; 4I–4M; 5A–5I.

Life History

Feeding Narrative

Adult: San Diego fairy shrimp are opportunistic filter feeders. In general, Anostracans feed on need algae, bacteria, protozoa, rotifers, and bits of detritus. Although the species typically occurs in pools absent of other anostracans, San Diego fairy shrimp may compete with other fairy shrimp in their environment. San Diego fairy shrimp swim upside down as they filter-feed on algae and zooplankton with their 11 pairs of leaf-like legs (Eriksen and Belk 1999; USFWS 2008). Typically, San Diego fairy shrimp do not live with other fairy shrimp (Eriksen and Belk 1999).

Reproduction Narrative

Adult: San Diego fairy shrimp are usually observed from mid-December to early May. However, the hatching period may change in years with early or late rainfall (Eriksen and Belk 1999; USFWS 2008). Cysts typically hatch within 8 days at 5° Celsius (°C) (41 degrees Fahrenheit [°F]), but the hatching period is shortened to 3 to 5 days when temperatures are between 10 to 15°C (50 to 59°F). Larvae die if the temperature remains at 5°C (41°F). In a laboratory, if the temperature is raised and kept at 20 to 22°C (71°F), the San Diego fairy shrimp mature in 7 to 10 days. In the field, San Diego fairy shrimp typically mature in 10 to 20 days. San Diego fairy shrimp then live for another 3 weeks, or a maximum of 42 days (Eriksen and Belk 1999).Cysts from successful reproduction are either dropped to the pool bottom or remain in the brood sac until the female dies and sinks (USFWS 2008). In a laboratory setting, San Diego fairy shrimp produced 149 to 479 cysts over their lifetime. The cysts are about 0.30 mm (.0.1 in.) and are capable of withstanding temperature extremes and prolonged drying. Cysts can withstand extreme environmental conditions because of their protective coatings. Unless they are smashed or punctured, cysts are not digested when moved down the intestines of animals. When fairy shrimp cysts dry up, they are even more tolerant of extreme conditions and can be subjected to temperatures of up to 65°C (150°F), or can be frozen for months. Cysts can also withstand near-vacuum conditions for 10 years without damage to the embryo. The cysts do not hatch until they receive proper environmental signals such as rain (Eriksen and Belk 1999).Only a portion of the cysts may hatch when the pools refill in the same or subsequent rainy seasons; therefore, cyst “banks” develop in pool soils that are composed of the cysts from several years of breeding. This partial hatching of cysts allows the San Diego fairy shrimp to persist in its extremely variable environment, because pools commonly fill and dry before hatched individuals can reproduce; and if all cysts hatched during an insufficient filling, the species could be extirpated from a pool. The ability of San Diego fairy shrimp to develop and maintain cyst banks is vital to the long-term survival of their populations. San Diego fairy shrimp cysts cannot hatch in perennial (i.e., containing water year-round) basins, because the re-wetting of dried cysts is one component of a set of environmental stimuli that trigger hatching (Eriksen and Belk 1999; USFWS 2008).

Geographic or Habitat Restraints or Barriers

Adult: Limited to their home pool. Cysts can be dispersed from dried-up pools, but survival is limited to vernal pools. Development and habitat alteration can isolate populations.

Spatial Arrangements of the Population

Adult: Clumped according to resources.

Environmental Specificity

Adult: Narrow

Tolerance Ranges/Thresholds

Adult: Low

Site Fidelity

Adult: High

Habitat Narrative

Adult: San Diego fairy shrimp are generally restricted to vernal pools and other nonvegetated ephemeral (i.e., containing water a short time) basins 5 to 30 cm (2 to 12 in.) in depth in coastal southern California and northwestern Baja California, Mexico (USFWS 2008). San Diego fairy shrimp are restricted to dilute vernal pools, having relatively low sodium (Na+) concentrations (below 60 millimoles per liter), low alkalinity (below 1,000 milligrams per liter), and neutral pH (near 7). San Diego fairy shrimp are unable to regulate internal ion levels, and mortality increases at higher Na+ concentrations and alkalinity Eriksen and Belk 1999).San Diego fairy shrimp need pool inundation sufficient to hatch cysts, and maintained to complete the reproduction lifecycle (USFWS 2008).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: Nonmigratory

Dispersal

Adult: Aquatic birds are the most likely agents of dispersal. Large mammals are also known distributors (Eriksen and Belk 1999).

Immigration/Emigration

Adult: No

Dispersal/Migration Narrative

Adult: San Diego fairy shrimp are nonmigratory and have relatively little ability to disperse on their own. Genetic mixing that does occur could happen via a combination of a number of potential mechanisms, including infrequent large-scale flooding events, dispersal of cysts by animals (e.g., waterfowl), and wind dispersal of cysts in desiccated soils (USFWS 2008). Certain fairy shrimp species are restricted in distribution, and adjacent soils may have different or no fairy shrimp. Pools observed after years seem to have the same species and structural and genetic diversity (Eriksen and Belk 1999).The San Diego fairy shrimp DNA study concluded that individuals of that species have likely been isolated from one another biologically for tens of thousands or perhaps millions of years with little or no dispersal or hybridization. San Diego fairy shrimp in a vernal pool complex or limited geographic area were found to be generally more closely related to each other than to those at more distant locations. Furthermore, the results indicate that gene flow between pool complexes is lower in areas that have fewer disturbances from urbanization and human activities (USFWS 2008).

Additional Life History Information

Adult: The San Diego fairy shrimp DNA study concluded that individuals of that species have likely been isolated from one another biologically for tens of thousands or perhaps millions of years with little or no dispersal or hybridization (USFWS 2008).

Population Information and Trends

Population Trends:

Increasing (USFWS, 2021)

Number of Populations:

53 occurrences (USFWS, 2021)

Population Size:

Unknown (NatureServe 2015; USFWS 2008)

Adaptability:

Moderate

Additional Population-level Information:

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. (USFWS, 2021)

Population Narrative:

At the time of listing, the San Diego fairy shrimp inhabited 25 vernal pool complexes in coastal areas of San Diego, Orange, and Santa Barbara counties and northwestern Baja California, Mexico. Currently, 137 occupied complexes have been identified in the United States. The population has remained stable since listing. Adequately quantifying occurrence and distribution of the San Diego fairy shrimp is difficult due to a number of factors. First, vernal pools are generally too small to appear on topographic maps and therefore difficult to identify, and San Diego fairy shrimp are restricted to certain pool types in a narrow geographic region; second, not all vernal pools fill in a given year, and pools may not fill long enough for hatching (i.e., discovery) of the San Diego fairy shrimp; and finally, in any given pool that has retained water long enough to hatch San Diego fairy shrimp, surveys may miss collecting adults simply due to their low hatching percent. Therefore, once vernal pools are identified, surveys may not detect individuals in a particular year even when viable cysts are present. Surveying populations for changes in numbers of individuals and demographic trends over time is not possible due to the small size and life history traits of San Diego fairy shrimp. San Diego fairy shrimp abundance has not increased or decreased substantially since listing, because the additional occupied complexes identified since listing were likely in existence (though undocumented) when the species was listed (USFWS 2008). 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. (USFWS, 2021)

Threats and Stressors

Stressor: Development
Exposure: Human population growth.
Response: Habitat destruction; isolation and fragmentation of habitat; and alteration of hydrology.
Consequence: Mortality and population extirpation.
Narrative: San Diego is one of the fastest-growing counties in the nation, and is estimated to have a population of approximately 3.6 million people by the year 2020. These predicted growth rates suggest that urban and commercial/industrial development pressures will continue to rise within the extant range of the San Diego fairy shrimp. Additionally, development of border security measures threatens San Diego fairy shrimp habitat along the international border with Mexico. Such development can result in direct impacts to San Diego fairy shrimp habitat, i.e., destruction of vernal pools or their watersheds, and isolation of pools and fragmentation of pool systems; development can also cause alterations in the hydrology of adjacent pools (USFWS 2008).

Stressor: Habitat loss
Exposure: Development
Response: Habitat loss or modification.
Consequence: Reduction in population numbers, and mortality.
Narrative: It has been estimated that 90 to 97 percent of the historical habitat of San Diego fairy shrimp in San Diego County has been destroyed, and that similar declines have occurred elsewhere. Habitat loss associated with development is the result of destruction and modification of vernal pools and their watersheds due to filling, grading, discing, leveling, and other activities. Because the species is dependent on this specific habitat type for survival, habitat loss results in the mortality of San Diego fairy shrimp occupying the developed habitat. Most of these losses and impacts are the result of urban development, followed by industrial/commercial, and international border security and military training facilities, development, and infrastructure. Unauthorized habitat loss continues to occur in known occupied complexes, such as at the Arjons property in Kearny Mesa and the Habib complex in Ramona. In total, approximately 31 complexes on private lands are not preserved and are thus vulnerable to future development. These privately owned lands support 23 percent of all known remaining occupied complexes. As the human population within the range of the San Diego fairy shrimp continues to grow, it is expected that the pressure to convert this species' habitat to development will increase (USFWS 2008).

Stressor: Habitat isolation and fragmentation
Exposure: Development
Response: Fragmentation and isolation of populations, change in food source and nutrients, and change in hydrology.
Consequence: Population extirpation, and increased susceptibility to stochastic events.

Narrative: Fragmentation can isolate pools/complexes from upland habitats, which provide much of the San Diego fairy shrimp's food sources (algae, diatoms, and particulate organic matter brought into pools via overland flow of rainwater runoff). Because of the transportation of water, soil, minerals, and nutrients over the landscape into vernal pools, the upland or upslope areas associated with vernal pools are an important source of these necessities for vernal pool organisms. Because vernal pools are mostly rain-fed, they tend to have low nutrient levels. Most of the nutrients that vernal pool crustaceans derive from their vernal pool habitat come from the detritus (decaying organic matter) that washes into pools from the adjacent upslope areas; these nutrients provide the foundation for the food chain in the vernal pool aquatic community, of which the fairy shrimp fauna constitutes an important component. Whenever vernal pools in a complex are impacted by development, some degree of fragmentation occurs in and among complexes. Fragmentation and associated impacts to hydrology continue to impact the San Diego fairy shrimp habitat throughout its range (USFWS 2008).

Stressor: Altered hydrology
Exposure: Alterations to topographic watershed.
Response: Alteration of pool hydrology, unsuitability or degradation of habitat.
Consequence: Reduced fitness, inability to complete life cycle.
Narrative: Development in a vernal pool watershed can alter the timing, temperature, frequency, and duration of inundation of nearby vernal pools. Persistence of San Diego fairy shrimp in occupied vernal pools and complexes is dependent on maintaining suitable hydrology. Impacts outside of occupied habitat but within the watershed can alter this vital component of San Diego fairy shrimp habitat and thus threaten San Diego fairy shrimp persistence. The complex hydrology of vernal pools is supported by both surface flows in a pool's topographic watershed (e.g., the surface area in which water drains into a vernal pool) and subsurface flows that may extend beyond the surface watershed. Surface and subsurface lateral flows between vernal pools and the surrounding uplands influence the onset and level of inundation, and the seasonal drying of vernal pools. Alterations of ponding could negatively affect the ability of San Diego fairy shrimp to grow and reproduce, because their phenology is dependent on the onset and duration of ponding. Decreased inundation could result in pools not filling long enough for fairy shrimp to complete their life cycle. Conversely, increased inundation from artificial water sources (e.g., runoff from adjacent development) could cause pools to stay inundated longer than normal or even convert vernal pools into perennial pools that are not suitable for San Diego fairy shrimp (USFWS 2008).

Stressor: Nonnative plants
Exposure: Invasion of nonnative species.
Response: Native plants out-competed, change in hydrology.
Consequence: Habitat may no longer be suitable for the species.
Narrative: San Diego fairy shrimp habitat has been impacted by the introduction of invasive, nonnative plants throughout the range of the species, including two nonnative wetland grasses: Pacific bentgrass (Agrostis avenacea) and annual rabbitsfoot grass (Polypogon monspeliensis). Several factors contribute to the decline in habitat conditions, including native plant species being out-competed by nonnative plant species for nutrients, light, and water. Nonnative invasive plants can overtake pools, and because of their water uptake decrease the number of days of inundation following rain events to the point that the pools may no longer provide suitable habitat for San Diego fairy shrimp. For example, U.S. Fish and Wildlife Service (USFWS) files show that several vernal pools previously known from the 29-30 complex on Otay Mesa no

longer pond due to dense cover of nonnative weeds; a similar situation has occurred in pools in the Ramona grasslands complex. Nonnative plants may also affect water chemistry and other aspects of pool hydrology, but more study is needed to ascertain the magnitude of these threats (USFWS 2008).

Stressor: Inadequate regulatory mechanisms.
Exposure:
Response:
Consequence:
Narrative: No state or local laws exist that adequately protect the San Diego fairy shrimp. Other regulatory mechanisms necessary for the conservation of its vernal pool habitat have also proven inadequate and ineffective. The federal Endangered Species Act provides the greatest regulatory protection to the San Diego fairy shrimp. The additional potential protection provided by other federal, state, and local laws and ordinances is discretionary, incomplete, subject to funding availability and changing missions, and/or largely dependent on the federally listed status of the San Diego fairy shrimp. As a result, other federal, state, and local laws and ordinances do not independently or collectively provide adequate regulatory protection to the San Diego fairy shrimp (USFWS 2008).

Stressor: Human access and disturbance
Exposure: Development, foot traffic, and motorized vehicles.
Response: Habitat degradation.
Consequence: Cyst mortality.
Narrative: The potential for human access and disturbance in fairy shrimp habitat increases as greater numbers of people are brought in close proximity to the habitat via encroaching development. Human encroachment into San Diego fairy shrimp habitat on foot or on motorized or nonmotorized vehicles affects the species by crushing San Diego fairy shrimp cysts. In addition to crushing fairy shrimp cysts, this type of off-road activity (including motorcycles and bicycles) can generally degrade San Diego fairy shrimp habitat, altering pool shape and compacting soil, and potentially impacting pool hydrology. USFWS files show that threats from recreational off-highway vehicle (OHV) use have increased since listing, and continue to pose a substantive threat to the San Diego fairy shrimp. This threat is especially pervasive in Otay Mesa, Marron Valley, and Proctor Valley, due to OHV use associated with Border Patrol activities, which have created many unauthorized roads often used and expanded by recreational OHV users; and at MCB Camp Pendleton due to military training (USFWS 2008).

Stressor: Pesticides and other pollutants
Exposure: Use of Roundup, pesticides, and control agents for mosquitos and blackflies; airborne pollutants; and dumped trash.
Response: Unknown
Consequence: Unknown
Narrative: San Diego fairy shrimp may be exposed to pesticides used to control weeds and insects. Herbicides are commonly used to control weeds outside of vernal pools (e.g., along roads, farms, and residential landscaping) and in vernal pools themselves (e.g., for enhancement/restoration projects). One study showed that the commonly used herbicide Roundup® may pose a risk to San Diego fairy shrimp. Additionally, pesticide applications for mosquito larvae control have become increasingly common to combat West Nile Virus. Although at this time the degree of this threat to San Diego fairy shrimp is unknown, the fact that some

pesticides are designed specifically for the purpose of killing certain invertebrates adds strength to the argument that they may be a substantive threat to San Diego fairy shrimp in areas where they are used. Runoff may also introduce pollutants that could be toxic to the species, or alter aspects of water chemistry such as pH, alkalinity, and salinity, to which the species has been shown to be sensitive. Airborne pollutants can be introduced via rainfall and runoff as well. Dumped trash and other litter may decrease water quality as materials dissolve or decompose. Dumped material can also fill pools, leaving little or no space for water to collect; or cover the bottom of pools, preventing larvae hatching from cysts from moving from the soil into the water column (USFWS 2008).

Stressor: Drought and climate change
Exposure: Weather conditions causing pools to dry up, and rising global temperatures.
Response: Depletion of cyst banks, pools drying up before fairy shrimp can complete their lifecycle, habitat degradation, and decreased inundation periods.
Consequence: No reproductive output, mortality, reduction in population numbers, and reduced fitness.
Narrative: Drought is likely to decrease or terminate reproductive output as pools fail to flood, or dry up before reproduction is complete. Weather conditions in which vernal pool flooding promotes hatching, but in which pools dry (or become too warm) before embryos are fully developed, are expected to have the greatest negative effect on fairy shrimp resistance and resilience. Long-term or continuing drought conditions may deplete cyst banks in affected pools as new cysts are not deposited and depletion of cyst banks occurs. Though the species is adapted to some degree of unpredictability in its habitat, it is unknown how the species would respond to exacerbation of drought conditions potentially brought on by climate change, and the combination of drought with other threats (USFWS 2008). Climate change has the potential to adversely affect the fairy shrimp through changes in vernal pool inundation patterns and consistency. Climate scientists are able to predict, with a high level of certainty, that California’s climate will become warmer in the 21st century, although there is still uncertainty about regional effects of warming. Current climate change predictions for terrestrial areas in the Northern Hemisphere indicate warmer air temperatures, more intense precipitation events, and increased summer continental drying. The ability of fairy shrimp to survive is likely to depend in part on their ability to disperse to pools where conditions are suitable. Loss and fragmentation of vernal pool habitat is thought to decrease dispersal ability. Therefore, any range shift prompted by climate change may be more difficult due to factors such as the loss of potential habitat from development, occupation of potential habitat by nonnative species, and lack of appropriate soil substrates. Remnant suitable habitats, even in conservation banks, may be too far apart to allow dispersal or natural recolonization after a disturbance. Existing preserves in California may not provide the full range of conditions needed to sustain fairy shrimp during variable climatic conditions (USFWS 2008).

Stressor: Habitat fragmentation
Exposure: Habitat fragmentation.
Response: Disruption of hydrological systems.
Consequence: Reduction in gene flow.
Narrative: Habitat fragmentation in complexes or groups of nearby complexes may also disrupt hydrological systems and the low levels of gene flow that appear to be needed to maintain the natural, overall genetic diversity of the species. The mixing that does occur could happen via a combination of any of a number of potential mechanisms, including infrequent large-scale

flooding events, dispersal of cysts by animals (e.g., waterfowl), and wind dispersal of cysts in desiccated soils. It is presumed that extirpated populations of San Diego fairy shrimp could be reestablished through these natural dispersal mechanisms in the absence of habitat fragmentation. Due to the lack of information regarding dispersal of San Diego fairy shrimp over larger distances, it is not possible to predict what effects fragmentation of habitat on a regional scale will have on the genetic make-up (USFWS 2008).

Stressor: Disease (USFWS, 2021)
Exposure:
Response:
Consequence:
Narrative: 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 (USFWS, 2021)

Stressor: Off-Highway Vehicles and Human Access (USFWS, 2021)
Exposure:
Response:
Consequence:
Narrative: 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. (USFWS, 2021)

Stressor: Hybridization and Competition (USFWS, 2021)
Exposure:
Response:
Consequence:
Narrative: 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. (USFWS, 2021)

Recovery

Reclassification Criteria:

Although the Recovery Plan is outdated in some respects, the general approach is appropriate for San Diego fairy shrimp conservation and recovery. The recovery criteria for stabilization and downlisting the San Diego fairy shrimp are summarized below, and include only those portions relevant to San Diego fairy shrimp (USFWS 2008):

Existing vernal pools and their associated watersheds contained in the complexes identified in the Recovery Plan (see Appendix F) must be secured from further loss and degradation in a configuration that maintains habitat function and species viability (as determined by recommended research) in order to maintain genetic diversity and population stability of the species.

Existing vernal pools and their associated watersheds contained in the complexes identified in the Recovery Plan (see Appendix G) must be secured in a configuration that maintains habitat function and species viability (as determined by recommended research) before reclassification of the species to threatened status may be considered (USFWS 1998).

Secured vernal pools must be enhanced or restored in such a way that population levels of existing species are stabilized or increased (USFWS 1998).

Population trends must be shown to be stable or increasing for a minimum of 10 consecutive years prior to allow consideration for reclassification (USFWS 1998).

Recovery Priority Number: 8C

Delisting Criteria:

Delisting of the San Diego fairy shrimp may be considered in the future and is conditional on the downlisting criteria: improvement (stabilized or increasing population trends) at all currently known sites; restoration, protection, and management of the minimum habitat area and configuration needed to ensure long-term viability; and establishment of historic but locally extirpated species populations when needed to ensure viability (USFWS 1998).

USFWS must also determine that the following factors are no longer present, or continuing to adversely affect the San Diego fairy shrimp: (1) the present or threatened destruction, modification, or curtailment of their habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; and (5) other natural or manmade factors affecting their continued existence (50 Code of Federal Regulations 424.11).

In the interest of ensuring these criteria are clearly articulated, we are amending the following clarification to the existing recovery plan. This amendment does not represent a revision of the delisting criteria, it simply provides more specific terminology. Delisting for the species covered by the 1998 recovery plan may be considered when the downlisting criteria have been met and: 1. All 74 geographic areas and associated vernal pool complexes as identified in Appendices F and G of the 1998 Recovery Plan under each of the specific management areas are protected and managed to ensure long-term viability. 2. The U.S. Fish and Wildlife Service must determine that the following factors are no longer present, or continue to adversely affect, Eryngium aristulatum var. parishii, Pogogyne abramsii, Pogogyne nudiuscula, Orcuttia californica, and the Riverside and San Diego fairy shrimp: (1) the present or threatened destruction, modification, or curtailment of their habitat range; (2) over utilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; and (5) other natural and manmade factors affecting their continued existence (50 CFR 424.11). 3. Population trends for all seven taxa continue to be stable or increasing for 10 consecutive years after threats have been sufficiently ameliorated or managed (completion of delisting criterion 2) prior to consideration for delisting. (USFWS, 2019)

Recovery Actions:

- Design and establish a vernal pool habitat preserve system in each Management Area that will maximize the ecological distribution of the species, minimize risk of habitat loss, retain genetic differentiation, and provide the opportunity for expansion of populations (USFWS 1998).
- In each Management Area, reestablish vernal pool habitat to historic structure and composition to increase genetic diversity and population stability (USFWS 1998).
- In each Management Area, rehabilitate and enhance secured vernal pool habitats and their constituent species (USFWS 1998).
- Manage protected habitat (USFWS 1998).
- Monitor protected habitat and listed species (USFWS 1998).
- Support continued conservation, enhancement, management, and monitoring of vernal pool habitat, including monitoring of restored/enhanced habitat, to determine whether vernal pool restoration projects continue to be viable through time (e.g., artificial clay layer remains stable and supports adequate ponding) (USFWS 2008).
- Support completion and peer review of U.S. Marine Corps' study evaluating the impact of tracked vehicle training on fairy shrimp, and develop conservation measures based on the results (USFWS 2008).
- Determine the extent of all remaining occupied habitat, including status (e.g., conserved, restored, managed, monitored, impacted, or illegally impacted) and needs (e.g., conservation, restoration, management, or monitoring) categories for all San Diego fairy shrimp habitat complexes (USFWS 2008).
- Track past and present use of vernal pool inoculum in San Diego fairy shrimp habitat restoration projects. Determine degree of genetic risk (contamination) of past reintroduction of San Diego fairy shrimp into restored pools and enhanced vernal pools, and determine remediation triggers and methods (USFWS 2008).
- 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 San Diego fairy shrimp 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 San Diego fairy shrimp, and as standards for determining San Diego fairy shrimp habitat restoration success (USFWS 2008).

- Consider revising the Recovery Plan to incorporate new information, and address issues discussed in “Recovery Criteria” section of this review. Recovery criteria should include PVA and genetic information available for the San Diego fairy shrimp to help determine which areas should be preserved, and to guide translocation efforts. Recovery criteria should include quantifiable thresholds for downlisting and delisting (USFWS 2008).
-

Conservation Measures and Best Management Practices:

- 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. (USFWS, 2021)

Additional Threshold Information:

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SPECIES ACCOUNT: *Cambarus aculabrum* (Cave crayfish)

Species Taxonomic and Listing Information

Listing Status: Endangered; 4/27/1993; Southeast Region (Region 4) (USFWS, 2015)

Physical Description

An albinistic cave crayfish. Albinistic; eyes without pigment and much reduced; 2 terminal elements of first pleopod of male bent >90 degrees, central projection ca. 135 degrees; body strongly compressed (Hobbs and Brown 1987). The length is from 28.5 TCL, to 45 TL and the width is to 12cm. (NatureServe, 2015)

Taxonomy

This species was inadvertently omitted from the first edition of the AFS checklist. (NatureServe, 2015)

Historical Range

Not Available

Current Range

This species is known from two caves in Benton County, Arkansas (Hobbs, 1989; Robison and Allen, 1995; USFWS, 1996) and just into Missouri (Graening et al., 2006). With all of the effort to look for cave organisms based out of Fayetteville, a great deal of search has been focused in the area to find more Cambarus aculabrum. It has long seemed confined to the original 2 caves, yet recent discoveries have added 2 additional sites nearby - both based on one or two specimens. Missouri has a cave biologist on staff and considerable survey work has been done with no discoveries of the species in that state (Brian Wagner, AR Game and Fish, to Cindy Osborne, AR Heritage, pers. comm., June 2002). (NatureServe, 2015)

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: Most cave forms exhibit opportunistic feeding habits (NatureServe, 2015). Fine benthic organic matter in sediments appears to sustain crustacean detritivores such as C. aculabrum (Graening 2005) (USFWS, 2013). Nutrients are transported from the surface as particulate organic matter or dissolved organic matter. Animals, such as bats, also provide particulate organic matter through their feces (guano) or their bodily remains (USFWS, 1996).

Reproduction Narrative

Adult: Spawning and actual mating periods unknown (NatureServe, 2015). First form males (reproductively active) have been collected during the months of October, December, January and February (Hobbs and Brown 1987). Most troglobitic species, including Cambarus aculabrum, have a low reproductive rate and need a relatively long period to attain maturity (USFWS, 1996) (USFWS, 1996).

Geographic or Habitat Restraints or Barriers

Adult: Cave boundaries, hydrological discontinuity (NatureServe, 2015)

Environmental Specificity

Adult: Very narrow (NatureServe, 2015)

Tolerance Ranges/Thresholds

Adult: Low (inferred from USFWS, 1996)

Site Fidelity

Adult: High (NatureServe, 2015)

Habitat Narrative

Adult: One of the caves from which this species is known is an Ozarkian solution channel and species has been observed along the side walls of a pool or at the stream margin (Robison and Allen, 1995). Cave streams in which this species lives are generally less than 50 cm deep. The environmental specificity of this species is very narrow. This species cannot survive outside the cave environment (Graening et al., 2006). Separation barriers are based on hydrological discontinuity (NatureServe, 2015). Cave crayfish are highly specialized for living in stable cave environments with 19w light and low temperatures and are unable to cope with changes in their habitats that may be induced by human activities. When found, crayfish are usually seen along the walls of pools or along stream edges. They can be found on silt, gravel, rubble and bedrock, or even hiding underneath trash (USFWS, 1996).

Dispersal/Migration

Motility/Mobility

Adult: Low (inferred from NatureServe, 2015)

Migratory vs Non-migratory vs Seasonal Movements

Adult: Non-migratory (NatureServe, 2015)

Dispersal

Adult: Low (inferred from NatureServe, 2015)

Dispersal/Migration Narrative

Adult: The home range probably not over 50 m; ability to survive outside cave practically nil. This species is non-migratory (NatureServe, 2015).

Population Information and Trends

Population Trends:

Decline of <30% (NatureServe, 2015)

Species Trends:

Stable (USFWS, 2013)

Number of Populations:

4 (USFWS, 2024)

Population Size:
1000 - 2500 individuals (NatureServe, 2015)

Adaptability:
Low (inferred from NatureServe, 2015)

Population Narrative:
A natural mortality factor is expulsion from the subterranean habitat by flooding during storm events. This has been documented on more than one occasion for the two largest occurrences (into Pea Ridge Hollow, Missouri thus expanding range of this species) (Graening et al., 2006). Natural dispersal of this species is limited by its confinement to a stygobitic habitat in very few localities. This species has experienced a long-term decline of <30%. The range extent is less than 40 square miles, with an estimated population size of 1,000 - 2,500 individuals. Two populations are considered viable and the species is highly vulnerable (NatureServe, 2015). The species status is stable, based on the 2011 Recovery Data Call. There were two known populations when the recovery plan was published; two new potential C. aculabrum populations have been identified since listing (USFWS, 2013). Cambarus aculabrum is currently known from four populations (i.e., Logan Cave, Bear Hollow Cave, Old Pendergrass, and Elm Springs Upwelling) in northwestern Arkansas and southwestern Missouri (Figure 1). At the time of listing C. aculabrum was only known from two cave streams, one in Benton County, Arkansas (Logan Cave) and another that crosses from Benton County, Arkansas, into McDonald County, Missouri (Bear Hollow Cave). Since being listed, a third population in a cave stream in Benton County, Arkansas (Old Pendergrass), and a fourth population at a groundwater upwelling in Washington County, Arkansas (Elm Springs Upwelling), have been identified. Additional populations are likely to exist, but are believed to be inaccessible to humans. Both populations discovered post listing are believed to be previously overlooked populations as the species has limited range expansion capabilities due to limited connectivity between independent cave stream habitats (USFWS, 2024).

Threats and Stressors

Stressor: Pollution (USFWS, 2013)
Exposure:
Response:
Consequence:
Narrative: Environmental water quality sampling of Bear Hollow and Logan Cave streams produced evidence of fecal coliform bacteria contamination and elevated levels of dissolved nutrients and metals in water, cave sediment, and tissues of cave animals. The study however failed to document any direct effects of these pollutants upon the ecosystems, but the pollutants are present and remain a constant stress upon C. aculabrum, which is adapted to oligotrophic, pristine groundwater habitats. Fine benthic organic matter in sediments appears to sustain crustacean detritivores such as C. aculabrum (Graening 2005). Heavy metals may accumulate in clastic (grain-sized pieces of eroded rock) sediments that contain numerous binding sites. A substantial amount of groundwater contamination from residential and commercial development occurs from inadequate sewage disposal systems. In addition, some 9 wastewater compounds and other contaminants were identified from Logan Cave in a recent study (Bidwell

et al. 2010). (USFWS, 2013)

Stressor: Land conversion (USFWS, 2013)
Exposure:
Response:
Consequence:
Narrative: In 1968, 59 percent of the Logan Cave recharge area was forested; this had decreased to 43 percent by 1987. By 2008, the only forested areas are along creek bottoms or ridge tops where it is too steep for livestock or poultry operations (Aley and Aley 1987; USFWS 2008). Two major land use activities occur in the Logan Cave recharge area: residential and commercial development and agriculture. Problems associated with these land uses include elevated nutrient concentrations, pesticides, and varied contaminants yielded from storm water runoff (Aley and Aley 1987; USFWS 2008). Numerous cattle, swine, and poultry farms operate within the recharge area and produce substantial quantities of animal waste. Land application of animal waste is commonly used as fertilizer to enhance pasture production. Leaks and spills associated with increased road density in the recharge area increases the likelihood of water quality contaminants entering the cave system. A large golf course exists on high vulnerability lands in Gordon Hollow that are within the delineated recharge area for Old Pendergrass Cave. Potential water quality issues associated with management of the golf course include increased nutrients and pesticides. There are a number of poultry houses and a large confined swine operation in the southern part of the recharge area outside of the Bella Vista development. There are approximately 43,400 feet of Arkansas state highways in or immediately adjacent to the recharge area for Old Pendergrass Cave. Problems associated with these land uses include elevated nutrient concentrations, pesticides, and varied contaminants yielded from storm water runoff (Aley and Slay 2007). (USFWS, 2013).

Stressor: Trampling (USFWS, 2013)
Exposure:
Response:
Consequence:
Narrative: Trampling of C. aculabrum has been documented and is considered a continuing threat to this species. Cave gates and fence have been placed on Logan (gate and fence) and Bear Hollow (gate only) Caves, but vandalism and trespass continue to be a problem. Both caves have had unauthorized entries, increasing the risk for trampling. Inadvertent trampling is currently thought to be a minimal threat (USFWS, 2013).

Recovery

Reclassification Criteria:
1. The populations are self-sustaining (as indicated by monitoring data to be reproducing and stable or increasing in size) (USFWS, 2013).

2. The populations are protected from trespass (USFWS, 2013).

3. The populations are protected from water quality degradation for a period of not less than 10 years.

Recovery Priority Number: 5

Delisting Criteria:
Delisting Recovery Criteria: C. aculabrum may be considered for downlisting when the following criteria are met: 1) Populations at Bear Hollow Cave, Logan Cave and one additional population exhibit a stable or increasing trend, natural recruitment, and multiple age classes (Factors A, B, C, & E). 2) Threats have been addressed and/or managed to the extent that the species will remain viable into the foreseeable future (Factors A, B, C, D, & E) (USFWS, 2019b).

Recovery Actions:

- Search for additional populations (USFWS, 1996).
- Study species biology (USFWS, 1996).
- Monitor and study troglophilic and epigean species (USFWS, 1996).
- Protect populations and habitat (USFWS, 1996).
- Educate public on sensitivity of groundwater and fauna to pollution (USFWS, 1996).
- Monitor populations and habitat, including water quality (USFWS, 1996).
- RECOMMENDATIONS FOR FUTURE ACTIONS: The following priority actions will promote recovery: 1) continue efforts to prevent human disturbance to cave systems containing C. aculabrum through the use of outreach, signage, surveillance, and gating, 2) continue to establish partnerships with private landowners, local businesses, and city and county officials, 3) continue searching for additional populations, 4) conduct recharge delineations if new locations are identified, 5) continue efforts to purchase conservation easements or acquire lands within recharge zones, and 6) continue biannual monitoring efforts (USFWS, 2019a).
- Continue efforts to prevent human disturbance to cave systems containing C. aculabrum through the use of outreach, signage, surveillance, and gating (USFWS, 2013).
- Continue to establish partnerships with private landowners, local businesses, and city and county officials (USFWS, 2013).
- Develop a hazardous materials spill action plan for implementation by local responders and AHTD (USFWS, 2013).
- Continue searching for additional populations (USFWS, 2013).
- Establish a water and sediment quality monitoring program at currently known sites (USFWS, 2013).
- Conduct recharge delineations if new locations are identified (USFWS, 2013).
- Continue efforts to purchase conservation easements or acquire lands within recharge zones (USFWS, 2013).
- Continue biannual monitoring efforts (USFWS, 2013).
- Finalize and begin implementation of the Cave Safe Harbor program for northwest Arkansas (USFWS, 2013).

Conservation Measures and Best Management Practices:

- RECOMMENDED FUTURE ACTIVITIES A detailed discussion of recovery actions and criteria are presented in the Recovery Plan (Service 1996) and the Recovery Plan Amendment (Service 2019a). In the course of this status review new and/or targeted potential recovery activities were identified and are included below. Recovery Activities • Additional work should be focused on perpetual protection of lands in the recharge areas via a conservation easement or fee-simple purchase. Prioritization should be for the extremely high and high vulnerability areas as defined in Aley and Goers 2023 at Logan Cave and Bear Hollow Cave due to the fact that they have the most intact recharge areas but should occur in all species locations. Monitoring and Research Activities • Surveys should be completed to identify additional C. aculabrum sites. • Genetic variation in C. setosus, C. zophonastes and C. aculabrum, starting with C. setosus, should be mapped across the species range such that sites with unknown cave crayfish species can be accurately identified (USFWS, 2024).

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SPECIES ACCOUNT: *Cambarus callainus* (Big Sandy crayfish)

Species Taxonomic and Listing Information

Listing Status: Threatened; 05/09/2016; Northeast Region (R5) (USFWS, 2016a)

Physical Description

A freshwater, tertiary burrowing crustacean of the Cambaridae family. Adult body lengths range from 75.7 to 101.6 millimeters (mm) (3.0 to 4.0 inches (in)), and the cephalothorax (main body section) is streamlined and elongate, and has two well-defined cervical spines. The elongate convergent rostrum (the beak-like shell extension located between the crayfish's eyes) lacks spines or tubercles (bumps). The gonopods (modified legs used for reproductive purposes) of Form I males (those in the breeding stage) are bent 90 degrees to the gonopod shaft (Loughman 2014, p. 1). Carapace (shell) coloration ranges from olive brown to light green, and the cervical groove is outlined in light blue, aqua, or turquoise. The rostral margins and post orbital (behind the eye) ridges are crimson red. The abdominal terga (dorsal plates covering the crayfish's abdomen) range from olive brown to light brown to light green and are outlined in red. The walking legs of the Big Sandy crayfish range from light green to green blue to green, and the chelae are usually aqua but sometimes green blue to blue (Loughman 2014, p. 1–2; Thoma et al. 2014, p. 547) (USFWS, 2016a).

Taxonomy

A member of the Cambaridae family (USFWS, 2016b).

Historical Range

Cambarus callainus is endemic to the Levisa Fork, Tug Fork, and Russell Fork watersheds in the upper Big Sandy River basin of Kentucky, Virginia, and West Virginia (NatureServe, 2015). The historical range of the Big Sandy crayfish is limited to the upper Big Sandy River basin in eastern Kentucky, southwestern Virginia, and southern West Virginia (USFWS, 2016b). The historical range of the Big Sandy crayfish was limited to the upper Big Sandy River basin in eastern Kentucky, southwestern Virginia, and southern West Virginia (USFWS, 2025).

Current Range

While the species is still found in all four subwatersheds, current data (2006 to 2015) indicate notable differences in the species' distribution in each subwatershed. In the Russell Fork subwatershed, the Big Sandy crayfish was found in 92 percent of the stream systems surveyed (52 percent of sites). In the other subwatersheds, the species was less well distributed. In the Levisa Fork and Upper Levisa Fork watersheds, only 13 percent of the surveyed stream systems were occupied (19 and 24 percent of sites, respectively) and in the Tug Fork subwatershed, 35 percent of surveyed stream systems were occupied (23 percent of sites) (USFWS, 2016b). Currently, the Big Sandy crayfish is known from 21 stream systems in 3 8-digit hydrological unit code (HUC) watersheds: Tug Fork, upper Levisa Fork, and lower Levisa Fork (81 FR 20449-20481). Since 2016, surveys have expanded our knowledge of Big Sandy crayfish presence in streams where the species was known to exist. Additionally, the species has been recorded in approximately 18.0 skm (11.2 smi) of the upper Levisa Fork, downstream of its confluence with Dismal Creek (USFWS, 2025).

Critical Habitat Designated

Yes; 4/14/2022.

Legal Description
We, the U.S. Fish and Wildlife Service (Service), designate critical habitat for the Big Sandy crayfish (Cambarus callainus) and Guyandotte River crayfish (C. veteranus) under the Endangered Species Act (Act). In total, approximately 717 stream kilometers (446 stream miles) in Kentucky, Virginia, and West Virginia fall within the boundaries of the critical habitat designation. The effect of this final rule is to designate critical habitat for the Big Sandy crayfish, which is a threatened species under the Act, and Guyandotte River crayfish, which is an endangered species under the Act.

Critical Habitat Designation
Critical habitat units are depicted for Martin, Pike, Johnson, and Floyd Counties, Kentucky; Buchanan, Dickenson, and Wise Counties, Virginia; and McDowell, Mingo, and Wayne Counties, West Virginia.

Unit 1: Upper Levisa Fork—Dismal Creek, Buchanan County, Virginia. (i) Unit 1 includes approximately 29.2 stream kilometers (skm) (18.1 smi) of Dismal Creek from its confluence with Laurel Fork downstream to its confluence with Levisa Fork in Buchanan County, Virginia.

Unit 2: Russell Fork—Buchanan, Dickenson, and Wise Counties, Virginia, and Pike County, Kentucky. (i) Subunit 2a: Russell Fork, Buchanan and Dickenson Counties, Virginia, and Pike County, Kentucky. (A) Subunit 2a consists of approximately 83.8 skm (52.1 smi) of Russell Fork from its confluence with Ball Creek at Council, Virginia, downstream to its confluence with Levisa Fork at Levisa Junction, Kentucky

Subunit 2b: Hurricane Creek, Buchanan County, Virginia. (A) Subunit 2b consists of approximately 5.9 skm (3.7 smi) of Hurricane Creek from its confluence with Gilbert Fork downstream to its confluence with Russell Fork at Davenport, Virginia.

Subunit 2c: Indian Creek, Buchanan and Dickenson Counties, Virginia. (A) Subunit 2c consists of approximately 7.4 skm (4.6 smi) of Indian Creek from its confluence with Three Forks in Buchanan County, Virginia, downstream to its confluence with Russell Fork in Buchanan and Dickenson Counties, Virginia.

Subunit 2d: Fryingpan Creek, Dickenson County, Virginia. (A) Subunit 2d consists of approximately 4.6 skm (2.9 smi) of Fryingpan Creek from its confluence with Priest Fork downstream to its confluence with Russell Fork.

Subunit 2e: Lick Creek, Dickenson County, Virginia. (A) Subunit 2e consists of approximately 16.2 skm (10.1 smi) of Lick Creek from its confluence with Cabin Fork near Aily, Virginia, downstream to its confluence with Russell Fork at Birchfield, Virginia.

Subunit 2f: Russell Prater Creek, Dickenson County, Virginia. (A) Subunit 2f consists of approximately 8.4 skm (5.2 smi) of Russell Prater Creek from its confluence with Greenbrier Creek downstream to its confluence with Russell Fork at Haysi, Virginia.

Subunit 2g: McClure River, Open Fork and McClure Creek, Dickenson County, Virginia. (A) Subunit 2g consists of approximately 35.6 skm (22.1 smi) of the McClure River and McClure Creek from the confluence of McClure Creek and Honey Branch downstream to the confluence of McClure River and Russell Fork; and approximately 4.9 km (3.0 mi) of Open Fork from the confluence of Middle Fork Open Fork and Coon Branch downstream to the confluence of Open Fork and McClure Creek at Nora, Virginia.

Subunit 2h: Elkhorn Creek, Pike County, Kentucky. (A) Subunit 2h consists of approximately 8.5 skm (5.3 smi) of Elkhorn Creek from its confluence with Mountain Branch downstream to its confluence with Russell Fork at Elkhorn City, Kentucky.

Subunit 2i: Cranes Nest River and Birchfield Creek, Dickenson and Wise Counties, Virginia. (A) Subunit 2i consists of approximately 24.6 skm (19.0 smi) of the Cranes Nest River from its confluence with Birchfield Creek downstream to its confluence with Lick Branch and approximately 6.9 skm (4.3 smi) of Birchfield Creek from its confluence with Dotson Creek downstream to its confluence with Cranes Nest River.

Subunit 2j: Pound River, Dickenson and Wise Counties, Virginia. (A) Subunit 2j consists of approximately 28.5 skm (17.7 smi) of the Pound River from its confluence with Bad Creek downstream to the confluence of the Pound River and Jerry Branch.

Unit 3: Lower Levisa Fork—Floyd, Johnson, and Pike Counties, Kentucky. (i) Subunit 3a: Levisa Fork, Floyd, Johnson, and Pike Counties, Kentucky. (A) Subunit 3a consists of approximately 15.9 km (9.9 mi) of Levisa Fork from its confluence with Russell Fork at Levisa Junction, Kentucky, downstream to its confluence with Island Creek at Pikeville, Kentucky; and 17.5 skm (10.9 smi) of Levisa Fork from its confluence with Abbott Creek downstream to its confluence with Miller Creek at Auxier, Kentucky.

Subunit 3b: Shelby Creek and Long Fork, Pike County, Kentucky. (A) Subunit 3b consists of approximately 32.2 skm (20.0 smi) of Shelby Creek from its confluence with Burk Branch downstream to its confluence with Levisa Fork at Shelbiana, Kentucky; and approximately 12.9 skm (8.0 smi) of Long Fork from the confluence of Right Fork Long Fork and Left Fork Long Fork downstream to the confluence of Long Fork and Shelby Creek at Virgie, Kentucky.

Unit 4: Tug Fork—McDowell, Mingo, and Wayne Counties, West Virginia; Buchanan County, Virginia; and Pike and Martin Counties, Kentucky. (i) Subunit 4a: Tug Fork, McDowell, Mingo, and Wayne Counties, West Virginia; Buchanan County, Virginia; and Pike and Martin Counties, Kentucky. (A) Subunit 4a consists of approximately 106.1 skm (65.9 smi) of the Tug Fork from its confluence with Elkhorn Creek at Welch, West Virginia, downstream to its confluence with Blackberry Creek in Pike County, Kentucky; and 11.7 skm (7.3 smi) of the Tug Fork from its confluence with Little Elk Creek downstream to its confluence with Bull Creek at Crum, West Virginia.

Subunit 4b: Dry Fork and Bradshaw Creek, McDowell County, West Virginia. (A) Subunit 4b consists of approximately 45.2 skm (28.1 smi) of Dry Fork from its confluence with Jacobs Fork downstream to its confluence with Tug Fork at Iaeger, West Virginia; and approximately 4.6 skm (2.9 smi) of Bradshaw Creek from its confluence with Hite Fork at Jolo, West Virginia, downstream to its confluence with Dry Fork at Bradshaw, West Virginia.

Subunit 4c: Panther Creek, McDowell County, West Virginia. (A) Subunit 4c consists of approximately 10.7 skm (6.6 smi) of Panther Creek from its confluence with George Branch downstream to its confluence with Tug Fork at Panther, West Virginia.

) Subunit 4d: Knox Creek, Buchanan County, Virginia, and Pike County, Kentucky. (A) Subunit 4d consists of approximately 16.6 skm (10.3 smi) of Knox Creek from its confluence with Cedar Branch downstream to its confluence with Tug Fork in Pike County, Kentucky

Subunit 4e: Peter Creek, Pike County, Kentucky. (A) Subunit 4e consists of approximately 10.1 skm (6.3 smi) of Peter Creek from the confluence of Left Fork Peter Creek and Right Fork Peter Creek at Phelps, Kentucky, downstream to the confluence of Peter Creek and Tug Fork at Freeburn, Kentucky.

Subunit 4f: Blackberry Creek, Pike County, Kentucky. (A) Subunit 4f consists of approximately 9.1 skm (5.7 smi) of Blackberry Creek its confluence with Bluespring Branch downstream to the confluence of Blackberry Creek and Tug Fork.

Subunit 4g: Pigeon Creek and Laurel Fork, Mingo County, West Virginia. (A) Subunit 4g consists of approximately 14.0 skm (8.7 smi) of Pigeon Creek from its confluence with Trace Fork downstream to its confluence with Tug Fork; and approximately 11.1 skm (6.9 smi) of Laurel Fork from its confluence with Lick Branch downstream to its confluence with Pigeon Creek at Lenore, West Virginia.

Primary Constituent Elements/Physical or Biological Features

Within these areas, the physical or biological features essential to the conservation of the Big Sandy crayfish consist of the following components:

(i) Fast-flowing stream reaches with unembedded slab boulders, cobbles, or isolated boulder clusters within an unobstructed stream continuum (i.e., riffle, run, pool complexes) of permanent, moderate- to large-sized (generally third order and larger) streams and rivers (up to the ordinary high water mark as defined at 33 CFR 329.11).

(ii) Streams and rivers with natural variations in flow and seasonal flooding sufficient to effectively transport sediment and prevent substrate embeddedness.

(iii) Water quality characterized by seasonally moderated temperatures and physical and chemical parameters (e.g., pH, conductivity, dissolved oxygen) sufficient for the normal behavior, growth, reproduction, and viability of all life stages of the species.

(iv) An adequate food base, indicated by a healthy aquatic community structure including native benthic macroinvertebrates and fishes, and plant matter (e.g., leaf litter, algae, detritus).

(v) Aquatic habitats protected from riparian and instream activities that degrade the physical and biological features described in paragraphs (2)(i) through (iv) of this entry or cause physical (e.g., crushing) injury or death to individual Big Sandy crayfish.

(vi) An interconnected network of streams and rivers that have the physical and biological features described in paragraphs (2)(i) through (iv) of this entry and that allow for the movement of individual crayfish in response to environmental, physiological, or behavioral drivers. The scale of the interconnected stream network should be sufficient to allow for gene flow within and among watersheds.

Special Management Considerations or Protections

The features essential to the conservation of the Big Sandy and Guyandotte River crayfishes may require special management considerations or protections to reduce the following threats:

(1) Resource extraction (coal mining, timber harvesting, and oil and gas development)

(2) road construction and maintenance (including unpaved roads and trails)

(3) instream dredging or construction projects

4) off-road vehicle (ORV) use

(5) activities that may modify water quantity or quality

(6) other sources of point and nonpoint source pollution, including spills.

Life History

Feeding Narrative

Adult: This species likely functions as an opportunistic omnivore, with seasonal-mediated tendencies for animal or plant material (Loughman 2014, p. 21) (USFWS, 2016a).

Reproduction Narrative

Adult: The general life cycle pattern of the species is 2 to 3 years of growth, maturation in the third year, and first mating in midsummer of the third or fourth year. Following midsummer mating, the annual cycle involves egg laying in late summer or fall, spring release of young, and late spring/early summer molting. The likely lifespan is thought to be 5 to 7 years, with the possibility of some individuals reaching 10 years of age (Thoma 2009, entire; Thoma 2010, entire) (USFWS, 2016a).

Spatial Arrangements of the Population

Adult: Linear (inferred from USFWs, 2016a)

Tolerance Ranges/Thresholds

Adult: Low (USFWS, 2016b)

Habitat Narrative

Adult: Suitable instream habitat is generally described as clean, third order or larger (width of 4 to 20 meters (m) (13 to 66 feet (ft.))), fast-flowing, permanent streams and rivers with unembedded slab boulders on a bedrock, cobble, or sand substrate (Channell 2004, pp. 21–23; Jezerinac et al. 1995, p. 171; Loughman 2013, p. 1; Loughman 2014, pp. 22–23; Taylor and Shuster 2004, p. 124; Thoma 2009, p. 7; Thoma 2010, pp. 3–4, 6) (USFWS, 2016a). Tertiary burrowing crayfish do not exhibit complex burrowing behavior; instead, they shelter in shallow excavations under loose cobbles and boulders on the stream bottom. The species appears to be intolerant of excessive sedimentation and embeddedness of the stream bottom substrate (USFWS, 2016b).

Dispersal/Migration

Dispersal/Migration Narrative

Adult: Not available

Population Information and Trends

Population Trends:

Unknown; occupies 30% of historical range (USFWS, 2016b)

Number of Populations:

21 (USFWS, 2016b)

Population Size:

Unknown (USFWS, 2016b)

Additional Population-level Information:

Since 2016, survey data have helped us understand the distribution of Big Sandy crayfish throughout its range. The most notable occurrence data collected provided evidence that the species inhabits more of the upper Levisa Fork than previously believed. Prior to listing, the Big Sandy crayfish was known from one record in the upper Levisa Fork, near its confluence with Dismal Creek (Jones et al 2010). Surveys conducted in 2022 documented Big Sandy crayfish presence nearly 18.0 skm (11.2 smi) downstream of the 2002 capture location (VDWR 2023). These data indicate that the Big Sandy crayfish can recolonize areas with suitable habitat. It is also possible that the new detections are a product of increased sampling efforts since the species was listed in 2016 (USFWS, 2025)

Population Narrative:

The Big Sandy crayfish is currently known from a total of 21 stream systems in four subwatersheds. There are no historical or current total population estimates for the Big Sandy crayfish. The Big Sandy crayfish currently occupies approximately 38 percent of the presumed historically suitable stream systems within its historical range (USFWS, 2016b).

Threats and Stressors

Stressor: Habitat degradation (USFWS, 2016b)
Exposure:
Response:
Consequence:
Narrative: The best available data indicate that the primary threats to the Big Sandy crayfish throughout its range is land-disturbing activities that increase erosion and sedimentation, which degrades the stream habitat required by both species. Identified sources of ongoing erosion and sedimentation that occur throughout the ranges of the species include active surface coal

mining, commercial forestry, unpaved roads, gas and oil development, road construction, and stream modifications that cause channel instability. These activities are ongoing (e.g., imminent) and expected to continue at variable rates into the future. For example, while active coal mining may decline, the legacy effects will continue, and oil and gas activities and road construction are expected to increase. There are numerous active freight rail lines in the Big Sandy and Upper Guyandotte River basins (Virginia Department of Rail and Public Transportation (VDRPT) 2013, p. 3–7; West Virginia Department of Transportation (WVDOT) 2013, p. 2–3; Kentucky Transportation Cabinet (KTC) 2015, p. 2–5). These lines were built primarily to haul locally-mined coal to outside markets, but data indicate a shift to more freight traffic through the region, crude oil shipments from Midwest shale oil fields to eastern refineries or ports, and increased rail traffic associated with shale gas development in West Virginia (VDRPT 2013, p. 5–14; WVDOT 2013, pp. 2–57– 2–59; KTC 2015, pp. 2–23–2–24). This increases the risk to aquatic habitats in the event of accidental spills of petroleum or other hazardous materials (USFWS, 2016b).

Stressor: Inadequacy of existing regulatory mechanisms (USFWS, 2016b)
Exposure:
Response:
Consequence:
Narrative: Degradation of Big Sandy crayfish habitat is ongoing despite existing regulatory mechanisms. While these regulatory efforts have led to some improvements in water quality and aquatic habitat conditions, the declines of this species within most of its range has continued to occur. In addition, there are no existing regulatory mechanisms that address effects to the species associated with this species endemism and its isolated and small population sizes, as well as the contributing stressor of climate change (USFWS, 2016b).

Stressor: Small isolated populations (USFWS, 2016b)
Exposure:
Response:
Consequence:
Narrative: The Big Sandy crayfish is known to exist only in the Appalachian Plateaus physiographic province and is limited to certain stream classes and habitat types within river basins. Furthermore, the extant populations are limited to certain subwatersheds, which are physically isolated from the others by steep topography, stream distance, human-induced inhospitable intervening habitat conditions, and/or physical barriers (e.g., dams and reservoirs). Species that are restricted in range and population size are more likely to suffer loss of genetic diversity due to genetic drift, potentially increasing their susceptibility to inbreeding depression, and reducing the fitness of individuals (Soule 1980, pp. 157–158; Hunter 2002, pp. 97–101; Allendorf and Luikart 2007, pp. 117–146). Similarly, the random loss of adaptive genes through genetic drift may limit the ability of the Big Sandy crayfish to respond to changes in its environment such as chronic sedimentation and water quality effects or catastrophic events (Noss and Cooperrider 1994, p. 61).

Stressor: Interspecific competition (USFWS, 2016b)
Exposure:
Response:
Consequence:
Narrative: The Big Sandy crayfish is associated with faster moving water of riffles and runs with unembedded substrate, while other native species such as the spiny stream crayfish (Orconectes

cristavarius) are typically associated with the lower velocity portions of streams and appear to be tolerant of higher levels of sedimentation. Because the lower velocity stream habitats suffer the effects of increased sedimentation and bottom embeddedness before the effects are manifested in the faster moving reaches, the native crayfish using these habitats likely migrated into the relatively less affected riffle and run habitats that are normally the niche of the Big Sandy crayfish (Loughman 2014, pp. 32–33). In the ensuing competition between the habitat-specialist Big Sandy crayfish and the more generalist species, the former are thought to be at a competitive disadvantage (Loughman 2015a, pp. 42– 43; Loughman 2015b, p. 36). The 2015 survey data indicated generally that at degraded sites, species such as O. cristavarius were dominant, with the Big Sandy crayfish being absent or occurring in low numbers (USFWS, 2016b).

Stressor: Climate change (USFWS, 2016b)
Exposure:
Response:
Consequence:
Narrative: The U.S. Geological Survey's and individual State's climate predictions support a finding that conditions within the range of the Big Sandy crayfish is expected to undergo significant temperature and precipitation changes by 2050 (Byers and Norris 2011, pp. 19– 21; Kentucky's Comprehensive Wildlife Conservation Strategy (KCWCS) 2013, pp. 12–16; Kane et al. 2013, pp. 11–13; Alder and Hostetler 2014, entire). Because the Big Sandy crayfish is confined in latitude to specific river basins, and because suitable habitats in the lower reaches of each river system are limited (primarily as a result of past environmental degradation), the species has already been largely restricted to the higher elevation streams within each river basin. Additionally, as discussed in the April 7, 2015, proposed rule (80 FR 18710, pp. 18732–18734), habitat fragmentation caused by dams and poor habitat conditions further restricts the movement of individual crayfish within watersheds (USFWS, 2016b).

Stressor: Invasive Species (USFWS, 2025)
Exposure:
Response:
Consequence:
Narrative: An invasive species, the virile crayfish (Faxonius virilis), has been observed alongside the Big Sandy crayfish in Kentucky during surveys (Floyd pers. comm. 2022a; Loughman pers. comm. 2022). Faxonius virilis is highly mobile, produces many young, and is tolerant of a wide range of environmental variables making the species a very successful invader (Hazlett 1974; Hamr 2002; Larson and Olden 2011). The virile crayfish competes directly with the Big Sandy crayfish for resources such as food and shelter (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm. 2022). More research is needed to understand the implications of virile crayfish competition on Big Sandy crayfish populations (USFWS, 2025).

Stressor: Spills (USFWS, 2025)
Exposure:
Response:
Consequence:
Narrative: Spills of pollutants and sediments into waterways have the potential to negatively impact water quality and habitats that Big Sandy crayfish rely on and likely results in reduced survival of individuals, reduced recruitment, increased vulnerability to other stressors (poor water quality can result in decreased health) and may change behaviors of individuals including

limiting sheltering habitats (burying substrates). More information on the effects of water quality degradation on the Big Sandy crayfish is available in the species listing rule (USFWS, 2025)

Recovery

Reclassification Criteria:
Not available - this species does not have a recovery plan.

Recovery Priority Number: 11C (USFWS, 2018).

Delisting Criteria:
Not available - this species does not have a recovery plan.

Recovery Actions:

- Research and Monitoring: 1. Conduct research to better understand the species life history, habitat needs, and threats. 2. Develop and implement captive holding, propagation, and reintroduction techniques. 3. Monitor listed crayfish populations and their associated habitat conditions. 4. Conduct surveys in streams within the range of the species to determine if suitable habitat or additional occupied habitat is present. Maintaining and Enhancing Resiliency of Existing Populations: 1. Protect habitat integrity and quality of streams within watersheds that currently support the species. 2. Reduce the potential for spills and develop a spill response plan. 3 Protect and restore streams that support the species. 4. Protect and restore riparian areas within crayfish watersheds. Increasing Redundancy of the Species: 1. Establish connectivity between existing populations and/or establish additional populations. Communication, Outreach, and Education: 1. Conduct outreach and education to increase understanding of and participation in crayfish conservation efforts (USFWS, 2018)
- Not available

Conservation Measures and Best Management Practices:

- RECOMMENDATIONS FOR FUTURE ACTIONS The primary recommendation is for the Service to engage partners across Kentucky, Virginia, and West Virginia and develop a draft Recovery Plan, complete with detailed, prioritized recovery actions. A Recovery Implementation Strategy should be developed and kept current through regular updates. Recovery efforts should focus on avoiding and minimizing disturbances and degradation of streams where the Big Sandy crayfish exists (section 2.3.2.1); developing a spill prevention and remedial action plan (section 2.3.2.5); developing captive holding/propagation techniques; and conducting additional research on the species to address key information gaps, such as life history and water quality parameters that are necessary to support viable populations of the species (section 2.3.1.1). Additional surveys in understudied streams or stream reaches, particularly in the lower Levisa Fork and the lower reaches of the Tug Fork will also be beneficial to fill important data gaps. (USFWS, 2025)

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SPECIES ACCOUNT: *Cambarus cracens* (Slenderclaw Crayfish)

Species Taxonomic and Listing Information

Listing Status: Endangered

Physical Description

The slenderclaw crayfish is a relatively small, freshwater crustacean with a comparatively elongate, slender front claw (chela) (Figure 2- 1; Bouchard and Hobbs 1976, p. 2). This species is a cryptic, stream-dwelling crayfish and is considered a tertiary burrower (R. Bearden pers. comm. 2017). The largest individual collected was a female with a carapace length of 1.56 inches (in) (39.7 millimeters (mm)) (Bouchard and Hobbs 1976, p. 7). First form males have ranged from 1.09 in (27.7 mm) to 1.47 in (37.3 mm) carapace length (Bouchard and Hobbs 1976, p. 8). The areolas are 3.4 times as long as they are broad and have six widely spaced pore-like punctations across at the narrowest part. Variations have been noted in the morphology and color of the slenderclaw crayfish. The spination of the carapace was more pronounced in most of the individuals collected at the type locality when compared to individuals collected from other sites (Bouchard and Hobbs 1976, p. 7). Also, the marginal spines on the rostrum were reduced in most of the individuals collected outside of the type locality (Bouchard and Hobbs 1976, p.7). Two color forms have been documented from one site. The first color form documented has a mostly uniform olive green to rusty brown on the carapace (Schuster et al. 2017, p. 97). The second color variation has a distinct mottled pattern, and the basal color of the carapace is light gray to straw colored and overlain with speckling of rusty red to dark brown (G. Schuster pers. comm. 2017; Schuster et al. 2017, p. 97) (USFWS, 2018).

Taxonomy

Originally, the slenderclaw crayfish was described as the sole member of the subgenus Exilicambarus, and therefore named Cambarus (Exilicambarus) cracens (Bouchard and Hobbs 1976, p. 2). The slenderclaw crayfish was described from collections from Short Creek at State Route 75, 1.1 miles southwest of the junction with State Route 68, Marshall County, Alabama (Bouchard and Hobbs 1976, p. 7). Recently, based on the absence of phylogenetic validity, the subgenus Exilicambarus was eliminated along with all other subgeneric classifications in the genus Cambarus (Crandall and De Grave 2017, p. 5). The slenderclaw crayfish, Cambarus cracens, is currently recognized as a valid taxon (Owen et al. 2015, p. 4; Taylor et al. 2007, p. 382). The currently accepted classification of the slenderclaw crayfish is: Phylum: Arthropoda Class: Crustacea Order: Decapoda Infraorder: Astacidea Superfamily: Astacoidea Family: Cambaridae Genus: Cambarus Species: Cambarus cracens (USFWS, 2018)

Historical Range

The historical range of the slenderclaw crayfish included two known populations, Short and Town Creeks, in watersheds leading into the Tennessee River in Alabama. Within the Short Creek population, a total of 90 slenderclaw crayfish, with 56 of those being juveniles, were collected during the period 1970–1974 (Bouchard and Hobbs 1976, entire; Schuster 2017, unpublished data). Historically, only one crayfish was collected in the Town Creek population in the period 1970– 1974 (Bouchard and Hobbs 1976, entire; Schuster 2017, unpublished data). Surveys conducted from 2009 through 2017 have documented the slenderclaw crayfish within the same two populations, Short Creek (three sites in Shoal Creek) and Town Creek (one site in Bengis Creek and one site in Town Creek) (Kilburn et al. 2014, pp. 116–117; Bearden et al. 2017, pp. 17–18; Schuster 2017, unpublished data; Taylor 2017, unpublished data) (USFWS, 2021).

Current Range

AL; The slenderclaw crayfish is endemic to is endemic to streams on Sand Mountain within the Tennessee River Basin in DeKalb and Marshall Counties, Alabama (USFWS, 2021). Currently, the species is found at three sites in Marshall County (Shoal Creek) and two sites in DeKalb County (Bengis Creek and Town Creek) (Figure 2-4) (USFWS, 2018).

Distinct Population Segments Defined

For the slenderclaw crayfish, two populations were delineated using Hydrologic Unit Code (HUC) 12 (U.S. Geological Survey) watershed boundaries and tributaries leading to the Tennessee River (Figure 2-5) which includes Short Creek mainstem and its tributaries and Town Creek mainstem and its tributaries. In the Short Creek Population, the crayfish has been collected at six sites (one historical location on Short Creek, two historical locations on Scarham Creek, and three current locations on Shoal Creek). Within the Short Creek population, 90 slenderclaw crayfish, with 56 of those being juveniles, were collected from 1970-1974 (Table 2-3). In the Town Creek Population, the crayfish has been collected at three sites (one historical location on Bengis Creek, one current location on Bengis Creek, and one current location on Town Creek). Only one crayfish was historically collected in the Town Creek population (Table 2-3) (USFWS, 2018).

Critical Habitat Designated

Yes; 10/8/2021.

Legal Description

We, the U.S. Fish and Wildlife Service (Service), determine endangered species status under the Endangered Species Act of 1973, as amended (Act), for the slenderclaw crayfish (Cambarus cracens), a cryptic freshwater crustacean that is endemic to streams on Sand Mountain within the Tennessee River Basin in DeKalb and Marshall Counties, Alabama. This rule adds this species to the Federal List of Endangered and Threatened Wildlife. In addition, we designate approximately 78 river miles (126 river kilometers) in DeKalb and Marshall Counties, Alabama, as critical habitat for the species under the Act (USFWS, 2021).

Critical Habitat Designation

We are designating approximately 78 river mi (126 river km) in two units as critical habitat for the slenderclaw crayfish. The critical habitat areas, described below, constitute our current best assessment of areas that meet the definition of critical habitat for the slenderclaw crayfish. The two units are: (1) Town Creek Unit, and (2) Short Creek Unit. Unit 2 is subdivided into two subunits: (2a) Shoal Creek and Short Creek subunit, and (2b) ScarhamLaurel Creek subunit. Table 2 shows the name, occupancy of the unit, land ownership of the riparian areas surrounding the units, and approximate river miles of the designated critical habitat units for the slenderclaw crayfish (USFWS, 2021).

Primary Constituent Elements/Physical or Biological Features

Slenderclaw Crayfish (Cambarus cracens) (1) Critical habitat units are depicted for DeKalb and Marshall Counties, Alabama, on the maps in this entry. (2) Within these areas, the physical or biological features essential to the conservation of the slenderclaw crayfish consist of the following components: (i) Geomorphically stable, small to medium, flowing streams: (A) That are typically 19.8 feet (ft) (6 meters (m)) wide or smaller; (B) With attributes ranging from: (1)

Streams with predominantly large boulders and fractured bedrock, with widths from 16.4 to 19.7 ft (5 to 6 m), low to no turbidity, and depths up to 2.3 ft (0.7 m); to (2) Streams dominated by small substrate types with a mix of cobble, gravel, and sand, with widths of approximately 9.8 feet (3 m), low to no turbidity, and depths up to 0.5 feet (0.15 m); (C) With substrate consisting of boulder and cobble containing abundant interstitial spaces for sheltering and breeding; and (D) With intact riparian cover to maintain stream morphology and to reduce erosion and sediment inputs. (ii) Seasonal water flows, or a hydrologic flow regime (which includes the severity, frequency, duration, and seasonality of discharge over time), necessary to maintain benthic habitats where the species is found and to maintain connectivity of streams with the floodplain, allowing the exchange of nutrients and sediment for maintenance of the crayfish's habitat and food availability. (iii) Appropriate water and sediment quality (including, but not limited to, conductivity; hardness; turbidity; temperature; pH; and minimal levels of ammonia, heavy metals, pesticides, animal waste products, and nitrogen, phosphorus, and potassium fertilizers) necessary to sustain natural physiological processes for normal behavior, growth, and viability of all life stages. (iv) Prey base of aquatic macroinvertebrates and detritus. Prey items may include, but are not limited to, insect larvae, snails and their eggs, fish and their eggs, and plant and animal detritus.(USFWS, 2021).

Special Management Considerations or Protections

Critical habitat does not include manmade structures (such as buildings, aqueducts, runways, roads, and other paved areas) and the land on which they are located existing within the legal boundaries on October 8, 2021 (USFWS, 2021).

Life History

Reproduction Narrative

Adult: In the southern United States, cambarid crayfish generally mate in the spring and extrude eggs in the fall (Taylor et al. 1996, p. 27). An ovigerous (egg-bearing) female is referred to as being "in berry." Female crayfish generally carry eggs on the underside of their abdomen for several weeks before hatching (Mclay et al. 2016, p. 99). The eggs are attached to the abdomen by glair that is produced by cement glands (or glair glands). The female fans the eggs to keep them oxygenated and free of sediment (G. Schuster pers. comm. 2017). During this time, the female is vulnerable and takes shelter for protection, because she is unable to flip her tail to swim away while the eggs are on her abdomen (G. Schuster pers. comm. 2017). After hatching, juveniles remain on the underside of the female's abdomen for several weeks to potentially several months (Jurcak et al. 2016, p. 100). Juvenile slenderclaw crayfish have been collected in March, April, August, October, and November suggesting that this species has a prolonged spawning window and the release of eggs is likely flexible depending on environmental conditions (Table 2-1; C. Taylor pers. comm. 2017). In order to grow, crayfish must shed and separate from their exoskeleton and grow a new one through a process called molting. After molting, the crayfish is unable to move effectively and has a soft body, and is therefore vulnerable during this time. Like other cambarid crayfishes, adult slenderclaw crayfish have two forms: Form I, which is reproductively active (breeding), and Form II, which is reproductively inactive (non-breeding) (Figure 2-2). By molting, male crayfish undergo form alternation between Form I and Form II. Form I males have been collected in March, April, August, October, and November (Schuster et al. 2017, p. 97; Bouchard and Hobbs 1976, p. 7). Cambarid female crayfish also undergo form alternation by molting (Wetzel 2002, p. 326). Form I females have wider abdomens to accommodate the carrying of eggs and young and visible (swollen) white glair glands, while Form II females have narrower abdomens and no visible white glair glands (Wetzel 2002, pp. 328-331). No ovigerous slenderclaw crayfish females have been collected, though females with cement glands have been collected in November, an indication that their ovaries were mature at that time (Bouchard and Hobbs 1976, p. 8). Sexual maturity is believed to be reached by year one (G. Schuster pers. comm. 2017). The slenderclaw crayfish likely has a life span of two to three years (G. Schuster pers. comm. 2017) (USFWS, 2018).

Environmental Specificity

Adult: Narrow (inferred from USFWS, 2018)

Habitat Narrative

Adult: Adult and juvenile slenderclaw crayfish are normally found in flowing water in streams, with intact riparian cover and boulder/cobble structure, and are found exclusively on Sand Mountain, DeKalb and Marshall counties, Alabama. Historical surveys of slenderclaw crayfish documented the habitat at the type locality, Short Creek, as a clear, slow flowing stream with bedrock and sandy substrate, and large rocks throughout (Bouchard and Hobbs 1976, p 8). Recent surveys have documented two slightly different habitat types. The first type of habitat is streams with predominantly large boulders and fractured bedrock, widths ranging from 16.4 feet (ft) – 19.7 ft (5 – 6 meters (m)), no turbidity, and depths up to 2.3 ft (0.7 m). The second type of habitat is streams with larger amounts of smaller substrate types with a mix of sand, gravel, and cobble, widths approximately 9.8 ft (3 m), no turbidity, and depths up to 0.5 ft (0.15 m) (R. Bearden pers. comm. 2017). During low stream flow periods, slenderclaw crayfish appear to use any available water, so during these low flow events, individuals have been found in pool habitats or near undercut banks. No individuals have been found in dry channels during sampling effort in low water conditions (R. Bearden pers. comm. 2017) (USFWS, 2918). We have determined that the following physical or biological features are essential to the conservation of the slenderclaw crayfish: (1) Geomorphically stable, small to medium, flowing streams: (a) That are typically 19.8 feet (ft) (6 meters (m)) wide or smaller; (b) With attributes ranging from: (i) Streams with predominantly large boulders and fractured bedrock, with widths from 16.4 to 19.7 ft (5 to 6 m), low to no turbidity, and depths up to 2.3 ft (0.7 m), to (ii) Streams dominated by small substrate types with a mix of cobble, gravel, and sand, with widths of approximately 9.8 feet (3 m), low to no turbidity, and depths up to 0.5 feet (0.15 m); (c) With substrate consisting of boulder and cobble containing abundant interstitial spaces for sheltering and breeding; and (d) With intact riparian cover to maintain stream morphology and to reduce erosion and sediment inputs. (2) Seasonal water flows, or a hydrologic flow regime (which includes the severity, frequency, duration, and seasonality of discharge over time), necessary to maintain benthic habitats where the species is found and to maintain connectivity of streams with the floodplain, allowing the exchange of nutrients and sediment for maintenance of the crayfish's habitat and food availability. (3) Appropriate water and sediment quality (including, but not limited to, conductivity; hardness; turbidity; temperature; pH; and minimal levels of ammonia, heavy metals, pesticides, animal waste products, and nitrogen, phosphorus, and potassium fertilizers) necessary to sustain natural physiological processes for normal behavior, growth, and viability of all life stages. (4) Prey base of aquatic macroinvertebrates and detritus. Prey items may include, but are not limited to, insect larvae, snails and their eggs, fish and their eggs, and plant and animal detritus (USFWS, 2018a).

Dispersal/Migration

Population Information and Trends

Resiliency:

Each population (Short Creek and Town Creek) of the slenderclaw crayfish needs to be able to withstand, or be resilient to, stochastic events or disturbances (e.g. drought, major storms and flooding, accidental discharge of pollutants into streams, or fluctuations in reproduction rates). To be resilient, these populations need to have an adequate number of individuals, cover a large enough area (multiple sites within a population) that a localized event does not eliminate a population, and have connectivity among sites within a population such that areas could be repopulated if local site extirpations were to occur. We determined the factors of low abundance, non-native virile crayfish invasion, and water quality as affecting the current condition of slenderclaw crayfish and carried these forward into our current condition analyses. To assess current population resiliency of slenderclaw crayfish, we used abundance, evidence of reproduction, presence of virile crayfish, and water quality condition by population. To summarize the overall current population resiliency of the slenderclaw crayfish, we ranked the slenderclaw crayfish populations into a current condition category (High, Moderate, Low, and Very Low) based on the demographic and habitat factors outlined above. The slenderclaw crayfish resiliency analysis resulted in low overall condition for both Short and Town creek populations (Table ES-1) (USFWS, 2018).

Representation:

Each population (Short Creek and Town Creek) of the slenderclaw crayfish needs to be able to withstand, or be resilient to, stochastic events or disturbances (e.g. drought, major storms and flooding, accidental discharge of pollutants into streams, or fluctuations in reproduction rates). To be resilient, these populations need to have an adequate number of individuals, cover a large enough area (multiple sites within a population) that a localized event does not eliminate a population, and have connectivity among sites within a population such that areas could be repopulated if local site extirpations were to occur. We determined the factors of low abundance, non-native virile crayfish invasion, and water quality as affecting the current condition of slenderclaw crayfish and carried these forward into our current condition analyses. To assess current population resiliency of slenderclaw crayfish, we used abundance, evidence of reproduction, presence of virile crayfish, and water quality condition by population. To summarize the overall current population resiliency of the slenderclaw crayfish, we ranked the slenderclaw crayfish populations into a current condition category (High, Moderate, Low, and Very Low) based on the demographic and habitat factors outlined above. The slenderclaw crayfish resiliency analysis resulted in low overall condition for both Short and Town creek populations (Table ES-1) (USFWS, 2018).

Redundancy:

The metric of redundancy reflects a species' ability to remain extant after experiencing extreme catastrophic events. Redundancy for the slenderclaw crayfish is characterized by having multiple resilient populations and occupied sites distributed throughout its range. These populations should also maintain natural levels of connectivity between them; currently, the Town Creek population is separated from the Short Creek population due to Guntersville Lake resulting in reduced connectivity. The slenderclaw crayfish exhibits low natural redundancy given its narrow range. Currently, there are two populations spread throughout the species' historical range with three extirpated historical sites in the Short Creek population and one extirpated historical site in the Town Creek population, and thus the slenderclaw crayfish has limited redundancy. In addition, the currently occupied sites in the Short Creek population are in a single tributary, and one catastrophic event could impact the entire population (USFWS, 2018).

Number of Populations:
Two (USFWS, 2018)

Threats and Stressors

Stressor: Nonnative Species
Exposure:
Response:
Consequence:
Narrative: The adaptive nature of the virile crayfish, the effects of this nonnative species on other crayfish species in their native ranges, and records of the virile crayfish's presence in the slenderclaw crayfish's historical and current range indicate that the virile crayfish is a factor that negatively influences the viability of the slenderclaw crayfish in the near term and future. Also, considering that the virile crayfish is a larger crayfish, is a strong competitor, and tends to migrate, while the slenderclaw crayfish has low abundance and is a smaller-bodied crayfish, it is reasonable to infer that once the virile crayfish is established at a site, it will out-compete slenderclaw crayfish (USFWS, 2018a).

Stressor: Water Quality
Exposure:
Response:
Consequence:
Narrative: Direct impacts of poor water quality on the slenderclaw crayfish are unknown; however, aquatic macroinvertebrates (i.e., mayflies, caddisflies, stoneflies) are known to be negatively affected by poor water quality, and this may indirectly impact the slenderclaw crayfish, which feeds on them. Degradation of water quality has been documented to impact aquatic macroinvertebrates and may even cause stress to individual crayfish (Arthur et al. 1987, p. 328; Devi and Fingerman 1995, p. 749; Rosewarne et al. 2014, p. 69). Although crayfish generally have a higher tolerance to ammonia than some aquatic species (i.e., mussels), their food source, larval insects, is impacted by ammonia at lower concentrations (Arthur et al. 1987, p. 328). Juvenile slenderclaw crayfish likely feed exclusively on aquatic macroinvertebrates, which are impacted by elevated ammonia and poor water quality (USFWS, 2018a).

Stressor: Hydrological Alteration and Variation
Exposure:
Response:
Consequence:
Narrative: Dams and reservoirs on the Tennessee River have reduced connectivity between slenderclaw crayfish populations by altering some of the habitat from a flowing stream to standing, impounded water. T

Stressor: Land Use
Exposure:
Response:
Consequence:

Narrative: Within DeKalb and Marshall Counties, the amount of land area in farms (pastureland, poultry production, and row crop production) has decreased over time (Bearden et al. 2017, p. 27). Prior to the discovery of the slenderclaw crayfish, DeKalb and Marshall Counties' total acreage in farms in 1969 was 60 percent (299,316 acres (ac) (121,128 hectares (ha))) and 51 percent (205,105 ac (83,003 ha)), respectively, which included pastureland, poultry production, and row crop production (USDA 1972, p. 285). By 2012, the total acreage in farms had decreased to 46 percent (229,294 ac (92,792 ha)) and 41 percent (162,980 ac (65,956 ha)) in DeKalb and Marshall Counties, respectively (USDA 2014, pp. 230, 234). However, although the amount of area in farm land has decreased since 1969, water quality is still impacted by agricultural practices, as discussed above (Bearden et al. 2017, p. 18). In the future, land use is not expected to change drastically; however, a change from agriculture and poultry farming to urban uses could potentially impact the slenderclaw crayfish. The expansion of urban areas could reduce available habitat for the slenderclaw crayfish, as well as increase impervious surfaces and resultant runoff, which can reduce water quality.

Stressor: Low Abundance and Scientific Collection
Exposure:
Response:
Consequence:
Narrative: The current estimated low abundance (n=32), scientific collection, and genetic drift may negatively affect populations of the slenderclaw crayfish. In general, the fewer populations a species has or the smaller its population size, the greater the likelihood of extinction by chance alone (Shaffer and Stein 2000, p. 307). Genetic drift occurs in all species, but is more likely to negatively affect populations that have a smaller effective population size (Caughley 1994, pp. 219–220; Huey et al. 2013, p. 10). There are only two populations of the slenderclaw crayfish with limited connectivity between those populations, which may have reduced genetic diversity.

Stressor: Synergistic Effects
Exposure:
Response:
Consequence:
Narrative: In addition to impacting the species individually, it is likely that several of the above summarized risk factors are acting synergistically or additively on the species. The combined impact of multiple stressors is likely more harmful than a single stressor acting alone. For example, in the Town Creek watershed, Town Creek was previously listed as an impaired stream due to ammonia and organic enrichment/dissolved oxygen impairments, and recent surveys documented eutrophic conditions of elevated nutrients and low dissolved oxygen. In addition, hydrologic variation and alteration has occurred within the Town Creek watershed. Low water conditions naturally occur in streams where the slenderclaw crayfish occurs, and alteration causing prolonged low water periods could have a negative impact on the reproductive success of the slenderclaw crayfish. Further, connectivity between Town Creek and Short Creek watersheds is likely low due to Guntersville Lake. The combination of all of these stressors on the sensitive aquatic species in this habitat has probably impacted slenderclaw crayfish, in that only four individuals have been recorded here since 2009.

Recovery

Reclassification Criteria:

Recovery Priority Number: 5

Delisting Criteria:
A minimum of two populations of slenderclaw crayfish maintain moderate or higher resiliency, as defined by the SSA (Service 2019, p. 31, or the most recent version) over a 10-year monitoring period (approximately 3 generations). (USFWS, 2025)

Each population maintains at least 5 self-sustaining occupied sites spread among multiple stream branches and habitat types throughout the population's boundaries, with consistent evidence of natural recruitment over a 10-year monitoring period. (USFWS, 2025)

Recovery Actions:

- 1. Assess and evaluate slenderclaw crayfish population abundances and distributions, genetic differences, habitat preferences, food requirements, reproductive requirements, and other life history traits across the species' range (USFWS, 2025)
- 2. Monitor slenderclaw crayfish populations across their range to assess trends over time (USFWS, 2025)
- 3. Assess the establishment and spread of virile and other nonnative, invasive crayfish species within the range of slenderclaw crayfish. (USFWS, 2025)
- 4. Conduct ecological and life history studies on virile and other nonnative crayfish, including competitive interactions, that occur in the range of slenderclaw crayfish. (USFWS, 2025)
- 5. Develop and implement management techniques to mitigate the threats of virile crayfish and other invasive species to slenderclaw populations as appropriate (USFWS, 2025)
- 6. Develop a controlled propagation plan (in accordance with the USFWS Controlled Propagation Policy, 65 FR 56916) and carry out captive rearing, reintroductions, and augmentations as necessary and appropriate. (USFWS, 2025)
- 7. Evaluate stream habitat quality throughout the species' range and carry out restoration and enhancement activities to meet slenderclaw crayfish requirements for survival and reproduction. (USFWS< 2025)
- 8. Develop educational and outreach programs to raise awareness on the spread of nonnative crayfish, water quality issues, and conservation of native crayfish. (USFWS, 2025)

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SPECIES ACCOUNT: *Cambarus veteranus* (Guyandotte River crayfish)

Species Taxonomic and Listing Information

Listing Status: Endangered; 05/09/2016; Northeast Region (R5) (USFWS, 2016a)

Physical Description

A freshwater, tertiary burrowing crustacean of the Cambaridae family. Adult body lengths range from 75.7 to 101.6 millimeters (mm) (3.0 to 4.0 inches (in)), and the cephalothorax (main body section) is streamlined and elongate, and has two well-defined cervical spines. The elongate convergent rostrum (the beak-like shell extension located between the crayfish's eyes) lacks spines or tubercles (bumps). The gonopods (modified legs used for reproductive purposes) of Form I males (those in the breeding stage) are bent 90 degrees to the gonopod shaft (Loughman 2014, p. 1). Carapace (shell) coloration ranges from olive brown to light green, and the cervical groove is outlined in light blue, aqua, or turquoise. The rostral margins and post orbital (behind the eye) ridges are crimson red. The abdominal terga (dorsal plates covering the crayfish's abdomen) range from olive brown to light brown to light green and are outlined in red. The walking legs of the Guyandotte River crayfish are blue and the chelae range from blue green to light blue (Loughman 2014, p. 1–2; Thoma et al. 2014, p. 547) (USFWS, 2016a).

Taxonomy

A member of the Cambaridae family. The species is closely related to the Big Sandy crayfish (C. callainus) and the two share many basic physical characteristics (USFWS, 2016a).

Historical Range

The historical range of the Guyandotte River crayfish is limited to the Upper Guyandotte River basin in West Virginia (NatureServe, 2015). Historical survey information, historical stream connectedness, current distribution data, genetic evidence, and expert opinion support that this species once occupied most, perhaps all, third order or larger stream systems throughout its range (USFWS, 2016b).

Current Range

The Guyandotte River crayfish is currently known from two disjunct stream systems in the Upper Guyandotte River basin (USFWS, 2016b).

Critical Habitat Designated

Yes; 4/14/2022.

Legal Description

We, the U.S. Fish and Wildlife Service (Service), designate critical habitat for the Big Sandy crayfish (Cambarus callainus) and Guyandotte River crayfish (C. veteranus) under the Endangered Species Act (Act). In total, approximately 717 stream kilometers (446 stream miles) in Kentucky, Virginia, and West Virginia fall within the boundaries of the critical habitat designation. The effect of this final rule is to designate critical habitat for the Big Sandy crayfish, which is a threatened species under the Act, and Guyandotte River crayfish, which is an endangered species under the Act.

Critical Habitat Designation

Critical habitat units are depicted for Logan and Wyoming Counties, West Virginia

Unit 1: Upper Guyandotte—Logan and Wyoming Counties, West Virginia. (i) Subunit 1a: Pinnacle Creek, Wyoming County, West Virginia. (A) Subunit 1a consists of approximately 28.6 skm (17.8 smi) of Pinnacle Creek from its confluence with Beartown Fork downstream to its confluence with the Guyandotte River at Pineville, West Virginia.

(ii) Subunit 1b: Clear Fork and Laurel Fork, Wyoming County, West Virginia. (A) Subunit 1b consists of approximately 38.0 skm (23.6 smi) of Clear Fork and its primary tributary Laurel Fork from the confluence of Laurel Creek and Acord Branch downstream to the confluence of Clear Fork and the Guyandotte River.

(iii) Subunit 1c: Guyandotte River, Wyoming County, West Virginia. (A) Subunit 1c consists of approximately 35.8 skm (22.2 smi) of the Guyandotte River from its confluence with Pinnacle Creek at Pineville, West Virginia, downstream to its confluence with Clear Fork.

(iv) Subunit 1d: Indian Creek, Wyoming County, West Virginia. (A) Subunit 1d consists of approximately 4.2 skm (2.6 smi) of Indian Creek from the confluence of Indian Creek and Brier Creek at Fanrock, West Virginia, to the confluence of Indian Creek and the Guyandotte River.

(v) Subunit 1e: Huff Creek, Wyoming and Logan Counties, West Virginia. (A) Subunit 1e consists of approximately 28.0 skm (17.4 smi) of Huff Creek from its confluence with Straight Fork downstream to its confluence with the Guyandotte River at Huff, West Virginia.

Primary Constituent Elements/Physical or Biological Features

) Within these areas, the physical or biological features essential to the conservation of the Guyandotte River crayfish consist of the following components:

(i) Fast-flowing stream reaches with unembedded slab boulders, cobbles, or isolated boulder clusters within an unobstructed stream continuum (i.e.. riffle, run, pool complexes) of permanent, moderate- to large-sized (generally third order and larger) streams and rivers (up to the ordinary high water mark as defined at 33 CFR 329.11).

(ii) Streams and rivers with natural variations in flow and seasonal flooding sufficient to effectively transport sediment and prevent substrate embeddedness.

(iii) Water quality characterized by seasonally moderated temperatures and physical and chemical parameters (e.g., pH, conductivity, dissolved oxygen) sufficient for the normal behavior, growth, reproduction, and viability of all life stages of the species.

(iv) An adequate food base, indicated by a healthy aquatic community structure including native benthic macroinvertebrates, fishes, and plant matter (e.g., leaf litter, algae, detritus).

(v) Aquatic habitats protected from riparian and instream activities that degrade the physical and biological features described in paragraphs (2)(i) through (iv) of this entry or cause physical (e.g., crushing) injury or death to individual Guyandotte River crayfish.

(vi) An interconnected network of streams and rivers that have the physical and biological features described in paragraphs (2)(i) through (iv) of this entry and that allow for the movement of individual crayfish in response to environmental, physiological, or behavioral drivers. The scale of the interconnected stream network should be sufficient to allow for gene flow within and among watersheds

Special Management Considerations or Protections

The features essential to the conservation of the Big Sandy and Guyandotte River crayfishes may require special management considerations or protections to reduce the following threats:

(1) Resource extraction (coal mining, timber harvesting, and oil and gas development)

(2) road construction and maintenance (including unpaved roads and trails)

(3) instream dredging or construction projects;

(4) off-road vehicle (ORV)

(5) activities that may modify water quantity or quality

(6) other sources of point and nonpoint source pollution, including spills

Life History

Feeding Narrative

Adult: This species likely functions as an opportunistic omnivore, with seasonal-mediated tendencies for animal or plant material (Loughman 2014, p. 21) (USFWS, 2016a).

Reproduction Narrative

Adult: This is based on information extrapolated from the Big Sandy crayfish (Thoma 2009, entire; Thoma 2010, entire). The general life cycle pattern of the species is 2 to 3 years of growth, maturation in the third year, and first mating in midsummer of the third or fourth year. Following midsummer mating, the annual cycle involves egg laying in late summer or fall, spring release of young, and late spring/early summer molting. The likely lifespan is thought to be 5 to 7 years, with the possibility of some individuals reaching 10 years of age (USFWS, 2016a).

Spatial Arrangements of the Population

Adult: Linear (inferred from USFWS, 2016a)

Tolerance Ranges/Thresholds

Adult: Low (USFWS, 2016b)

Habitat Narrative

Adult: Suitable instream habitat for the Guyandotte River crayfish is similar to the Big Sandy crayfish and is generally described as clean, third order or larger (width of 4 to 20 meters (m) (13 to 66 feet (ft.))), fast-flowing, permanent streams and rivers with unembedded slab boulders on a bedrock, cobble, or sand substrate (Channell 2004, pp. 21–23; Jezerinac et al. 1995, p. 171; Loughman 2013, p. 1; Loughman 2014, pp. 22–23; Taylor and Shuster 2004, p. 124; Thoma 2009,

p. 7; Thoma 2010, pp. 3–4, 6). Tertiary burrowing crayfish do not exhibit complex burrowing behavior; instead, they shelter in shallow excavations under loose cobbles and boulders on the stream bottom (USFWS, 2016a). The species appears to be intolerant of excessive sedimentation and embeddedness of the stream bottom substrate (USFWS, 2016b).

Dispersal/Migration

Dispersal/Migration Narrative

Adult: Not available

Population Information and Trends

Population Trends:

Unknown; occupies 8% of historical range (USFWS, 2016b)

Number of Populations:

2 subpopulations (USFWS, 2023)

Population Size:

Unknown (USFWS, 2016b)

Population Narrative:

The Guyandotte River crayfish currently occupies only two streams, or approximately 8 percent of the presumed historically suitable stream systems within its historical range. Within these two streams, the species is currently found at 12 percent of the individual sites surveyed. There are no historical or current total population estimates for the Guyandotte River crayfish (USFWS, 2016b). Two subpopulations, both in Wyoming County, WV, occur in the indigenous range of the species: Pinnacle Creek and Clear Fork watershed. At the time of listing in 2016, the Guyandotte River crayfish was known to occur within approximately 4.8 skm (3.0 smi) in Pinnacle Creek, and 21.7 skm (13.5 smi) in the Clear Fork watershed, totaling 26.5 skm (16.5 smi) (Loughman 2015). Since 2016, surveys in both watersheds resulted in detections of the species beyond the previously recorded locations. In 2019, the species was found in new Clear Fork watershed locations approximately 8.6 skm (5.3 smi) upstream from the previously known most upstream Laurel Fork site and 1.2 skm (0.75 smi) upstream from the inlet Clear Fork site (Little Clear Fork; Tidmore 2020; figure 1). In 2021, surveys in Pinnacle Creek resulted in confirmation of the species in 11.3 skm (7.0 smi; WVDNR 2021b). Additionally, in 2021, surveys in the mainstem of the Guyandotte River resulted in the capture of three adult Guyandotte River crayfish in locations that are within the species' historical range, but which were presumed to be unoccupied (figure 1). A nonreproductive adult male was captured in the mainstem directly next to the confluence with Pinnacle Creek, and both a female and a male were captured approximately 0.35 skm (0.21 smi) downstream from the confluence of the mainstem with Pinnacle Creek (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm., 2021; R. Aulick, U.S. Fish and Wildlife, Davis, WV; WVDNR 2021a) (USFWS, 2023).

Threats and Stressors

Stressor: Habitat degradation (USFWS, 2016b)
Exposure:

Response:
Consequence:
Narrative: The best available data indicate that the primary threats to both the Guyandotte River crayfish throughout its range is land-disturbing activities that increase erosion and sedimentation, which degrades the stream habitat required by both species. Identified sources of ongoing erosion and sedimentation that occur throughout the ranges of the species include active surface coal mining, commercial forestry, unpaved roads, gas and oil development, road construction, and stream modifications that cause channel instability. These activities are ongoing (e.g., imminent) and expected to continue at variable rates into the future. For example, while active coal mining may decline, the legacy effects will continue, and oil and gas activities and road construction are expected to increase. An additional threat specific to the Guyandotte River crayfish is the ongoing operation of ORVs in and adjacent to one of only two known locations for the species; this ORV use is expected to continue. There are numerous active freight rail lines in the Big Sandy and Upper Guyandotte River basins (Virginia Department of Rail and Public Transportation (VDRPT) 2013, p. 3–7; West Virginia Department of Transportation (WVDOT) 2013, p. 2–3; Kentucky Transportation Cabinet (KTC) 2015, p. 2–5). These lines were built primarily to haul locally-mined coal to outside markets, but data indicate a shift to more freight traffic through the region, crude oil shipments from Midwest shale oil fields to eastern refineries or ports, and increased rail traffic associated with shale gas development in West Virginia (VDRPT 2013, p. 5–14; WVDOT 2013, pp. 2–57– 2–59; KTC 2015, pp. 2–23–2–24). This increases the risk to aquatic habitats in the event of accidental spills of petroleum or other hazardous materials (USFWS, 2016b).

Stressor: Inadequacy of existing regulatory mechanisms (USFWS, 2016b)
Exposure:
Response:
Consequence:
Narrative: Degradation of Guyandotte River crayfish habitat is ongoing despite existing regulatory mechanisms. While these regulatory efforts have led to some improvements in water quality and aquatic habitat conditions, the declines of the Guyandotte River crayfish within most of its range has continued to occur. In addition, there are no existing regulatory mechanisms that address effects to the species associated with this species' endemism and its isolated and small population sizes, as well as the contributing stressor of climate change (USFWS, 2016b).

Stressor: Small isolated populations (USFWS, 2016b)
Exposure:
Response:
Consequence:
Narrative: The Guyandotte River crayfish is known to exist only in the Appalachian Plateaus physiographic province and is limited to certain stream classes and habitat types within river basins. Furthermore, the extant populations are limited to certain subwatersheds, which are physically isolated from the others by steep topography, stream distance, human-induced inhospitable intervening habitat conditions, and/or physical barriers (e.g., dams and reservoirs). Species that are restricted in range and population size are more likely to suffer loss of genetic diversity due to genetic drift, potentially increasing their susceptibility to inbreeding depression, and reducing the fitness of individuals (Soule 1980, pp. 157–158; Hunter 2002, pp. 97–101; Allendorf and Luikart 2007, pp. 117–146). Similarly, the random loss of adaptive genes through genetic drift may limit the ability of the Guyandotte River crayfish to respond to changes in its

environment such as chronic sedimentation and water quality effects or catastrophic events (Noss and Cooperrider 1994, p. 61) (USFWS, 2016b).

Stressor: Interspecific competition (USFWS, 2016b)
Exposure:
Response:
Consequence:
Narrative: The Guyandotte River crayfish is associated with faster moving water of riffles and runs with unembedded substrate, while other native species such as the spiny stream crayfish (Orconectes cristavarius) are typically associated with the lower velocity portions of streams and appear to be tolerant of higher levels of sedimentation. Because the lower velocity stream habitats suffer the effects of increased sedimentation and bottom embeddedness before the effects are manifested in the faster moving reaches, the native crayfish using these habitats likely migrated into the relatively less affected riffle and run habitats that are normally the niche of the Guyandotte River crayfish (Loughman 2014, pp. 32–33). In the ensuing competition between the habitat-specialist Guyandotte River crayfish and the more generalist species, the former are thought to be at a competitive disadvantage (Loughman 2015a, pp. 42– 43; Loughman 2015b, p. 36). The 2015 survey data indicated generally that at degraded sites, species such as O. cristavarius were dominant, with the Guyandotte River crayfish being absent or occurring in low numbers (USFWS, 2016b).

Stressor: Climate change (USFWS, 2016b)
Exposure:
Response:
Consequence:
Narrative: The U.S. Geological Survey's and individual State's climate predictions support a finding that conditions within the range of the Guyandotte River crayfish is expected to undergo significant temperature and precipitation changes by 2050 (Byers and Norris 2011, pp. 19– 21; Kentucky's Comprehensive Wildlife Conservation Strategy (KCWCS) 2013, pp. 12–16; Kane et al. 2013, pp. 11–13; Alder and Hostetler 2014, entire). Because the Guyandotte River crayfish is confined in latitude to specific river basins, and because suitable habitats in the lower reaches of each river system are limited (primarily as a result of past environmental degradation), the species has already been largely restricted to the higher elevation streams within each river basin. Additionally, as discussed in the April 7, 2015, proposed rule (80 FR 18710, pp. 18732–18734), habitat fragmentation caused by dams and poor habitat conditions further restricts the movement of individual crayfish within watersheds (USFWS, 2016b).

Recovery

Reclassification Criteria:
Not available - this species does not have a recovery plan.

Recovery Priority Number 5C (USFWS, 2018)

Delisting Criteria:
Not available - this species does not have a recovery plan.

Recovery Actions:

- Research and Monitoring: 1. Conduct research to better understand the species life history, habitat needs, and threats. 2. Develop and implement captive holding, propagation, and reintroduction techniques. 3. Monitor listed crayfish populations and their associated habitat conditions. 4. Conduct surveys in streams within the range of the species to determine if suitable habitat or additional occupied habitat is present. Maintaining and Enhancing Resiliency of Existing Populations: 1. Protect habitat integrity and quality of streams within watersheds that currently support the species. 2. Reduce the potential for spills and develop a spill response plan. 3 Protect and restore streams that support the species. 4. Protect and restore riparian areas within crayfish watersheds. Increasing Redundancy of the Species: 1. Establish connectivity between existing populations and/or establish additional populations. Communication, Outreach, and Education: 1. Conduct outreach and education to increase understanding of and participation in crayfish conservation efforts (USFWS, 2018).
- Not available

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USFWS. 2016a. Environmental Conservation Online System (ECOS) – Species Profile. http://ecos.fws.gov/ecp0/. Accessed August 2016

USFWS 2016b. Endangered and Threatened Wildlife and Plants

Threatened Species Status for the Big Sandy Crayfish and Endangered Species Status for the Guyandotte River Crayfish

Final Rule. 81 Federal Register 67. April 7, 2016. Pages 20449 - 20481.

FR Vol. 87, No. 50. Endangered and Threatened Wildlife and Plants

Designation of Critical Habitat for Big Sandy Crayfish and Guyandotte River Crayfish. Final Rule. Pages 14662-14719.

USFWS. 2016b. Endangered and Threatened Wildlife and Plants

Final Rule. 81 Federal Register 67. April 7, 2016. Pages 20449 - 20481. USFWS. 2023. Guyandotte River crayfish (Cambarus veteranus) 5-Year Review: Summary and Evaluation. USFWS. West Virginia Field Office Davis, West Virginia. 19 pages.

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SPECIES ACCOUNT: *Cambarus williami* (Brawleys Fork crayfish)

Species Taxonomic and Listing Information

Listing Status: Proposed Threatened

Physical Description

Brawleys Fork crayfish are markedly smaller than other Cambarus with individuals ≤ 2 years old having an average carapace length (CL) of 13–15 millimeters (mm) (0.5–0.6 inches (in)) (Bouchard and Bouchard 1995, p. 6; Giddens and Mattingly 2020, pp. 5–6). Reproductively mature form I males as small as 9.2 mm CL and reproductively mature females as small as 10.7 mm CL have been observed (Giddens and Mattingly 2020, p. 7). The species' coloration is variable with most individuals exhibiting a green to greenish-brown color, and some individuals occasionally exhibiting a blue or yellowish-green coloration during winter months (Figure 2.1 A, C, D) (Bouchard and Bouchard 1995, p. 6; Giddens and Mattingly 2020, pp. 9–10). Recently molted individuals may exhibit a slight reddish-orange coloration (USFWS, 2023).

Taxonomy

The Brawleys Fork crayfish was described as a new species within the genus Cambarus in 1995 (Bouchard and Bouchard 1995, p. 2; Crandall and De Grave 2017, p. 13). The species description is based on individuals collected from Brawleys Fork, a tributary of the East Fork Stones River located in Cannon County, Tennessee, within the Cumberland River basin (Bouchard and Bouchard 1995, pp. 2, 6–7). The Brawleys Fork crayfish is considered to be most closely related to the hairy crayfish (Cambarus friaufi) based on similar claw proportions, areola1 featuring less punctation, and club-like end observed in the form I (reproductive form) male gonopod2 (Bouchard and Bouchard 1995, p. 8). Diagnostic features of Brawleys Fork crayfish can be determined by close examination of the species' secondary sexual characteristics (Bouchard and Bouchard 1995, p. 8). The reduced central projection angle of the gonopod is only exhibited by three other species within the genus, the Big South Fork crayfish (C. bouchardi), the Obey crayfish (C. obeyensis), and the pristine crayfish (C. pristinus), representing three of the most primitive members of Cambarus (Bouchard 1975, p. 585; Bouchard and Bouchard 1995, p. 8). Female Brawleys Fork crayfish also feature a prominent two-lobed swelling, a primitive characteristic of the reproductive structure that is only expressed by Brawleys Fork crayfish within Cambarus (Bouchard and Bouchard 1995, p. 8). The taxonomic status of the Brawleys Fork crayfish has not changed since its original description and there is no taxonomic uncertainty around the species (USFWS, 2023).

Historical Range

The species occurs primarily in small- to medium-sized streams (first- to third-order streams) of the Stones and Collins river systems, and in one medium sized river (fifth order). Brawleys Fork crayfish is known to occur in 20 streams in five Hydrologic Unit Code-12 (HUC 12) watersheds within its range (USFWS, 2023).

Current Range

The species occurs primarily in small- to medium-sized streams (first- to third-order streams) of the Stones and Collins river systems, and in one medium sized river (fifth order). Brawleys Fork crayfish is known to occur in 20 streams in five Hydrologic Unit Code-12 (HUC 12) watersheds within its range (USFWS, 2023).

Critical Habitat Designated

No;

Life History

Food/Nutrient Resources

Food Source

Adult: Likely smaller invertebrates, periphyton, and/or plant and detritus (specific diet unknown) (USFWS, 2023)

Food/Nutrient Narrative

Adult: The specific diet of the Brawleys Fork crayfish is unknown, but crayfish are generally omnivores that feed on a variety of dietary resources such as smaller invertebrates, aquatic vegetation, as well as decaying plant and animal matter. When sedimentation occurs, these benthic food resources are buried under a layer of silt which blocks exposure to sunlight essentially suffocating these benthic organisms. This, in turn, leaves the crayfish with limited food resources and restricts the number of individuals that a given habitat can support (USFWS, 2023).

Reproductive Strategy

Adult: Oviparity (USFWS, 2023)

Lifespan

Adult: ~ 3 years (USFWS, 2023)

Breeding Season

Adult: A portion of males are in reproductive form in all months except August. Females bear eggs in the spring as typical of most crayfish species (USFWS, 2023).

Reproduction Narrative

Adult: Individuals reach reproductive maturity by one year. A portion of males are in reproductive form in all months except August. Females bear eggs in the spring as typical of most crayfish species. The species' lifespan appears to be three years with two to three age classes present in healthy populations (USFWS, 2023). Timing of Reproductive Events A recent life history study provides a detailed account of the timing of Brawleys Fork crayfish reproductive events (Figure 2.2) (Giddens and Mattingly 2020, entire). Form I (reproductive form) males are present throughout the year with the exception of the month of August, when form II (nonreproductive form) males are dominant until the occurrence of a widespread molting event between September and October (Giddens and Mattingly 2020, pp. 8– 9). Females are ovigerous (egg-bearing) during the spring (March to June) and hatchlings develop during the spring and summer (May to June) (Giddens and Mattingly 2020, p. 8). Females exhibit glair (a cloudy adhesive substance appearing on the ventral surface of the abdomen) during the winter (November to February) and again in early spring (January to April) (Giddens and Mattingly 2020, p. 8). Potential copulation was observed in a pair of Brawleys Fork crayfish during June 2019; however, no other pairs have been observed exhibiting potential reproductive behavior (Giddens and Mattingly 2020, p. 9). Sex ratios remained at or near 1:1 Male:Female throughout a 12-month period; however, sampled sites had slightly more males from March to June and slightly more females during August, September, and December (Giddens and Mattingly 2020, pp. 6–7). Brawleys Fork crayfish are reproductively mature within their first year (Giddens and Mattingly 2020, p. 7). This evolutionary adaptation is attributed to the species' occupancy of headwater streams, which frequently experience fluctuations in habitat structure (Giddens and Mattingly 2020, p. 7). Rapid development into reproductive maturity may increase species viability by allowing rapid reproduction and recruitment, thus increasing the likelihood of maintaining gene flow despite the occurrence of stochastic events (including low or high stream flows). Frequency of Molting Molting (shedding of the exoskeleton) occurs throughout the year but peaks during October (Giddens and Mattingly 2020, p. 7), with at least 50% of individuals sampled recently molted during October (Giddens and Mattingly 2020, p. 7). Molting appeared to occur more frequently from October to April and less frequently from May to September (Giddens and Mattingly 2020, p. 7). Age-Specific Growth Rate Three age classes occurred in populations of Brawleys Fork crayfish sampled during a recent 12-month study in East Fork Stones River, Hollis Creek, and Mountain Creek (Appendix B; (Giddens and Mattingly 2020, p. 6). The youngest class experiences the most rapid growth rate, with little change in the oldest age class (age 2) (Table 2.1) (Giddens and Mattingly 2020, p. 6). The Brawleys Fork crayfish appears to have a lifespan of approximately three years (H. Mattingly 2021 pers. comm.) (USFWS, 2023).

Habitat Type

Adult: Streams (USFWS, 2023)

Habitat Narrative

Adult: Brawleys Fork crayfish typically occupies runs and riffles with moderate to fast flow and layered cherty gravel substrate and cobble with ample interstitial space not consolidated by fine substrates such as silt. Individuals often burrow a short distance into the cherty substrate during times of normal and reduced stream flows (USFWS, 2023). Brawleys Fork crayfish primarily occurs in first- to third-order streams with fast to moderately rapid flow and frequently burrow into cherty3 gravel substrate within the wetted stream channel (Figure 2.3; Bouchard and Bouchard 1995, p. 6; Giddens and Mattingly 2020, pp. 2–3; Williams et al. 2017, p. 51). The species also occurs in one fifth-order stream, the West Fork Stones River, in Rutherford County, Tennessee (J. Johansen 2021, pers. comm.). However, Brawleys Fork crayfish most often occupies first-, second-, and third-order streams (J. Johansen 2021, pers. comm.; H. Mattingly 2021, pers. comm.; J. Simmons 2021, pers. comm.; C. Williams 2021, pers. comm.;). Brawleys Fork crayfish occur in streams with fast to moderately rapid flow and thalweg depths ranging from 5–30 centimeters (cm) (2–12 in) (Withers and McCoy 2005, pp. 3, 27–48; Rohrbach and Withers 2006, p. 3; Williams et al. 2017, p. 51). Brawleys Fork crayfish typically occupy runs and riffles with moderate to fast flow and layered cherty gravel substrate with ample interstitial space not consolidated by finer substrates such as sand or silt (T. Khan, TTU, unpublished data). Streams with Brawleys Fork crayfish occurrence are characterized by water temperatures ranging from 10–23°Celsius (°C) (50–73 °Fahrenheit (°F) (Giddens and Mattingly 2020, pp. 4–5; J. Simmons 2021, pers. comm.). Ample riparian cover is an important habitat characteristic that creates shaded conditions and maintains a cooler water temperature required by the species. Riparian vegetation also buffers streams against pollutants carried by stormwater runoff. Brawleys Fork crayfish site occupancy is associated with a high volume of clean ground water discharged into the stream from subterranean aquifers (J. Simmons 2021, pers. comm.). The individual needs of Brawleys Fork crayfish are primarily a function of habitat condition and are summarized in Table 2.2 (USFWS, 2023).

Dispersal/Migration

Population Information and Trends

Population Trends:

Declining (USFWS, 2023)

Resiliency:

Of the five delineated Brawleys Fork crayfish AUs, two are in moderate condition (Hollis Creek – East Fork Stones River and Brawleys Fork) and three are in low condition (Lower West Fork Stones River, Bullpen Creek, and Mountain Creek) (USFWS, 2023).

Representation:

Brawleys Fork crayfish has a known distribution encompassing five AUs that occur in different EPA level IV ecoregions that possess correspondingly different stream habitat conditions. The best available information indicates that the species' current representation is not reduced from historical representation (i.e., through range contraction or extirpation of populations). As part of our resiliency assessment, we calculated a total demographic score that includes parameters expected to indicate adaptive capacity of the species including extent, abundance, and age class distribution influencing gene flow and subsequent genetic diversity. Four of five AUs exhibit moderate levels of the assessed attributes that are expected to contribute to adaptive capacity (Table 4.7). Bullpen Creek, with a single known occurrence and low extent, does not express high levels of attributes that represent adaptive capacity. Overall, we have determined that the Brawleys Fork crayfish species-level representation is not reduced from historical levels and is sufficient to support current species viability (USFWS, 2023)

Redundancy:

We consider the Brawleys Fork crayfish to have redundancy that has not declined from historical levels. As an endemic species with a limited range, Brawleys Fork crayfish may have naturally lower redundancy than a more broadly distributed species. Within the known range, Brawleys Fork crayfish typically occurs in low or very low abundance at most sites with 8 of 15 streams with species abundance data. Available information indicates no loss of populations or analysis units over time and the current known range of the species is wider than the historical range (no range reduction). (USFWS, 2023).

Number of Populations:

5 Analysis Units (USFWS, 2023)

Additional Population-level Information:

We determined Brawleys Fork crayfish currently exhibits low resiliency in three of five AUs, and species' redundancy and representation that have not declined from historical levels with no known extirpations or range contraction (Table 4.7; Figure 4.1). All AUs scored low in the habitat parameters analyzed, suggesting habitat may be a limiting factor for resiliency. Four of the five Brawleys Fork crayfish AUs exhibit moderate demographic condition suggesting that Brawleys Fork crayfish has sufficient levels of adaptive capacity to withstand environmental change (Table 4.7). However, isolation and a lack of connectivity in four of the five AUs suggests that Brawleys

Fork crayfish could be susceptible to the deleterious effects of inbreeding, although we have no information that indicates the effects of limited gene flow are currently affecting the species (USFWS, 2023).

Population Narrative:

We delineated populations using spatial occurrence data (1955–2020) from peerreviewed research (Bouchard and Bouchard 1995), an interim research report (Giddens and Mattingly 2020), and State agency (TDEC) survey reports (Withers and McCoy 2005; Rohrbach and Withers 2006). We determined analysis units (AUs) at a scale useful for assessing the species condition. We proposed these divisions based on our knowledge of the species' current and historical distribution in the Stones and Collins rivers systems, and the level of current geographic isolation observed among tributary systems. We determined AUs based on subwatershed (HUC 12) assessment of the occurrences and threats to the species at a biologically meaningful level. Therefore, we have delineated five Brawleys Fork crayfish AUs across the range of the species including 20 streams with records of Brawleys Fork crayfish occurrence (USFWS, 2023).

Threats and Stressors

Stressor: Urbanization (USFWS, 2023)
Exposure:
Response:
Consequence:
Narrative: Future urbanization was assessed quantitatively based on SLEUTH model projections of urban growth likely to occur within each Brawleys Fork crayfish AU in 15 years (2036) and 30 years (2051) (Jantz et al. 2010; Belyea 2013; Chaudhuri and Clarke 2013). Because SLEUTH model projections are estimated in 10-year increments, our assessment of urbanization likely to occur in 2036 was estimated by taking the average growth expected to occur between the years 2030 and 2040. We used SLEUTH projections for the year 2050 to assess the probability of urban growth in 2051 Stream flow in the Southeast has been shown to become impacted when the amount of urban land use reaches 10% of the watershed (Suttles et al. 2018, p. 813). Therefore, we based our assessment of the impact of urbanization on 10% or more of the land within each analysis unit having a ≥50% probability of becoming urbanized within the years 2036 and 2051. The three scenarios under which future urbanization was evaluated to assess and score Brawleys Fork crayfish future condition are described below in 5.1.2 Future Scenarios and Resiliency Calculations (USFWS, 2023).

Stressor: Climate Change (USFWS, 2023)
Exposure:
Response:
Consequence:
Narrative: Future climate change was assessed quantitatively based on USGS National Climate Change Viewer (NCCV 2021) model projections of future annual air temperatures and precipitation likely to occur within the Stones River watershed and the Collins River watershed in 15 years (2036) and 30 years (2051) under two climate scenarios: RCP 4.5 and RCP 8.5. Representative concentration pathways (RCPs) are potential future climate scenarios based on various levels of CO2 concentrations in the atmosphere expected to rise by the year 2100 as a result of varying levels of action that could potentially be taken in the future to address climate change. Under the RCP 4.5 scenario, concentrations of CO2 stabilize at ~850 parts per million

(ppm) after 2100 (Van Vuuren et al. 2011, p. 12). Under the RCP 8.5 scenario, concentrations of CO_2 increase to ~1370 ppm by 2100 (Van Vuuren et al. 2011, p. 12). Fluctuations in average annual air temperature can be expected to vary from year to year with some years experiencing cooler average annual air temperature than the previous year, rather than a continual linear increase in average annual air temperature through time. To account for among-year variability, we assessed future change in average annual air temperature using projections for average change three years before and three years after each timestep (i.e., we used seven years of data from 2033–2039 for the 2036 timestep and seven years of data from 2048–2054 for the 2051 timestep). We also evaluated projected average change in annual precipitation, runoff, and evaporation for the Stones River watershed and the Collins River watershed at both timesteps under both climate change scenarios. However, average annual change for these three parameters did not exceed 0.25 inches/month at either timestep or under RCP 4.5 or 8.5 climate change scenario. This level of change is not expected to affect the Brawleys Fork crayfish or its habitat conditions in a biologically meaningful way. Therefore, we did not consider precipitation, runoff, or evaporation to be viable parameters for assessing and scoring the influence of future climate change on Brawleys Fork crayfish resiliency (USFWS, 2023).

Stressor: Land Use Change (USFWS, 2023)
Exposure:
Response:
Consequence:
Narrative: Future land use change was assessed quantitatively based on USGS Earth Resources Observation and Science Center FOREcasting SCEnarios (FORE-SCE) to model projections of land use change likely to occur within each Brawleys Fork crayfish AU in 15 years (2036) and 30 years (2051). Land use change was assessed within the model under two different Special Report on Emission Scenarios (SRES) for both timesteps: SRES B1 and SRES A2. SRES B1 assumes a future with low population growth, development, and emissions similar to what is assumed under RCP 4.5 (Nakicenovic et al. 2000, entire; Sohl et al. 2014, entire). SRES A2 assumes a future with high population growth, development, and emissions similar to what is assumed under RCP 8.5 (Nakicenovic et al. 2000, entire; Sohl et al. 2014, entire). For the purpose of this assessment, our definition of land use change is the percent change in cropland within each Brawleys Fork crayfish AU (USFWS, 2023).

Stressor: Water Withdrawal (USFWS, 2023)
Exposure:
Response:
Consequence:
Narrative: Because the likelihood of water withdrawal increasing in the future cannot be estimated with quantitative modeling programs, we qualitatively assessed the influence of future water withdrawal on the assumption that as an increase in average annual air temperature and drought can be expected to result in limited water supply, water withdrawal can also be expected to increase to some degree. For example, periods of decreased precipitation and prolonged drought would likely result in more intense irrigation related to horticultural practices, particularly in regions such as the Eastern Highland Rim that have a higher concentration of plant nurseries. Furthermore, under the TDEC Division of Water Resources Rule 0400-40-13, inter-basin transfer of up to 500,000 gallons of water per day is permitted for the benefit of (or to supply) the receiving basin’s public water system (TDEC 2021). Under this rule, permission has been granted to transfer water from the Stones River watershed to the Duck River watershed to

meet water supply demands as development within the Duck River watershed increases. We expect water supply demand to continue to increase within the Duck River watershed due to development resulting in increased water usage and decreased groundwater recharge, which will likely require water withdrawal from the Stones River watershed to continue. Water withdrawals for municipal purposes are typically in higher order mainstream rivers and may not include headwater tributaries. However, smaller, unpermitted agricultural withdrawals are expected in the Brawleys Fork range and are expected to increase with increasing water demand. Continuation of water withdrawal from the Stones River watershed in the future could potentially exacerbate the influence of drought on Brawleys Fork crayfish resiliency by contributing to decreased water availability. Therefore, we qualitatively assessed the influence of water withdrawal on Brawleys Fork crayfish within each AU in 15 years (2036) and 30 years (2051). The various scenarios under which future water withdrawal were evaluated to assess Brawleys Fork crayfish future condition are described below in subsection 5.1.2 Future Scenarios and Resiliency Calculations (USFWS, 2023).

Recovery

Conservation Measures and Best Management Practices:

•

Additional Threshold Information:

•

•

References

USFWS. 2023. Species status assessment report for the Brawleys Fork crayfish (Cambarus williami), Version 1.1. February 2023. Atlanta, GA. 73 pages.

SPECIES ACCOUNT: *Cambarus zophonastes* (Cave crayfish)

Species Taxonomic and Listing Information

Listing Status: Endangered; 4/7/1987; Southeast Region (Region 4) (USFWS, 2015)

Physical Description

An albinistic cave crayfish. Albinistic; eyes much reduced and unpigmented. The similar C. SETOSUS has a subapical notch on the central projection of the first form male, and the main body of the rostrum is more subretangular. The length is 6cm and the width is 1cm. (NatureServe, 2015)

Taxonomy

Not Available

Historical Range

Not Available

Current Range

This species is known only from two caves in north-central Arkansas. Extensive surveys in northern Arkansas and Missouri have failed to find additional populations (USFWS, 1987; Graening et al., 2006). (NatureServe, 2015)

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: Probably, as most troglobites, totally opportunistic. This species is a detritivore. Activity probably more geared to energy input from epigean sources than anything else (NatureServe, 2015). The energy input for Hell Creek cave is primarily the result of flood waters, which bring organic matter into the cave (USFWS, 1988).

Reproduction Narrative

Adult: No data on season or fecundity; one presumes females brood eggs under abdomen and keep young for 3 instars, but no data (NatureServe, 2015). An ovigerous (egg bearing) female was discovered in Hell Creek Cave suggesting reproduction occurs in the late winter and spring months with higher water levels and nutrient inputs triggering reproduction (Smith 1984) (USFWS, 2012).

Geographic or Habitat Restraints or Barriers

Adult: Cave boundaries, hydrological discontinuity (NatureServe, 2015)

Environmental Specificity

Adult: Very narrow (NatureServe, 2015)

Tolerance Ranges/Thresholds

Adult: Low (inferred from NatureServe, 2015)

Site Fidelity

Adult: High (see dispersal/migration narrative)

Habitat Narrative

Adult: This species is found in 2 caves created by a solution channel with considerable permanent water. The species is known from two cave pools, but as well as subterranean (some periodically dry) streams further into the caves (Robison and Allen, 1995; Graening et al., 2006; USFWS, 1987; 1988). Detailed physical and chemical characters, nutrition parameters, metals and dissolved elements are provided in Graening et al. (2006). The environmental specificity of this species is very narrow, as it is a cave obligate and incapable of living outside the cave environment in which it is found. Separation barriers are based on hydrological discontinuity (NatureServe, 2015). C. zophonastes are found on muddy stream bottoms, cave stream walls, and other in-stream habitats (USFWS, 2012).

Dispersal/Migration

Motility/Mobility

Adult: Moderate (inferred from NatureServe, 2015)

Migratory vs Non-migratory vs Seasonal Movements

Adult: Non-migratory (NatureServe, 2015)

Dispersal

Adult: Low (NatureServe, 2015)

Dispersal/Migration Narrative

Adult: This species is ambulatory and a strong swimmer, but non-migratory. Dispersal capabilities are poor as this is a stygobitic species with only two known occurrences despite extensive surveys in nearby areas. (NatureServe, 2015).

Population Information and Trends

Population Trends:

Decline of <30% (NatureServe, 2015)

Species Trends:

Stable (USFWS, 2012)

Number of Populations:

5 (NatureServe, 2024)

Population Size:

50 - 250 individuals (NatureServe, 2015)

Adaptability:

Low (inferred from NatureServe, 2015)

Population Narrative:

This species is known only from two caves in north-central Arkansas and the range extent is less than 40 square miles The estimated population size is 50 - 250 individuals and it is highly vulnerable (NatureServe, 2015). The species status is stable, based on the 2011 Recovery Data Call (USFWS, 2012). Cambarus zophonastes is a stygobitic crayfish without pigment or eyes that is endemic to the North-Central region of the Ozark mountains of Arkansas. The species was originally described and listed based on a single population at Hell Creek Cave. The species is now known to have a broader distribution with a total of five confirmed locations (Hell Creek Cave, Nesbitt Springs Cave, Legion Spring, Cave River Cave, and Flitterin Pit). Two of the most recently confirmed locations (Cave River Cave and Flitterin Pit) are believed to be connected. The density of individuals observed during species surveys is very low in all sites except Flitterin Pit. However, the extreme difficulty of conducting surveys and accessing much of the habitat make population estimates and trends challenging. The extremely low number of individuals observed at Hell Creek Cave and the failure to detect individuals at Legion Spring may be indicative of highly impacted populations or populations with low viability due to other unknown reasons. The status of the Nesbitt Springs population is unknown due to access denial, but there has been an increase in threats from development since the last five-year review. The Cave River Cave/Flitterin Pit population appears to have good population numbers but was only recently discovered and there is limited understanding of the recharge area and no water quality nor long-term monitoring data available (USFWS, 2024).

Threats and Stressors

Stressor: Land use activities (USFWS, 2012)
Exposure:
Response:
Consequence:
Narrative: Overall land use within the Hell Creek Cave recharge zone has changed little from early site characterization by Aley and Aley (1985), with the exception of a few additional houses and poultry operations. In 2006, a small development adjacent to the Hell Creek Cave recharge zone failed to apply sufficient erosion control measures, leading to creek sedimentation. The predicted recharge zone for Nesbitt Spring is mostly a rural setting and contains few identified threats. Subsequent to determination of this site as being occupied by C. zophonastes, a timber management action within the predicted recharge zone removed trees from sinkholes thereby possibly increasing sedimentation to the cave (USFWS, 2012).

Stressor: Contamination (point and non-point) (USFWS, 2024).
Exposure:
Response:
Consequence:
Narrative: Primary threats for the species include point and nonpoint-source contaminants from dumps, businesses, yards, malfunctioning septic systems, agricultural and land management practices, discharge of urban storm water and treated municipal sewage, and climate change. Assessment of land use within all C. zophonastes recharge areas is indicative of a shift towards developed areas ranging from very minimal shifts of only a couple residences in the Nesbitt Springs recharge area to substantive urban and commercial development in the Hell Creek Cave recharge area. Because of ongoing threats and the current condition of the species, this species

continues to meet the definition of an endangered species (USFWS, 2024).

Stressor: Trampling (USFWS, 2012)
Exposure:
Response:
Consequence:
Narrative: Trampling of cave crayfish has been documented and is considered a continued threat to this species. While a cave gate and fence have been placed on Hell Creek Cave, no such human barrier has been installed at Nesbitt Spring Cave. Both caves have had unauthorized entries increasing the risk for trampling as well as collection of this species for various purposes. However, collection or inadvertent trampling is currently thought to be a minimal threat (USFWS, 2012).

Recovery

Reclassification Criteria:
1. Protection of the existing Hell Creek Cave population by minimizing present and future threats within the cave and the recharge area by developing and implementing land use regulations and obtaining conservation agreements or acquiring fee title on all private lands in the extremely high hazard area (USFWS, 2012).

2. Excluding recreational cavers and collectors from the cave (USFWS, 2012).

3. Location and protection (as above) of at least two other viable populations sufficiently removed from Hell Creek Cave and each other so that a single event is unlikely to impact any two populations. Viable populations are those with different age classes including males and females (USFWS, 2012).

Recovery Priority Number: 5 (USFWS, 2019).

Delisting Criteria:
1. The Hell Creek Cave population and at least nine others are known to exist (USFWS, 2012).

2. At least five viable populations and their habitat are protected from present and foreseeable human related and natural threats that may interfere with the survival of any of the populations (USFWS, 2012).

Recovery Actions:
- Protect Hell Creek Cave and its recharge area (USFWS, 1988).
- Survey additional caves for C. zophonastes (USFWS, 1988).
- Conduct a population study of C. zophonastes (USFWS, 1988).
- Gather baseline data on water quality (USFWS, 1988).
- RECOMMENDATIONS FOR FUTURE ACTIONS: The following priority actions should be undertaken: 1) continue efforts to prevent human disturbance to cave systems containing C. zophonastes through the use of outreach, signage, surveillance, and gating, 2) continue to establish partnerships with private landowners, local businesses, city officials, and county officials to share the importance of the cave ecosystem and solicit their support in conservation initiatives, 3) continue searching for additional sites, 4) establish a water

quality monitoring program at currently known sites, 5) continue efforts to purchase conservation easements or acquire lands within recharge zones, and 6) continue biannual monitoring efforts (USFWS, 2019).

- Continue efforts to prevent human disturbance to cave systems containing C. zophonastes through the use of outreach, signage, surveillance, and gating (USFWS, 2012).
- Finalize, apply for permits, and begin implementation of the cave safe harbor agreement and candidate conservation agreement with assurances (USFWS, 2012).
- Continue to establish partnerships with private landowners, local businesses, city and county officials to share the importance of the cave ecosystem and solicit their support in conservation initiatives (such as, the cave safe harbor agreement) (USFWS, 2012).
- Develop a hazardous materials spill action plan for implementation by local responders and AHTD (USFWS, 2012).
- Continue searching for additional sites (USFWS, 2012).
- Establish a water quality monitoring program at currently known sites (USFWS, 2012).
- Conduct recharge delineations at identified locations (USFWS, 2012).
- Continue efforts to purchase conservation easements or acquire lands within recharge zones (USFWS, 2012).
- Continue biannual monitoring efforts which include the use of cave divers (USFWS, 2012).

Conservation Measures and Best Management Practices:

- RECOMMENDED FUTURE ACTIVITIES A detailed discussion of recovery actions and criteria are presented in the Recovery Plan (Service 1988). In the course of this status review new and/or targeted potential recovery activities were identified and are included below. Recovery Activities • Additional work should be focused on perpetual protection of lands in the recharge areas via a conservation easement or fee-simple purchase. Perpetual protection of Cave River Cave, Flitterin Pit and Nesbitt Springs recharge areas are of particularly high priority because significant portions of all three are currently owned by one conservation interested landowner, presenting a rare opportunity to provide significant protection to over 50% of the known individuals via a single action. • The City of Yellville has aging/failing clay sewer lines that are leaking into the Legion Spring recharge area. The Service should work with City staff to facilitate the replacement of those failing lines. Monitoring and Research Activities • Surveys should be completed to identify additional C. zophonastes sites. • Genetic variation in C. setosus should be mapped across the species range such that sites with unknown cave crayfish species, such as Dozens Den Cave, can be confirmed or denied as C. zophonastes (USFWS, 2024).

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SPECIES ACCOUNT: *Faxonius peruncus* (Big Creek Crayfish)

Species Taxonomic and Listing Information

Listing Status: Threatened

Physical Description

The Big Creek crayfish (Faxonius peruncus) is a small, olive-tan crayfish with blackish blotches and specks over the upper surface of pincers, carapace, and abdomen. Length of adult individuals ranges from 1.1 to 2.2 inches (in) (2.8 to 5.6 centimeters (cm)) (USFWS, 2020).

Taxonomy

The Big Creek Crayfish (Faxonius peruncus) is a small, olive-tan crayfish with blackish blotches and specks over the upper surface of pincers, carapace and abdomen (Fig. 2-1)(Pflieger 1996, p. 114). Length of adult individuals ranges from 2.8 to 5.6 centimeters (cm)(1.1 to 2.2 inches)(in)(Pflieger 1996, p. 114). The species was first described as Cambarus peruncus from specimens collected in Little Creek, a tributary to Big Creek in the Upper St. Francis River watershed (Creaser 1931, pp. 7-10) (USFWS, 2018).

Historical Range

Both the Big Creek Crayfish and the St. Francis River Crayfish have localized distributions in the St. Francis River basin upstream of Wappapello dam in Iron, Madison, St. Francois, and Wayne counties in southeastern Missouri (Fig. 2-2)(Pflieger 1996, pp. 116, 120; Riggert et al. 1999, p. 352). The Big Creek Crayfish appears most abundant in the Big Creek and other streams on the west side of the basin and primarily Twelvemile Creek subwatersheds on the east side (Pflieger 1996, p. 116; Riggert et al. 1999, p. 352; MDC 2017, unpublished data); while the St. Francis River Crayfish mainly inhabits the upper St. Francis River tributaries on the upper end of the Upper St. Francis River watershed (Riggert et al. 1999, p. 352; MDC 2017, unpublished data). Despite occupying the St. Francis River watershed at a coarse spatial scale, these two species have been observed at the same location only seven times and exhibit mostly discrete distributions (Westhoff 2011, pp. 34-36). (USFWS, 2018).

Current Range

Both the Big Creek Crayfish and the St. Francis River Crayfish have localized distributions in the St. Francis River basin upstream of Wappapello dam in Iron, Madison, St. Francois, and Wayne counties in southeastern Missouri (Fig. 2-2)(Pflieger 1996, pp. 116, 120; Riggert et al. 1999, p. 352). The Big Creek Crayfish appears most abundant in the Big Creek and other streams on the west side of the basin and primarily Twelvemile Creek subwatersheds on the east side (Pflieger 1996, p. 116; Riggert et al. 1999, p. 352; MDC 2017, unpublished data); while the St. Francis River Crayfish mainly inhabits the upper St. Francis River tributaries on the upper end of the Upper St. Francis River watershed (Riggert et al. 1999, p. 352; MDC 2017, unpublished data). Despite occupying the St. Francis River watershed at a coarse spatial scale, these two species have been observed at the same location only seven times and exhibit mostly discrete distributions (Westhoff 2011, pp. 34-36). (USFWS, 2018).

Critical Habitat Designated

Yes; 5/30/2023.

Legal Description

We, the U.S. Fish and Wildlife Service (Service), determine threatened species status under the Endangered Species Act of 1973 (Act), as amended, for the Big Creek crayfish (Faxonius peruncus) and the St. Francis River crayfish (Faxonius quadruncus), two crayfish species from southern Missouri. We also finalize a rule under the authority of section 4(d) of the Act that provides regulatory measures that are necessary and advisable to provide for the conservation of these species. In addition, we designate critical habitat for the species; in total, approximately 1,069 river miles (1,720 river kilometers) for the Big Creek crayfish and 1,043 river miles (1,679 river kilometers) for the St. Francis River crayfish in Iron, Madison, St. Francois, Washington, and Wayne Counties, Missouri, fall within the boundaries of the critical habitat designations. This rule applies the protections of the Act to these species and their designated critical habitats.

Critical Habitat Designation

(1) The critical habitat unit is depicted for Iron, Madison, St. Francois, Washington, and Wayne Counties in Missouri.

Primary Constituent Elements/Physical or Biological Features

Within the critical habitat unit, the physical or biological features essential to the conservation of the Big Creek crayfish consist of the following components:

(i) Stream flow velocity generally between 0 and 1.1 feet per second (ft/ s) (0 and 0.35 meters per second (m/s))

(ii) Stream depths generally between 0.2 and 1.6 feet (0.06 and 0.49 meters)

(iii) Water temperatures between 34 and 84 °F (1.1 and 28.9 °C)

(iv) Adequately low stream embeddedness so that spaces under rocks and cavities in gravel remain available to the Big Creek crayfish

(v) An available forage and prey base consisting of invertebrates, periphyton, and plant detritus

(vi) Connectivity among occupied stream reaches of the Big Creek crayfish (both within and among occupied subwatersheds)

(vii) Adequately low ratios or densities of nonnative species that allow for maintaining populations of the Big Creek crayfish

Special Management Considerations or Protections

When designating critical habitat, we assess whether the specific areas within the geographical area occupied by the species at the time of listing contain features that are essential to the conservation of the species and which may require special management considerations or protection. The features essential to the conservation of the Big Creek crayfish and St. Francis River crayfish may require special management considerations or protections to reduce the following threats:

(1) Facilitated movement of nonnative crayfish (for example, bait bucket dumping)

(2) nutrient pollution that impacts water quantity and quality, including, but not limited to, agricultural runoff and wastewater effluent

(3) significant alteration of water quality (for example, heavy metal contamination)

(4) forest management or silviculture activities that do not implement State-approved best management practices (BMPs) such that riparian corridors are impacted or sedimentation is increased

(5) sedimentation from construction of dams, culverts, and low water crossings that do not allow for the passage of species or materials, and pipeline and utility installation that creates barriers to movement

(6) other watershed and floodplain disturbances that release sediments or nutrients into the water. Management activities that could ameliorate these threats include, but are not limited to: Education to encourage responsible and legal bait use and proper disposal of unused bait; use of BMPs designed to reduce sedimentation, erosion, and bank side destruction; protection of riparian corridors and retention of sufficient canopy cover along banks; moderation of surface and ground water withdrawals to maintain natural flow regimes; increased use of stormwater management and reduction of stormwater flows into the systems; remediation of contaminated stream reaches and eroding stream banks; and reduction of other watershed and floodplain disturbances that release sediments, pollutants, or nutrients into the water.

Life History

Food/Nutrient Resources

Food Source

Adult: We are unaware of gut content or stable isotope analyses specific to the Big Creek Crayfish and St. Francis River Crayfish. However, we assume that their diet is similar to other Ozark-endemic crayfishes and consists of plant detritus, with invertebrates and periphyton also consumed. Invertebrates, periphyton, plant detritus (USFWS, 2022).

Reproductive Strategy

Adult: Oviparous (USFWS, 2022)

Lifespan

Adult: ~2 years (USFWS, 2022)

Breeding Season

Adult: Fall

Other Reproductive Information

Adult: Molting: Crayfish are encased in a rigid exoskeleton and must periodically discard the old shell and replace it with a new shell when they grow, a process called molting. Once crayfish shed the old shell, the new shell must harden, which can take up to 10 days. During this time crayfish are particularly vulnerable to predation and even cannibalism (Pflieger 1996, pp. 25-29). Thus, they usually find refuge in a protected place in preparation for molting (Pflieger 1996, pp.

25-29). Molting appears to be stressful, and some crayfish die during the process (Pflieger 1996, pp. 25-29). All crayfishes of the family Cambaridae, including the Big Creek Crayfish and St. Francis River Crayfish, exhibit a cyclic dimorphism associated with reproduction (Pflieger 1996, p. 27). Males molt prior to the breeding season, with the gonopod (the structure allowing males to mate) changing during the molting process (USFWS, 2022).

Reproduction Narrative

Adult: Similar to other crayfish occupying Ozark streams, the Big Creek Crayfish and St. Francis River Crayfish mate in the fall (Fig 2-3)(Pflieger 1996, pp. 116,122). During mating, males deposit a sperm plug in the sperm receptacle of the female. The plug remains until the eggs are extruded (or released) in the spring and functions to retain the sperm and perhaps to prevent the female from being inseminated by other males (Pflieger 1996, p. 78). Big Creek Crayfish females generate an average of 61 eggs (Pflieger 1996, pp. 116), ranging from 10 to 90 eggs on each female (DiStefano et al. 2002, p. 449). St. Francis River Crayfish generate an average of 43-81 eggs, with 21-161 eggs on each female (Pflieger 1996, p. 122; Mabery et al. 2017, pp. 16,18). Eggs are fertilized internally, extruded, and then attached to the female's abdomen the following spring (Pflieger 1996, p. 28). Once hatched, the young crayfish remain attached to the female's swimmerets (forked swimming limbs) until they complete two molts. They then begin making brief forays from the female, returning to the safety of her abdomen and clamping themselves to her swimmerets with their pincers when they feel threatened (Pflieger 1996, pp. 25-29). The normal lifespan for both the Big Creek Crayfish and St. Francis River Crayfish appears to be about 2 years. Similar to other crayfish occupying Ozark streams, the Big Creek Crayfish and St. Francis River Crayfish mate in the fall (Fig 2-3)(Pflieger 1996, pp. 116,122). During mating, males deposit a sperm plug in the sperm receptacle of the female. The plug remains until the eggs are extruded (or released) in the spring and functions to retain the sperm and perhaps to prevent the female from being inseminated by other males (Pflieger 1996, p. 78). Big Creek Crayfish females generate an average of 61 eggs (Pflieger 1996, pp. 116), ranging from 10 to 90 eggs on each female (DiStefano et al. 2002, p. 449). St. Francis River Crayfish generate an average of 43-81 eggs, with 21-161 eggs on each female (Pflieger 1996, p. 122; Mabery et al. 2017, pp. 16,18). Eggs are fertilized internally, extruded, and then attached to the female's abdomen the following spring (Pflieger 1996, p. 28). Once hatched, the young crayfish remain attached to the female's swimmerets (forked swimming limbs) until they complete two molts. They then begin making brief forays from the female, returning to the safety of her abdomen and clamping themselves to her swimmerets with their pincers when they feel threatened (Pflieger 1996, pp. 25-29). The normal lifespan for both the Big Creek Crayfish and St. Francis River Crayfish appears to be about 2 years (USFWS, 2022).

Habitat Type

Adult: Aquatic

Dependencies on Specific Environmental Elements

Adult: Slow current velocity (USFWS, 2022)

Environmental Specificity

Adult: Headwater streams Macrohabitats: Pools, runs, and riffles Stream Flow Velocity: Big Creek Crayfish: low water velocity (0.00-0.35 m/s) Water Depth: Big Creek Crayfish: 0.06-0.49 m Water Temperature: 1.1° C (34.0° F) to 28.9° C (84.0° F) Embeddedness: Low so that spaces under rocks and cavities in gravel remain available Refugia: Under rocks or in shallow burrows in gravel

Habitat Narrative

Adult: Early reports of the Big Creek Crayfish suggest the species was found only under small rocks and in shallow burrows in gravel of primary headwater streams (Creaser 1931, p. 9; Williams 1954, p. 847; Pflieger 1996, p. 116), with Pflieger (1996, p. 116) also reporting that the species occurs exclusively in small, high-gradient rocky creeks. Subsequent studies reported that the species was most abundant in smaller streams with widths less than 10 meters (m)(10.9 yards)(yd) and individuals were collected most often from shallow depths (less than 0.5 m), in association with pebble- and cobble-sized rocky substrate, and from habitats with slower current velocities generally ranging from 0.00-0.35 meters per second (m/s)(Riggert et al. 1999, pp. 352-258; Westhoff 2011, p. 95). Daytime water temperatures of sites from which the Big Creek Crayfish were captured ranged from 1.1° Celsius (C)(34.0° Fahrenheit)(F) in December to 28.9° C (84.0° F) in July (USFWS, 2022).

Dispersal/Migration

Population Information and Trends

Population Trends:

Decreasing (displacement by invasive species) (USFWS, 2022)

Number of Populations:

two populations (USFWS, 2018)

Additional Population-level Information:

As described in Chapter 3, the Woodland Crayfish has invaded the Upper St. Francis River watershed and as of 2008, was estimated to occupy 166 to 649 stream kilometers (km)(103 to 403 miles)(mi) in the watershed (DiStefano and Westhoff 2011, p. 40). At a minimum, the invasion has resulted in extirpation of the Big Creek Crayfish in 14.7 stream km (9.1 mi) and of the St. Francis River Crayfish in 13.7 stream km (8.5 mi)(Fig. 4-2)(Table 4-1). We presume that this is an extreme underestimate of the actual extent of both range contractions given that this represents conditions in only 2 of the 11 streams known to be invaded by the Woodland Crayfish (DiStefano and Westhoff 2011, p. 42). Although the Big Creek Crayfish and St. Francis River Crayfish have not been completely displaced in all stream reaches where the Woodland Crayfish has invaded, abundance appears to be substantially impacted. In Orr Hollow Creek, the St. Francis River Crayfish constituted approximately 50% of the crayfish community in uninvaded areas, while constituting only 13% of the community in invaded areas (DiStefano and Westhoff 2011, p. 40). In Marble Creek the St. Francis River Crayfish appears to have co-occurred with the Woodland Crayfish for over 10 years without being completely displaced, though the Woodland Crayfish appears to now be the dominant species in the crayfish community (Westhoff 2017, unpublished data). Similarly, the Big Creek Crayfish constituted 87% of the crayfish community in areas not invaded by the Woodland Crayfish in Carver Creek, but only 27% of the community in invaded areas However, the reduction of Big Creek Crayfish relative abundance in Carver Creek appeared to be followed by complete displacement (DiStefano and Westhoff 2011, pp. 40- 41). Although impacts are likely to vary among streams, these results suggest that the Woodland Crayfish has the potential to completely displace the Big Creek Crayfish in invaded areas and substantially reduce abundance of the St. Francis River Crayfish (USFWS, 2022).

Population Narrative:

The Big Creek Crayfish appears to consist of two populations; whereas the St. Francis River Crayfish appears to consist of only one population. However, to better represent groups of individuals that occupy the same area and are subject to the same ecological pressures, we describe population needs at the subpopulation level. For Big Creek Crayfish and St. Francis River Crayfish subpopulations to be healthy, they require a population size and growth rate sufficient to withstand natural environmental fluctuations, habitat of sufficient quantity and quality to support all life stages, gene flow among subpopulations, and a native community structure free from non-native crayfish species that may outcompete and ultimately displace the two species. (USFWS, 2018).

Threats and Stressors

Stressor: Non-native Crayfish (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: The Woodland Crayfish (Faxonius hylas) is native to southeastern Missouri in the Black River drainage and the headwaters of the Meramec and Big rivers (Fig. 3-1)(Pflieger 1996, p. 82). In 1984, the species was discovered outside of its native range in Stouts Creek, a tributary of the St. Francis River (Pflieger 1996, p. 82), presumably from a bait bucket introduction (Westhoff et al. 4 2011, p. 2416). Subsequent sampling has documented the Woodland Crayfish in multiple reaches of the Upper St. Francis River watershed (Figs. 3-1, 3-2)(Riggert et al. 1999, pp. 360-361; DiStefano 2008a, p. 191; DiStefano 2008b, p. 419; DiStefano and Westhoff 2011, pp. 40-41, MDC 2018a, unpublished data). As of 2011, the Woodland Crayfish was estimated to occupy 166 to 649 stream kilometers (km)(103 to 403 miles)(mi) in 11 streams (DiStefano and Westhoff 2011, p. 40). This constitutes 5-20% of the total stream distance in the Upper St. Francis River watershed (DiStefano and Westhoff 2011, p. 40). (USFWS, 2018).

Stressor: Lead Mining Contamination (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: Southeastern Missouri has been a primary producer of lead since the early 1700s in an area referred to as the Old Lead Mining Belt (Fig. 3-4). Though mining ceased in the 1970s, waste from mining operations is still present in the landscape (Missouri Natural Resource Trustee Council, p. 14), resulting in contamination of fish and other aquatic biota, alteration of fish and invertebrate communities, and public health advisories against human consumption of lead-contaminated fish (Czarneski 1985; pp. 17-23; Schmitt et al. 1993, pp. 468-471). The relocation of mine waste (chat) throughout the area as topsoil, fill material, and aggregate for roads, railroads, concrete, and asphalt has further expanded the area of contamination, as has the use of lead mining tailings for 7 agricultural purposes due to its lime content. All of these uses have contributed to contamination of streams in portions of the St. Francis River watershed (Fig. 3-4). As a result, 32.4 miles of Little St. Francis River have been added to the Environmental Protection Agency's (EPA) 303(d) list of impaired waters for not meeting water quality standards for lead; while 34.1 miles of Big Creek have been added for not meeting water quality standards for lead and cadmium (EPA 2016, pp. 1,5 of attachment 2). (USFWS, 2018).

Stressor: Degraded Water Quality from Other Sources (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: Streams in the Upper St. Francis River watershed generally exhibit good water quality and most streams are classified as full use attainment, meaning that they can be used for fishing, swimming, public water supply, and agriculture, among other uses (Boone 2001, p. WQ1) . The basin also has good aquatic biodiversity, and most streams support a diverse benthic invertebrate fauna (Boone 2001, p. CO2). However, as noted in section 3.2, there have been some problems with lead contamination due to mining and smelting activities. There have also been impacts to water quality from inadequate wastewater treatment facilities in the watershed (Boone 2001, p. WQ3). These impacts have resulted in the addition of 93.1 miles of the St. Francis River to the EPA's 303(d) list of impaired waters for not meeting water quality standards for temperature and 1.5 miles of a tributary to Wolf Creek for not meeting water quality standards for dissolved oxygen (EPA 2016, pp. 8-9 of attachment 2). Though the effects of degraded water quality on the two species of crayfish is unclear, we presume that degraded water quality reduces reproduction and survivorship of crayfish. More information is needed to better understand potential impacts. (USFWS, 2018).

Stressor: Sedimentation (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: Many Ozark streams have been disturbed from their natural condition and have accelerated erosion and gravel accumulation (Jacobson and Primm 1994, pp. 80-81). However, in the Upper St. Francis River basin, the absence of a deep cherty (a hard, dark, opaque rock composed of silica) residuum in the igneous Ozark uplift, combined with the formation of erosion-resistant upland soils, results in little gravel accumulation in alluvial floodplain soils (Boone 2001, p. LO3). Streambank soils also are more cohesive than in most Ozark streams because of lower densities of gravel, with channel substrates containing a significant proportion of stable cobble, stone, and boulders (Boone 2001, p. LO3). There are some localized areas within the watershed, however, that do have excessive sedimentation due to eroding or breached mine tailings (Boone 2001, p. WQ4, DiStefano 2008a, p. 191). For example, in 1992 a breached tailings barrier spilled 1,150 cubic meters (1,500 yd) of non-toxic powdered rhyolite rock into Big Creek near Annapolis, Missouri (Boone 2001, p. WQ4). The breach resulted in deposition of fine sediments, two feet deep, for a distance of one mile and temporarily caused extreme turbidity for 24 (km)(15 mi)(Boone 2001, p. WQ4). According to Boone (2001, p. WQ4), macroinvertebrate communities did not fully recover until most of the sediment had been flushed out of the system (over 1.5 yrs later). Excessive deposition of fine sediment can cover rocks and cavities used by the Big Creek Crayfish and St. Francis River Crayfish as refugia. We presume that the loss of refugia results in reduced foraging habitat, thereby reducing carrying capacity and the density of subpopulations. The loss of refugia may also increase competition with the Woodland Crayfish and potentially facilitate displacement of the Big Creek Crayfish and St. Francis River Crayfish. Dukat and Magoulick (1999, p. 47) documented lower predation rates on two Ozark-endemic crayfishes in stream reaches with greater substrate diversity. Thus, the loss of refugia by sedimentation likely also increases predation risk. These presumptions correspond with studies on other crayfish species demonstrating that crayfish presence was dependent on rocks

embedded in little or no sediment and open interstitial spaces (Loughman et al. 2016, p. 645; Loughman et al. 2017, p. 5). Furthermore, excessive sediment deposition negatively impacts macroinvertebrates (Jones et al. 2011, pp. 1056-1062), a primary food source of many stream-dwelling crayfishes (USFWS, 2018).

Stressor: Disease (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: Crayfishes are subject to a wide range of infectious and non-infectious agents that can cause mortalities in individuals and affect populations. Described below are the primary pathogens that have been documented in North American crayfish populations and could affect the Big Creek Crayfish and St. Francis River Crayfish. The Crayfish Plague is a water mold caused by Aphanomyces astaci (OIE 2009, p. 2). The fungus has led to widespread mortality of crayfish populations in Europe (Longshaw 2011, p. 55). While most crayfishes of the genus Faxonius are suspected to be carriers of A. astaci, however, infected individuals appear to succumb to A. astaci only under stress (Cerenius and Söderhäll 1992 as cited in Holdich et al. 2009, p. 3). Therefore, the crayfish plague is unlikely to affect subpopulations of the Big Creek Crayfish and St. Francis River Crayfish unless resiliency of the subpopulations is already reduced. White Spot Syndrome Virus (WSSV) is another infectious pathogen that has been documented in North American crayfish populations. The virus can infect a wide range of crustaceans, most notably shrimp and crayfish. The virus has been documented in the United States in freshwater-farmed crayfishes at multiple sites in Louisiana, including a Faxonius species (Baumgartner et al. 2009, pp. 15-16). Infected crayfish exhibit white spots on the abdomen, and mortality has reached 90% in some farmed crayfish populations (Baumgartner et al. 2009, pp. 15-16). Introduction of WSSV has previously been through shrimp aquaculture (from water, feed, infected females to young, untreated pond effluent, untreated processing effluent, flooding, escape of farmed species)(APHIS Veterinary Services 2007, p. 2; Baumgartner et al. 2009, p. 21), but other potential pathways of transmission include birds moving from infected to uninfected wetlands, imported frozen shrimp used for bait, and ballast water exchange (APHIS Veterinary Services 2007, p. 2). Currently the virus is not known to occur in Missouri, and the nearest shrimp farm is located approximately 160 km (100 mi) from the Upper St. Francis River watershed. If introduced into the Upper St. Francis, however, the WSSV has the potential to impact Big Creek Crayfish and St. Francis River Crayfish subpopulations, although the extent of the impact is unclear. Porcelain Disease, caused by the microsporidian Thelohania contejeani, is a third infectious pathogen documented in North American crayfish populations. The pathogen causes whitening of the skeletal muscle and reduced locomotor activity (Quilter 1976, pp. 226, 228), eventually resulting in the death of infected individuals (Pretto et al. 2018, p. 60). There are putative observations of the disease across the eastern United States and observed in the Ozarks (Fetzner 2018, pers. comm.). However, additional information on the disease’s prevalence and its impacts on North American crayfish is currently not available (USFWS, 2018).

Stressor: Narrow Distribution (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: Because species with small ranges are inherently more vulnerable to extirpation (Gilpin and Soulé 1986, p. 27), having a restricted range is one of the primary criteria used by the

American Fisheries Society Endangered Species Committee to assign conservation status to crayfishes (Taylor et al. 1996, p. 27; Taylor et al. 2007, p. 376). Although having a narrow range increases a species' vulnerability to other threats, it is not a threat itself (Westhoff 2011, p. 3). For this reason, we consider the size of the Big Creek Crayfish and St. Francis River Crayfish ranges in evaluating the 3Rs, rather than discussing it further in this chapter. (USFWS, 2018).

Stressor: Climate Change (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: We are unaware of data on the thermal preferences and tolerances of the Big Creek Crayfish, St. Francis River Crayfish, and Woodland Crayfish. Therefore, we cannot predict with certainty how the species will respond if stream temperatures increase. However, climate change could facilitate displacement of the native crayfishes by the Woodland Crayfish if the latter species has a higher tolerance to stream drying. Lower water levels could also reduce the amount of available habitat (e.g., stream edges and areas around gravel bars), thereby reducing abundance in areas occupied by the Big Creek Crayfish or St. Francis River Crayfish (USFWS, 2018).

Recovery

Conservation Measures and Best Management Practices:
-

Additional Threshold Information:
-
-

References

USFWS. 2020. Endangered and Threatened Wildlife and Plants

Threatened Species Status with Section 4(d) Rule for Big Creek Crayfish and St. Francis River Crayfish and Designations of Critical Habitat. Proposed Rule. FR Vol. 85, No 181. Pages 58192-58222. USFWS. 2018. Species Status Assessment Report for the Big Creek Crayfish (Faxonius peruncus) and St. Francis River Crayfish (Faxonius quadruncus). 69 pp.

USFWS. 2023. FR Vol. 88, No. 81. Pages 25512-25542. Endangered and Threatened Wildlife and Plants

Threatened Species Status With Section 4(d) Rule for Big Creek Crayfish and St. Francis River Crayfish and Designation of Critical Habitat

USFWS. 2022. Species status assessment report for the Big Creek Crayfish (Faxonius peruncus) and St. Francis River Crayfish (Faxonius quadruncus). Version 2.0, January 2022. Midwest Region, Bloomington, Minnesota. 51 pp. + app.

USFWS. 2018. Species Status Assessment Report for the Big Creek Crayfish (Faxonius peruncus) and St. Francis River Crayfish (Faxonius quadruncus). 69 pp. USFWS. 2022. Species status assessment report for the Big Creek Crayfish (Faxonius peruncus) and St. Francis River Crayfish (Faxonius quadruncus). Version 2.0, January 2022. Midwest Region, Bloomington, Minnesota. 51 pp. + app.

USFWS. 2018. Species Status Assessment Report for the Big Creek Crayfish (Faxonius peruncus) and St. Francis River Crayfish (Faxonius quadruncus). 69 pp.

SPECIES ACCOUNT: *Faxonius quadruncus* (St. Francis River Crayfish)

Species Taxonomic and Listing Information

Listing Status: Threatened

Physical Description

The St. Francis River crayfish (Faxonius quadruncus) is a small, dark brown crayfish with blackish blotches or specks over the upper surfaces of the pincers, carapace, and abdomen. Length of adult individuals of St. Francis River crayfish have been observed to be similar to adult Big Creek crayfish (USFWS, 2020).

Taxonomy

The St. Francis River Crayfish (Faxonius quadruncus) is a rather small, dark brown crayfish with blackish blotches or specks over the upper surfaces of the pincers, carapace, and abdomen (Fig. 2-1)(Pflieger 1996, p. 120). Length of adult individuals also ranges from 2.8 to 5.6 centimeters (cm)(1.1 to 2.2 inches)(in)(Pflieger 1996, p. 120). The species was first described as Faxonius quadruncus in 1933 from specimens collected in from the Little St. Francis River and Stout's Creek, a tributary to the St. Francis River (Creaser 1933, pp. 10-12). (USFWS, 2018).

Historical Range

Both the Big Creek Crayfish and the St. Francis River Crayfish have localized distributions in the St. Francis River basin upstream of Wappapello dam in Iron, Madison, St. Francois, and Wayne counties in southeastern Missouri (Fig. 2-2)(Pflieger 1996, pp. 116, 120; Riggert et al. 1999, p. 352). The Big Creek Crayfish appears most abundant in the Big Creek and other streams on the west side of the basin and primarily Twelvemile Creek subwatersheds on the east side (Pflieger 1996, p. 116; Riggert et al. 1999, p. 352; MDC 2017, unpublished data); while the St. Francis River Crayfish mainly inhabits the upper St. Francis River tributaries on the upper end of the Upper St. Francis River watershed (Riggert et al. 1999, p. 352; MDC 2017, unpublished data). Despite occupying the St. Francis River watershed at a coarse spatial scale, these two species have been observed at the same location only seven times and exhibit mostly discrete distributions (Westhoff 2011, pp. 34-36). (USFWS, 2018).

Current Range

Both the Big Creek Crayfish and the St. Francis River Crayfish have localized distributions in the St. Francis River basin upstream of Wappapello dam in Iron, Madison, St. Francois, and Wayne counties in southeastern Missouri (Fig. 2-2)(Pflieger 1996, pp. 116, 120; Riggert et al. 1999, p. 352). The Big Creek Crayfish appears most abundant in the Big Creek and other streams on the west side of the basin and primarily Twelvemile Creek subwatersheds on the east side (Pflieger 1996, p. 116; Riggert et al. 1999, p. 352; MDC 2017, unpublished data); while the St. Francis River Crayfish mainly inhabits the upper St. Francis River tributaries on the upper end of the Upper St. Francis River watershed (Riggert et al. 1999, p. 352; MDC 2017, unpublished data). Despite occupying the St. Francis River watershed at a coarse spatial scale, these two species have been observed at the same location only seven times and exhibit mostly discrete distributions (Westhoff 2011, pp. 34-36). (USFWS, 2018).

Critical Habitat Designated

Yes; 5/30/2023.

Legal Description

We, the U.S. Fish and Wildlife Service (Service), determine threatened species status under the Endangered Species Act of 1973 (Act), as amended, for the Big Creek crayfish (Faxonius peruncus) and the St. Francis River crayfish (Faxonius quadruncus), two crayfish species from southern Missouri. We also finalize a rule under the authority of section 4(d) of the Act that provides regulatory measures that are necessary and advisable to provide for the conservation of these species. In addition, we designate critical habitat for the species; in total, approximately 1,069 river miles (1,720 river kilometers) for the Big Creek crayfish and 1,043 river miles (1,679 river kilometers) for the St. Francis River crayfish in Iron, Madison, St. Francois, Washington, and Wayne Counties, Missouri, fall within the boundaries of the critical habitat designations. This rule applies the protections of the Act to these species and their designated critical habitats.

Critical Habitat Designation

The critical habitat unit is Iron, Madison, St. Francois, Washington, and Wayne Counties in Missouri (USFWS, 2023)

Primary Constituent Elements/Physical or Biological Features

Within the critical habitat unit, the physical or biological features essential to the conservation of the St. Francis River crayfish consist of the following components:

(i) Stream flow velocity generally between 0 and 1.1 feet per second (ft/ s) (0 and 0.35 meters per second (m/s))

(ii) Stream depths generally between 0.2 and 1.7 feet (0.06 and 0.52 meters)

(iii) Water temperatures between 34 and 84 °F (1.1 and 28.9 °C)

(iv) Adequately low stream embeddedness so that spaces under rocks and cavities in gravel remain available to the St. Francis River crayfish

(v) An available forage and prey base consisting of invertebrates, periphyton, and plant detritus

(vi) Connectivity among occupied stream reaches of the St. Francis River crayfish (both within and among occupied subwatersheds)

(vii) Adequately low ratios or densities of nonnative species that allow for maintaining populations of the St. Francis River crayfish

Special Management Considerations or Protections

When designating critical habitat, we assess whether the specific areas within the geographical area occupied by the species at the time of listing contain features that are essential to the conservation of the species and which may require special management considerations or protection. The features essential to the conservation of the Big Creek crayfish and St. Francis River crayfish may require special management considerations or protections to reduce the following threats:

(1) Facilitated movement of nonnative crayfish (for example, bait bucket dumping)

(2) nutrient pollution that impacts water quantity and quality, including, but not limited to, agricultural runoff and wastewater effluent

(3) significant alteration of water quality (for example, heavy metal contamination)

(4) forest management or silviculture activities that do not implement State-approved best management practices (BMPs) such that riparian corridors are impacted or sedimentation is increased

(5) sedimentation from construction of dams, culverts, and low water crossings that do not allow for the passage of species or materials, and pipeline and utility installation that creates barriers to movement

(6) other watershed and floodplain disturbances that release sediments or nutrients into the water. Management activities that could ameliorate these threats include, but are not limited to: Education to encourage responsible and legal bait use and proper disposal of unused bait; use of BMPs designed to reduce sedimentation, erosion, and bank side destruction; protection of riparian corridors and retention of sufficient canopy cover along banks; moderation of surface and ground water withdrawals to maintain natural flow regimes; increased use of stormwater management and reduction of stormwater flows into the systems; remediation of contaminated stream reaches and eroding stream banks; and reduction of other watershed and floodplain disturbances that release sediments, pollutants, or nutrients into the water

Life History

Food/Nutrient Resources

Food Source

Adult: Assume plant detritus, invertebrates and periphyton. (USFWS, 2018).

Food/Nutrient Narrative

Adult: We are unaware of gut content or stable isotope analyses specific to the Big Creek Crayfish and St. Francis River Crayfish. However, we assume that their diet is similar to other Ozark-endemic crayfishes and consists of plant detritus, with invertebrates and periphyton also consumed. (USFWS, 2018).

Reproductive Strategy

Adult: Oviparity (USFWS, 2018)

Lifespan

Adult: ~ 2 years (USFWS, 2018)

Breeding Season

Adult: Mate in Fall (USFWS, 2018)

Reproduction Narrative

Adult: Similar to other crayfish occupying Ozark streams, individuals of the Big Creek Crayfish and St. Francis River Crayfish mate in the fall (Fig 2-3)(Pflieger 1996, pp. 116,122). During mating, males deposit a sperm plug in the sperm receptacle of the female. The plug remains until the eggs are extruded (or released) in the spring, and functions to retain the sperm and perhaps to prevent the female from being inseminated by other males (Pflieger 1996, p. 78). Big Creek Crayfish females generate an average of 61 eggs (Pflieger 1996, pp. 116), ranging from 10 to 90 eggs on each female (DiStefano et al. 2002, p. 449). St. Francis River Crayfish generate an average of 43-81 eggs, with 21-161 eggs on each female (Pflieger 1996, p. 122; Mabery et al. 2017, pp. 16,18). Eggs are fertilized internally, extruded, and then attached to the female's abdomen the following spring (Pflieger 1996, p. 28). Once hatched, the young crayfish remain attached to the female's swimmerets (forked swimming limbs) until they complete two molts. They then begin making brief forays from the female, returning to the safety of her abdomen and clamping themselves to her swimmerets with their pincers when they feel threatened (Pflieger 1996, pp. 25-29). The normal lifespan for both the Big Creek Crayfish and St. Francis River Crayfish appears to be about 2 years (Pflieger 1996, pp. 116, 122). (USFWS, 2018).

Habitat Type

Adult: Aquatic (USFWS, 2018)

Habitat Vegetation or Surface Water Classification

Adult: Headwater streams/small streams (USFWS, 2018)

Habitat Narrative

Adult: The St. Francis River Crayfish was originally reported as being found under rocks in small, rocky headwater streams to moderately large rivers (Creaser 1933, p. 12; Williams 1954, p. 845; Pflieger 1996, p. 122). Creaser (1933, p. 12) also reported that the species was confined to swifty-moving streams with water tumbling over boulders and rocks in the stream bed. However, Riggert et al. (1999, p. 357) found lower densities in faster riffles as compared to pool/backwater and run macrohabitats, as did Westhoff (2011, p. 95) at some sampling sites. Riggert et al. (1999, p. 358) generally found the species in current velocities ranging from 0.00-0.39 m/s (although one individual was collected in a current velocity of 1.90 m/s). Westhoff (2011, p. 108) found the St. Francis River Crayfish in similar velocities ranging from 0.0-0.91 m/s with the average velocity often between 0.05 and 0.15 m/s. Daytime water temperatures of sites from which St. Francis River Crayfish were captured ranged from 1.1° C (34.0° F) in December to 28.9° C (84.0° F) in July (Riggert et al. 1999, p. 357). (USFWS, 2018).

Dispersal/Migration

Population Information and Trends

Number of Populations:

one population (USFWS, 2018)

Population Narrative:

The Big Creek Crayfish appears to consist of two populations; whereas the St. Francis River Crayfish appears to consist of only one population. However, to better represent groups of individuals that occupy the same area and are subject to the same ecological pressures, we describe population needs at the subpopulation level. For Big Creek Crayfish and St. Francis

River Crayfish subpopulations to be healthy, they require a population size and growth rate sufficient to withstand natural environmental fluctuations, habitat of sufficient quantity and quality to support all life stages, gene flow among subpopulations, and a native community structure free from non-native crayfish species that may outcompete and ultimately displace the two species. (USFWS, 2018).

Threats and Stressors

Stressor: Non-native Crayfish (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: The Woodland Crayfish (Faxonius hylas) is native to southeastern Missouri in the Black River drainage and the headwaters of the Meramec and Big rivers (Fig. 3-1)(Pflieger 1996, p. 82). In 1984, the species was discovered outside of its native range in Stouts Creek, a tributary of the St. Francis River (Pflieger 1996, p. 82), presumably from a bait bucket introduction (Westhoff et al. 4 2011, p. 2416). Subsequent sampling has documented the Woodland Crayfish in multiple reaches of the Upper St. Francis River watershed (Figs. 3-1, 3-2)(Riggert et al. 1999, pp. 360-361; DiStefano 2008a, p. 191; DiStefano 2008b, p. 419; DiStefano and Westhoff 2011, pp. 40-41, MDC 2018a, unpublished data). As of 2011, the Woodland Crayfish was estimated to occupy 166 to 649 stream kilometers (km)(103 to 403 miles)(mi) in 11 streams (DiStefano and Westhoff 2011, p. 40). This constitutes 5-20% of the total stream distance in the Upper St. Francis River watershed (DiStefano and Westhoff 2011, p. 40). (USFWS, 2018).

Stressor: Lead Mining Contamination (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: Southeastern Missouri has been a primary producer of lead since the early 1700s in an area referred to as the Old Lead Mining Belt (Fig. 3-4). Though mining ceased in the 1970s, waste from mining operations is still present in the landscape (Missouri Natural Resource Trustee Council, p. 14), resulting in contamination of fish and other aquatic biota, alteration of fish and invertebrate communities, and public health advisories against human consumption of lead-contaminated fish (Czarneski 1985; pp. 17-23; Schmitt et al. 1993, pp. 468-471). The relocation of mine waste (chat) throughout the area as topsoil, fill material, and aggregate for roads, railroads, concrete, and asphalt has further expanded the area of contamination, as has the use of lead mining tailings for 7 agricultural purposes due to its lime content. All of these uses have contributed to contamination of streams in portions of the St. Francis River watershed (Fig. 3-4). As a result, 32.4 miles of Little St. Francis River have been added to the Environmental Protection Agency's (EPA) 303(d) list of impaired waters for not meeting water quality standards for lead; while 34.1 miles of Big Creek have been added for not meeting water quality standards for lead and cadmium (EPA 2016, pp. 1,5 of attachment 2). (USFWS, 2018).

Stressor: Degraded Water Quality from Other Sources (USFWS, 2018)
Exposure:
Response:
Consequence:

Narrative: Streams in the Upper St. Francis River watershed generally exhibit good water quality and most streams are classified as full use attainment, meaning that they can be used for fishing, swimming, public water supply, and agriculture, among other uses (Boone 2001, p. WQ1) . The basin also has good aquatic biodiversity, and most streams support a diverse benthic invertebrate fauna (Boone 2001, p. CO2). However, as noted in section 3.2, there have been some problems with lead contamination due to mining and smelting activities. There have also been impacts to water quality from inadequate wastewater treatment facilities in the watershed (Boone 2001, p. WQ3). These impacts have resulted in the addition of 93.1 miles of the St. Francis River to the EPA's 303(d) list of impaired waters for not meeting water quality standards for temperature and 1.5 miles of a tributary to Wolf Creek for not meeting water quality standards for dissolved oxygen (EPA 2016, pp. 8-9 of attachment 2). Though the effects of degraded water quality on the two species of crayfish is unclear, we presume that degraded water quality reduces reproduction and survivorship of crayfish. More information is needed to better understand potential impacts. (USFWS, 2018).

Stressor: Sedimentation (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: Many Ozark streams have been disturbed from their natural condition and have accelerated erosion and gravel accumulation (Jacobson and Primm 1994, pp. 80-81). However, in the Upper St. Francis River basin, the absence of a deep cherty (a hard, dark, opaque rock composed of silica) residuum in the igneous Ozark uplift, combined with the formation of erosion-resistant upland soils, results in little gravel accumulation in alluvial floodplain soils (Boone 2001, p. LO3). Streambank soils also are more cohesive than in most Ozark streams because of lower densities of gravel, with channel substrates containing a significant proportion of stable cobble, stone, and boulders (Boone 2001, p. LO3). There are some localized areas within the watershed, however, that do have excessive sedimentation due to eroding or breached mine tailings (Boone 2001, p. WQ4, DiStefano 2008a, p. 191). For example, in 1992 a breached tailings barrier spilled 1,150 cubic meters (1,500 yd) of non-toxic powdered rhyolite rock into Big Creek near Annapolis, Missouri (Boone 2001, p. WQ4). The breach resulted in deposition of fine sediments, two feet deep, for a distance of one mile and temporarily caused extreme turbidity for 24 (km)(15 mi)(Boone 2001, p. WQ4). According to Boone (2001, p. WQ4), macroinvertebrate communities did not fully recover until most of the sediment had been flushed out of the system (over 1.5 yrs later). Excessive deposition of fine sediment can cover rocks and cavities used by the Big Creek Crayfish and St. Francis River Crayfish as refugia. We presume that the loss of refugia results in reduced foraging habitat, thereby reducing carrying capacity and the density of subpopulations. The loss of refugia may also increase competition with the Woodland Crayfish and potentially facilitate displacement of the Big Creek Crayfish and St. Francis River Crayfish. Dukat and Magoulick (1999, p. 47) documented lower predation rates on two Ozark-endemic crayfishes in stream reaches with greater substrate diversity. Thus, the loss of refugia by sedimentation likely also increases predation risk. These presumptions correspond with studies on other crayfish species demonstrating that crayfish presence was dependent on rocks embedded in little or no sediment and open interstitial spaces (Loughman et al. 2016, p. 645; Loughman et al. 2017, p. 5). Furthermore, excessive sediment deposition negatively impacts macroinvertebrates (Jones et al. 2011, pp. 1056-1062), a primary food source of many stream-dwelling crayfishes (USFWS, 2018).

Stressor: Disease (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: Crayfishes are subject to a wide range of infectious and non-infectious agents that can cause mortalities in individuals and affect populations. Described below are the primary pathogens that have been documented in North American crayfish populations and could affect the Big Creek Crayfish and St. Francis River Crayfish. The Crayfish Plague is a water mold caused by Aphanomyces astaci (OIE 2009, p. 2). The fungus has led to widespread mortality of crayfish populations in Europe (Longshaw 2011, p. 55). While most crayfishes of the genus Faxonius are suspected to be carriers of A. astaci, however, infected individuals appear to succumb to A. astaci only under stress (Cerenius and Söderhäll 1992 as cited in Holdich et al. 2009, p. 3). Therefore, the crayfish plague is unlikely to affect subpopulations of the Big Creek Crayfish and St. Francis River Crayfish unless resiliency of the subpopulations is already reduced. White Spot Syndrome Virus (WSSV) is another infectious pathogen that has been documented in North American crayfish populations. The virus can infect a wide range of crustaceans, most notably shrimp and crayfish. The virus has been documented in the United States in freshwater-farmed crayfishes at multiple sites in Louisiana, including a Faxonius species (Baumgartner et al. 2009, pp. 15-16). Infected crayfish exhibit white spots on the abdomen, and mortality has reached 90% in some farmed crayfish populations (Baumgartner et al. 2009, pp. 15-16). Introduction of WSSV has previously been through shrimp aquaculture (from water, feed, infected females to young, untreated pond effluent, untreated processing effluent, flooding, escape of farmed species)(APHIS Veterinary Services 2007, p. 2; Baumgartner et al. 2009, p. 21), but other potential pathways of transmission include birds moving from infected to uninfected wetlands, imported frozen shrimp used for bait, and ballast water exchange (APHIS Veterinary Services 2007, p. 2). Currently the virus is not known to occur in Missouri, and the nearest shrimp farm is located approximately 160 km (100 mi) from the Upper St. Francis River watershed. If introduced into the Upper St. Francis, however, the WSSV has the potential to impact Big Creek Crayfish and St. Francis River Crayfish subpopulations, although the extent of the impact is unclear. Porcelain Disease, caused by the microsporidian Thelohania contejeani, is a third infectious pathogen documented in North American crayfish populations. The pathogen causes whitening of the skeletal muscle and reduced locomotor activity (Quilter 1976, pp. 226, 228), eventually resulting in the death of infected individuals (Pretto et al. 2018, p. 60). There are putative observations of the disease across the eastern United States and observed in the Ozarks (Fetzner 2018, pers. comm.). However, additional information on the disease’s prevalence and its impacts on North American crayfish is currently not available (USFWS, 2018).

Stressor: Narrow Distribution (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: Because species with small ranges are inherently more vulnerable to extirpation (Gilpin and Soulé 1986, p. 27), having a restricted range is one of the primary criteria used by the American Fisheries Society Endangered Species Committee to assign conservation status to crayfishes (Taylor et al. 1996, p. 27; Taylor et al. 2007, p. 376). Although having a narrow range increases a species’ vulnerability to other threats, it is not a threat itself (Westhoff 2011, p. 3). For this reason, we consider the size of the Big Creek Crayfish and St. Francis River Crayfish ranges in evaluating the 3Rs, rather than discussing it further in this chapter. (USFWS, 2018).

Stressor: Climate Change (USFWS, 2018)
Exposure:
Response:
Consequence:
Narrative: We are unaware of data on the thermal preferences and tolerances of the Big Creek Crayfish, St. Francis River Crayfish, and Woodland Crayfish. Therefore, we cannot predict with certainty how the species will respond if stream temperatures increase. However, climate change could facilitate displacement of the native crayfishes by the Woodland Crayfish if the latter species has a higher tolerance to stream drying. Lower water levels could also reduce the amount of available habitat (e.g., stream edges and areas around gravel bars), thereby reducing abundance in areas occupied by the Big Creek Crayfish or St. Francis River Crayfish (USFWS, 2018).

Recovery

Conservation Measures and Best Management Practices:

-

Additional Threshold Information:

-
-

References

USFWS. 2020. Endangered and Threatened Wildlife and Plants

Threatened Species Status with Section 4(d) Rule for Big Creek Crayfish and St. Francis River Crayfish and Designations of Critical Habitat. Proposed Rule. FR Vol. 85, No 181. Pages 58192-58222. USFWS. 2018. Species Status Assessment Report for the Big Creek Crayfish (Faxonius peruncus) and St. Francis River Crayfish (Faxonius quadruncus). 69 pp.

USFWS. 2023. FR Vol. 88, No. 81. Pages 25512-25542. Endangered and Threatened Wildlife and Plants

Threatened Species Status With Section 4(d) Rule for Big Creek Crayfish and St. Francis River Crayfish and Designation of Critical Habitat

USFWS. 2018. Species Status Assessment Report for the Big Creek Crayfish (Faxonius peruncus) and St. Francis River Crayfish (Faxonius quadruncus). 69 pp.

SPECIES ACCOUNT: *Gammarus acherondytes* (Illinois cave amphipod)

Species Taxonomic and Listing Information

Listing Status: Endangered; 09/03/1998; Great Lakes-Big Rivers Region (R3) (NatureServe, 2015)

Physical Description

The Illinois cave amphipod is a subterranean crustacean that is light gray-blue in color. The eyes are small and degenerate with the pigment drawn away from the facets in an irregular black mass. The first antenna is long and slender and the second is about three-fourths as long as the first antenna. The flagellum lacks sensory organs in either sex (USFWS, 1998). (NatureServe, 2015)

Historical Range

This amphipod was known historically from six caves at the time of listing, but at that time was present in only three of these caves (USFWS, 2011)

Current Range

Endemic to 230 sq. km area within the Illinois Sinkhole Plain of Monroe and St. Clair counties in southern Illinois. Historically known from six caves, but at the time of listing was known at only three of the original six caves, all in Monroe County (USFWS, 1997; 2002). (NatureServe, 2015) Since the listing, there have been several additional caves and groundwater basins added to the Illinois cave amphipod's range. A survey of caves within the sinkhole plain in 1998 - 1999 revealed six new sites (Lewis et al. 1999). Four additional sites were also added in 2001 (Lewis 2001). (USFWS, 2011) Since 2007, biologists have consistently monitored 10 caves and observed ICA in all of these except Wednesday and Fogelpole Caves (Table 1). In summary, we consider the ICA's status as present in seven caves, extirpated in one, and unknown in eight. (USFWS 2020)

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: Illinois cave amphipods are omnivorous scavengers, feeding on dead animal and plant matter or the thin bacterial film covering most submerged surfaces throughout their aquatic habitat. (USFWS, 1997) Wilhelm et al. (2006) found that the cave-obligate Illinois cave amphipods have a lower metabolic rate than the cave-loving (but not obligate) larger Gammarus troglophilus. Cave environments can be food limiting and the lower metabolic rate generally is favorable to aquatic cave obligates. However, this adaptation may be damaging to Illinois cave amphipods because during times of high nutrient input to a cave system, if food is no longer a limiting factor, the cave-loving species (which can live outside of the cave environment) may out-compete them. (USFWS, 2011)

Reproduction Narrative

Adult: Females may lay up to 21 eggs at a time. (USFWS, 1997) Ovigerous females may be present year-round, but two major periods during which pre-juveniles and juveniles were present were identified (most reproduction is highly seasonal); one in late winter to late spring (February to May) and one in late summer to autumn (August to October). Eggs hatch in 90-120 days in the cooler late winter-early spring period, but hatch in 30-60 days in the warmer summer-autumn period. Vernasky et al. (2007) found that Illinois cave amphipods reached the immature stage in 7 – 8 months, and estimated the time to reach maturity at 14-16 months. Although they found the amphipod to live to 14-16 months, life expectancy could not be calculated. (USFWS, 2011)

Geographic or Habitat Restraints or Barriers

Adult: Lack of interconnections between cave streams (USFWS, 1997)

Environmental Specificity

Adult: Very narrow. Specialist. (NatureServe, 2015)

Site Fidelity

Adult: High (Inferred from USFWS, 1997)

Habitat Narrative

Adult: The Illinois cave amphipod is a species that lives in streams primarily in the dark zone of caves in parts of the Salem Plateau of Illinois. Little is known of the biology and habitat requirements of this species although it has been collected in mainstream gravel riffles, smaller tributary streams, rimstone pools, and from streams with silt overlying bedrock. As a group, amphipods require cool water temperatures and are intolerant of wide ranges in temperature. Limiting factors may include increased nutrient load, sedimentation, hydrologic changes and changes in water quality. (USFWS, 2002)

Dispersal/Migration

Migratory vs Non-migratory vs Seasonal Movements

Adult: Nonmigrant (NatureServe, 2015)

Immigration/Emigration

Adult: Low (inferred from USFWS, 2011)

Dispersal/Migration Narrative

Adult: This amphipod is cave-obligate and aquatic. There is no evidence of movements other than to escape high discharge rates. But during time of high water, connections forming between cave streams may allow for migration within systems. (NatureServe, 2015)

Population Information and Trends

Population Trends:

Unknown (NatureServe, 2015)

Number of Populations:

14 (USFWS, 2011)

Population Size:

1 - 1000 individuals (NatureServe, 2015)

Additional Population-level Information:

The ICA historically occurred in a 230-square-kilometer (89-square-mile) area within the Salem Plateau karst region in Monroe and St. Clair Counties, Illinois (USFWS 2002). Within this area, biologists documented ICA in the streams of 16 caves that occur in ten groundwater basins in three sub-regions between 1938 and 2014. Since biologists first documented the ICA, its range has decreased. Before its listing in 1998, biologists determined ICA had been extirpated from Stemler Cave as early as 1993. This represents extirpation from one groundwater basin and one sub-region (Table 1). From 2007 to 2014, researchers frequently monitored nine caves and observed ICA in all of these except Wednesday and Fogelpole caves (Table 1). Since 2014, only the population at Illinois Caverns has been monitored. We are uncertain of the species' status in Wednesday and Fogelpole caves and additional monitoring is needed for the other populations to confirm species persistence. Based on the uncertainties about the ICA's status at Wednesday and Fogelpole caves and limited monitoring over the last 10 years, we currently do not have enough information to determine if the ICA's range has decreased since our last status review. A map of the current range can be found at the link below. This map may be updated as new information on the species' range becomes available. (USFWS, 2025)

Population Narrative:

Generally speaking cave amphipods are intolerant of wide temperature fluctations and require cold water. They also are strongly sensitive to touch and react negatively to light (USFWS, 1997). The long-term population trend is unknown. Never considered abundant in the six caves where it has been collected. A 1995 survey by Webb found it in three caves and it constituted the following percentages of the amphipods sampled: Fogelpole Cave (5.4% = 19 specimens); Illinois Caverns (25% = 56 specimens); Kreuger-Dry Run Cave (2.9% = 2 specimens). No specimens were found in two of the caves and one cave is now inaccessible. Venarsky et al. (2007) found density in Reverse Stream Cave varied and was unusually low at times when discharge was above base flow suggesting the amphipods seek refugia from high discharge. Historically known from six caves or cave systems, but a 1995 survey by Webb found it at only three of the original six sites. It may be extant in a fourth cave but the entrance has been blocked. According to USFWS (1997), each of these caves is fed by a separate and distinct watershed or recharge area with no known interconnections with the exception of two that might become connected during high water (NatureServe, 2015). Based on the uncertainties about the ICA's status at Wednesday and Fogelpole Caves, we currently do not have enough information to determine if the ICA's range has decreased since our last status review (USFWS, 2020).

Threats and Stressors

Stressor: Contaminants
Exposure:
Response:
Consequence:
Narrative: Groundwater contamination is the primary threat. The USFWS (1997) lists the following possible contaminants: pesticides and fertilizers; bacteria from human and or animal waste, and toxic chemicals. The construction of residential and commercial buildings has increased rapidly since 1986 and this increased anthropogenic activity correlates with the degradation of groundwater quality and alteration of groundwater flow, which is thought to

contribute to the decline in populations (USFWS, 2002). Venarsky et al. (2008) conclude that populations have a high potential for recovery if disturbances (i.e. degradation of groundwater quality that leads to population declines) are removed. (NatureServe, 2015)

Stressor: Human activity in caves USFWS, 1997)
Exposure:
Response:
Consequence:
Narrative: Human utilization of cave environments is a potential threat to this species. Although some caves are protected from human intrusion, in accessible caves, habitat disturbance can cause direct injury to the habitat or even individuals because visitors must pass through the streams to access deeper passages. In addition, visitation can result in accidental or intentional introduction of materials toxic to this species or unauthorized collections. Cave ecosystems are considered to be delicate and are easily damaged, but the impact of human visitation on the amphipod is unknown. (USFWS, 1997)

Stressor: Climate change (USFWS, 2011)
Exposure:
Response:
Consequence:
Narrative: The Illinois cave amphipod has a very restricted habitat range which is intimately tied to the surface hydrology. Changes in rainfall and subsequent run-off due to climate change could directly affect Illinois cave amphipod populations. (USFWS, 2011)

Stressor: Agricultural and Residential Pesticides (USFWS, 2002)
Exposure:
Response:
Consequence:
Narrative: On the glacial till of Monroe and St. Clair Counties, a wide variety of pesticides are applied in the spring and summer. Data from studies of other amphipods show the adverse effects from agrichemicals. Bermingham et al. (1998) showed that the level of the herbicide Mecoprop to which leaves (food) had been exposed was a major factor in food choice by G. pseudolimnaeus. Soto et al. (2000) reported the rate at which 50 percent of the test group (juveniles of the marine, soft-sediment amphipod Ampelisca araucana) died from a variety of toxicants. The results range from 0.09 mg/L for a fungicide to 91.2 mg/L for a herbicide (USFWS, 2002).

Stressor: Predatory Fish (USFWS, 2020)
Exposure:
Response:
Consequence:
Narrative: In Fogelpole Cave, Lewis and Lewis (2014) documented potential threats to ICA habitat from predatory fish, detergent, and sewage or septic waste. In 2003, they observed rainwater overflowing the cave entrance washing fish into the cave stream. It is likely this overflow washed other pond species into the cave system. They observed various pond species again in 2007 and 2014. We are uncertain what the overall impacts are to the ICA and its habitat from predatory fish, detergent, and sewage or septic waste but believe they are potential threats to the species (USFWS, 2020).

Stressor: Detergent and sewage or septic waste (USFWS, 2020)
Exposure:
Response:
Consequence:
Narrative: In Fogelpole Cave, Lewis and Lewis (2014) documented potential threats to ICA habitat from predatory fish, detergent, and sewage or septic waste. In 2014, they observed the water smelled like detergent, and foam and bubbles floated on the surface. They did not detect ICA or stygobitic (groundwater adapted) animals, and they counted only one stygophilic amphipod (Gammarus troglophilus) and one Caecidotea brevicauda. They suspected that nutrient enrichment and the presence of toxin(s) were causing a decline in population sizes and an overall lack of species. Upstream from here in the cave, they noticed the stream smelled of sewage or septic waste and the presence of a microbial mat and bacterial growth on the gravel of the stream riffles. Again, they counted only one stygophilic amphipod and one Caecidotea brevicauda. We are uncertain what the overall impacts are to the ICA and its habitat from predatory fish, detergent, and sewage or septic waste but believe they are potential threats to the species (USFWS, 2020).

Stressor: non-native greenhouse millipedes (Oxidus gracilis) (USFWS, 2020)
Exposure:
Response:
Consequence:
Narrative: In 2001, Lewis and Lewis documented greenhouse millipedes throughout Wednesday Cave and were concerned this species might be toxic to ICA. They counted only two ICA, which was a decline from their previous count of nine in 1999. The greenhouse millipedes they observed in 2001 may have been an eruptive event with potentially temporary impacts to ICA since they did not note greenhouse millipedes in their subsequent surveys in 2007, 2011, and 2014. In addition, they noted a healthy population of ICA with a count of nine in 2007. We are uncertain what, if any, long-term threats greenhouse millipedes pose to ICA.

Stressor: non-native honeysuckles (Lonicera spp.). (USFWS, 2020)
Exposure:
Response:
Consequence:
Narrative: Lewis and Lewis (2015) also describe a potential threat to ICA habitat at Wednesday Cave from non-native honeysuckle species. From 2007 to 2014, they observed increasing soil erosion and siltation around and in Wednesday Cave likely caused by conversion of native vegetative species to a non-native honeysuckle monoculture. They suggest native plants retain soil but non-native honeysuckles do not, presumably due to the differences in root structure. This soil erosion led to mud slumping over the cave entrance and into the cave itself. By 2014, mud had buried the cave entrance, and they had to dig it out in order to enter the cave. Inside, they observed mud and leaves had replaced the stream habitat. They did not observe any ICA. Based on their assessment, conversion of native vegetation to non-native honeysuckles near cave entrances appears to be a threat to ICA habitat. Since only a short section of stream is accessible (Lewis 2001), we are uncertain if other sections of the stream continue to support ICA. (USFWS, 2020).

Stressor: Overutilization for commercial, recreational, scientific, or educational purposes (USFWS, 2025)
Exposure:
Response:
Consequence:
Narrative: Re-opening of Illinois Caverns For over a decade, IDNR closed public access to Illinois Caverns with the onset of white-nose syndrome in bat species. IDNR reopened public visitation to the cave on June 16, 2021, on a seasonal basis (April through October). The Service provided management recommendations to IDNR to decrease potential impacts to the ICA including cave ecosystem protection, access restrictions, visitation monitoring, and continued monitoring of the ICA population (USFWS 2021). (USFWS, 2025)

Recovery

Reclassification Criteria:
1. Five viable, stable populations in five separate groundwater basins with extant distribution in two of three sub-regions (USFWS, 2002)

2. Significant increase in use of best management practices in the groundwater recharge areas in each of the five groundwater basins. (USFWS, 2002)

Recovery Priority Number: 11C

Delisting Criteria:
1. Five viable, stable populations in five separate groundwater basins with extant distribution in two of three sub-regions (USFWS, 2002)

2. Persistent use of best management practices substantially protecting the groundwater recharge areas of the five groundwater basins. (USFWS, 2002)

Recovery Actions:
- Protect current populations and their habitats from known and suspected threats. (USFWS, 2002)
- Restore degraded habitat and reintroduce the species into historic habitats. (USFWS, 2002)
- Research basic biology and habitat requirements to increase the knowledge base about the species. (USFWS, 2002)
- Inform the public and provide technical assistance to local units of government and planning agencies. (USFWS, 2002)
- Develop a suite of best management practices designed to protect Illinois cave amphipod habitat, and the sinkholes and recharge areas that affect Illinois cave amphipod water quality in both agricultural and the increasingly urban landscape. Landowners should be contacted and provided information on the use of best management practices to protect the Illinois cave amphipod. The group could also devise a plan to reach existing and new landowners and help them to incorporate these practices. (USFWS, 2011)
- Evaluate sites where conditions are suitable for the Illinois cave amphipod and determine where and how often future surveys should be conducted. (USFWS, 2011)

- Identify sites that can be protected through land acquisition and conservation easements. (USFWS, 2011)
- Research the potential impacts of global warming on the Illinois cave amphipod. (USFWS, 2011)

Conservation Measures and Best Management Practices:

- De-silting operation: In 2018, IDNR completed de-silting operations on entrances at Fogelpole Cave in the Fogelpole Cave Nature Preserve. They used an industrial grade vacuum and high pressure water to loosen the silt. The project was successful in removing the silt blocking the cave entrance (Kath, IDNR, personal communication).
- Purchase of properties by Clifftop: In 2013, Clifftop, a not-for-profit organization, purchased 535 acres of land around the Fogelpole Cave (http://www.clifftopalliance.org/). According to their website, they plan to research and restore the area for passive recreation and wildlife, and they recognize the value of the area to the ICA and other listed and rare wildlife and plants.
- Bush honeysuckle removal: Managers removed bush honeysuckle and other invasive plants from the Armin Kruger Speleological Nature Preserve, which is privately owned (Newman, IDNR, personal communication). This effort benefits the Krueger-Dry Run Groundwater Basin.
- Additional Renault Karst land protection: The Illinois Nature Preserves Commission is working with additional landowners within the Renault Karst, specifically in the Fogelpole recharge area, towards land protection and best management practices (Newman, IDNR, personal communication).
- Closure of Illinois Caverns: IDNR has closed public access to Illinois Caverns with the onset of white-nose syndrome (Newman, IDNR, personal communication). Though the main reason for the closure is to protect bat species, the closure is likely to benefit ICA as well.
- SUMMARY: Currently, the criteria for downlisting the ICA are partially met. This criteria includes at least five viable stable populations in five separate groundwater basins. Currently, we consider ICA to be present in seven populations in seven groundwater basins, fulfilling part of the downlisting criteria. However, the counts of six of these populations have fluctuated between monitoring efforts from 2001 and 2014, so we do not consider the populations of these six caves to be stable. IDNR and conservation organizations have made efforts at some caves to improve ICA habitat, acquire land to conserve the area at and around caves, and improve management practices affecting groundwater recharge at ICA caves. However, across the ICA's range, we do not have demonstrated increase in the use of best management practices in the groundwater recharge areas affecting ICA populations in order to reduce the threat of habitat loss and degradation of groundwater quality from agriculture, rural housing, and urbanization. Furthermore, biologists have documented new threats affecting two populations that may have extirpated ICA from Fogelpole and Wednesday Caves. Based on these factors, the best scientific information currently available does not meet the criteria to downlist the species from endangered to threatened.
- RECOMMENDATIONS FOR FUTURE ACTIONS • Continue to plan and implement regular surveys that monitor ICA occurrence, groundwater quality, and habitat as well as any threats to ICA from non-natives species. • Conduct dye-tracing studies to better understand recharge areas and underground cave connections for ICA habitat. • Assess and conduct regular control of non-native species, as needed: o Assess the impact of greenhouse millipedes on ICA. o Restore habitat around the entrance to Wednesday Cave to improve soil stabilization. o Remove fish that predate the Illinois cave amphipod at Fogelpole Cave. • Seek opportunities for funding stewardship of the land purchased by conservation partners. • Coordinate with other agencies and non-governmental organizations to develop conservation strategies to alleviate threats to the ICA. o Address septic or sewage flow issues around Fogelpole Cave by conducting community outreach in those areas

affecting this cave

- Recommendations for future activities: Coordinate with other agencies and non-governmental organizations to develop conservation strategies to alleviate threats to the ICA. In addition, identify sites that can be protected through land acquisition and conservation easements and seek opportunities for funding stewardship of the land purchased by conservation partners. • 1.1. Recharge Area Protection – Agricultural • Recovery Task 1.1.1: Encourage voluntary best management practices and land use protection plans through landowner contacts using incentives from existing U.S. Department of Agriculture tools such as Environmental Quality Incentives Program (EQUIP), Conservation Reserve Program (CRP), Rural Development, and others, and promoting new programs specific to the Sinkhole Plains. • 1.2. Recharge Area Protection – Residential • Recovery Task 1.2.2.1: Encourage adequate storm water control ordinances that deal with the unique features of a karst terrain are implemented and enforced. • Recovery Task 1.2.3.1: Encourage enforcement of regulations pertaining to dumping of waste in sinkholes and other karst features. Implement a program to clean-up existing sinkholes. • Recovery Task 1.2.5: Encourage development of residential land use plans and regulations which would prevent perturbations to lands and its groundwater system. • 1.3. Cave Ecosystem Protection. • Recovery Task 1.3.2: Monitor visitation trends in selected caves containing G. acherondytes. • Recovery Task 1.3.3: Reduce the potential impacts of visitation in Illinois Caverns. • Recovery Task 1.3.4: Utilize measures to assist with controlling access to caves. Continue to plan and implement regular surveys that monitor ICA occurrence, groundwater quality, and habitat as well as any threats to ICA. • 3.1. Biology, Ecology, Life History and Habitat Requirements • Recovery Task 3.1.1: Conduct studies aimed at increasing understanding of the biology and ecology of G. acherondytes, including life history, behavior, and population level genetics. • Recovery Task 3.1.2. Assess potential adverse effects of contaminants and other water quality factors on the ICA. • 3.2. Determine the Current Range of the Species • Recovery Task 3.2.1: Conduct surveys to define the species' range. • 3.3. Monitor the Status of the Species and its Environment • Recovery Task 3.3.1: Quantitatively monitor population status of the ICA. • Recovery Task 3.3.2. Monitor and evaluate trends in land use practices. • Recovery Task 3.3.3: Monitor water quality both above ground and in shallow karst aquifers within the known range of the ICA (USFWS, 2025)
- Purchase of properties by Illinois Audubon Society In 2023, Illinois Audubon Society, a non-profit organization, purchased 18 hectares (44.5 acres) of land around the Fogelpole Cave. According to their website (see link below), they plan to protect the groundwater recharge basin that drains into the Fogelpole Cave Nature Preserve. (USFWS, 2025)

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SPECIES ACCOUNT: *Gammarus desperatus* (Noel's Amphipod)

Species Taxonomic and Listing Information

Listing Status: Endangered; 08/09/2005; Southwest Region (Region 2) (USFWS, 2016)

Physical Description

Brown-green in color with elongate, kidney-shaped eyes, and flanked with red bands along the thoracic and abdominal segments, often with a red dorsal stripe. Males slightly larger than females ranging from 8.5 to 14.8 mm (FWS, 2005). (NatureServe, 2015)

Current Range

Endemic to the Pecos River Basin from Roswell, New Mexico, south to Fort Stockton, Texas; with some extirpations recently (FWS, 2005). (NatureServe, 2015)

Critical Habitat Designated

Yes; 6/7/2011.

Legal Description

On June 7, 2011, the U.S. Fish and Wildlife Service, designate critical habitat for Noel’s amphipod (Gammarus desperatus) in Chaves county, New Mexico, under the Endangered Species Act of 1973, as amended (76 FR 33036 - 33064).

Critical Habitat Designation

The critical habitat designation for Gammarus desperatus includes three units totaling approximately 75.9 acres in Chaves County, New Mexico. The units are Sago/Bitter Creek Complex, Springsnail/Amphipod Impoundment Complex, and Rio Hondo.

Unit 1: Sago/Bitter Creek Complex: Unit 1 consists of 31.9 ac (12.9 ha) of habitat that was occupied by all four invertebrates at the time of listing and that remains occupied at the present time. The Service designates this unit as critical habitat for for all four species; it contains all of the physical and biological features essential to the conservation of these species. Unit 1 is located on the northern portion of the Middle Tract of Bitter Lake National Wildlife Refuge, Chaves County, New Mexico. The designation includes all springs, seeps, sinkholes, and outflows surrounding Bitter Creek and the Sago Springs complex. Habitat in this unit is in need of special management because of threats by subsurface oil and gas drilling or similar activities that contaminate surface drainage or aquifer water; wildfire; and nonnative fish, crayfish, snails, and vegetation. Therefore, the essential physical and biological features in this unit may require special management considerations or protection to minimize impacts resulting from these threats. The entire unit is owned by the Service.

Unit 2a: Springsnail/Amphipod Impoundment Complex: Unit 2a consists of 38.3 ac (15.5 ha) of habitat that was occupied by three of the four invertebrates at the time of listing and that remains occupied at the present time. The Service designates this unit as critical habitat for Roswell springsnail, Koster’s springsnail, and Noel’s amphipod; it contains all of the physical and biological features essential to the conservation of these species. Unit 2a is located on the southern portion of the Middle Tract of Bitter Lake National Wildlife Refuge and on property owned by the City of Roswell, Chaves County, New Mexico. This unit includes portions of impoundments 3, 6, 7, and 15, and Hunter Marsh. The designation includes all springs, seeps, sinkholes, and outflows surrounding the Refuge impoundments. Habitat in this unit is threatened by subsurface drilling for oil and gas or similar activities that contaminate surface drainage or aquifer water; wildfire; and nonnative fish, crayfish, snails, and vegetation. Therefore, the essential physical and biological features in this unit may require special management considerations or protection to minimize impacts resulting from these threats. Land ownership in this unit includes the Service and the City of Roswell, New Mexico.

Unit 3: Rio Hondo: Unit 3 consists of 5.8 ac (2.3 ha) of habitat that is currently occupied by Noel’s amphipod. The Service designates this unit as critical habitat for Noel’s amphipod only. It contains all of the features essential to the conservation of this species. The Service considers this site to be occupied by Noel’s amphipod at the time of listing. Although the amphipods were first found at this site in 2006, one year after listing (Warrick 2006, p. 1), they were taxonomically confirmed to be Noel’s amphipod in 2010 (Berg 2010, p. 1; Lang 2010, p. 1). Unit 3 is located on the South Tract of Bitter Lake National Wildlife Refuge, Chaves County, New Mexico. The designation includes all springs and seeps along approximately 0.4 mi (0.64 km) of the Rio Hondo, including the river channel and both banks. Habitat in this unit is threatened by subsurface drilling for oil and gas or similar activities that contaminate surface drainage or aquifer water; nonnative fish, crayfish, snails, and vegetation; chemical fertilizers and pesticides applied to adjacent farmland; contaminants in the Rio Hondo from upstream of the amphipod populations; and fire. Therefore, the essential physical and biological features in this unit may require special management considerations or protection to minimize impacts resulting from these threats. The entire unit is owned by the Service.

Primary Constituent Elements/Physical or Biological Features

The primary constituent element of critical habitat for Noel’s amphipod is springs and spring-fed wetland systems that:

(i) Have permanent, flowing water with no or no more than low levels of pollutants;

(ii) Have slow to moderate water velocities;

(iii) Have substrates including limestone cobble and aquatic vegetation;

(iv) Have stable water levels with natural diurnal (daily) and seasonal variations;

(v) Consist of fresh to moderately saline water;

(vi) Have minimal sedimentation;

(vii) Vary in temperature between 50– 68 °F (10–20 °C) with natural seasonal and diurnal variations slightly above and below that range; and

(viii) Provide abundant food, consisting of: (A) Submergent vegetation and decaying organic matter; (B) A surface film of algae, diatoms, bacteria, and fungi; and (C) Microbial foods, such as algae and bacteria, associated with aquatic plants, algae, bacteria, and decaying organic material.

Special Management Considerations or Protections

Critical habitat does not include manmade structures (such as buildings, aqueducts, runways, roads, and other paved areas) and the land on which they are located existing within the legal boundaries on the effective date of the rule.

Threats to the species include reducing or eliminating water in suitable or occupied habitat through drought or pumping; introducing pollutants to levels unsuitable for the species from urban areas, agriculture, release of chemicals, and oil and gas operations; fires that reduce or eliminate available habitat; and introducing non-native species into the species inhabited spring systems such that suitable habitat is reduced or eliminated.

Life History

Feeding Narrative

Adult: Because they are light-sensitive, these bottom-dwelling amphipods are active mostly at night and feed on algae, submergent vegetation, and decaying organic matter (Holsinger 1976; Pennak 1989). (USFWS, 2010)

Reproduction Narrative

Adult: Most amphipods complete their life cycle in one year and breed from February to October, depending on water temperature (Pennak 1978). (USFWS, 2010)

Geographic or Habitat Restraints or Barriers

Adult: Inhabits shallow, cool, well-oxygenated waters (USFWS, 2010)

Environmental Specificity

Adult: Medium (inferred from USFWS, 2010)

Habitat Narrative

Adult: Noel's amphipod is a small freshwater shrimp in the family Gammaridae that inhabits shallow, cool, well-oxygenated waters of streams, ponds, ditches, sloughs, and springs (Holsinger 1976, Pennak 1989). Found in warm (20-25 deg C), mineralized water; water sulfate-chloride type (principal cation Ca, anions sulfate/chloride). (USFWS, 2010; NatureServe, 2015)

Dispersal/Migration

Migratory vs Non-migratory vs Seasonal Movements

Adult: Non-migratory (NatureServe, 2015)

Dispersal

Adult: Low (inferred from USFWS, 2010)

Dispersal/Migration Narrative

Adult: Extremely limited dispersal capability effectively eliminated the ability of the amphipod to find and disperse to other suitable habitats or to move out of habitat that becomes unsuitable. (USFWS, 2010)

Population Information and Trends

Number of Populations:
5 (USFWS, 2020)

Population Narrative:
Noel's amphipod is currently found in five management units in New Mexico; Koster's springsnail is present in five units in New Mexico; Roswell springsnail is present in three units in New Mexico; and Pecos assiminea is currently found in three units in New Mexico and Texas. The distribution of each species among management units has remained stable over the past 5 years. All management units in New Mexico are located on Bitter Lake NWR. (USFWS, 2020)

Threats and Stressors

Stressor: Reduction of water in springs (USFWS, 2010)
Exposure:
Response:
Consequence:
Narrative: These four invertebrates depend on water for survival. Therefore, the loss or alteration of spring habitat continues to be the main threat to each of the four invertebrates. The scattered distribution of springs makes them aquatic islands of unique habitat in an arid-land matrix (Myers and Resh 1999). Members of the snail family Hydrobiidae (including Roswell and Koster's springsnails) are susceptible to extirpation or extinction because they often occur in isolated desert springs (Hershler 1989, Hershler and Pratt 1990, Hershler 1994, Lydeard et al. 2004). There is evidence these habitats have been historically reduced or eliminated by aquifer depletion (Jones and Balleau 1996). The lowering of water tables through aquifer withdrawals for irrigation and municipal use has degraded desert spring habitats, which the three snails and Noel's amphipod depend upon for survival. At least two historic sites for the invertebrates (South Spring, Lander Spring) are currently dry due to aquifer depletion (Cole 1981, Jones and Balleau 1996), and Berrendo Spring, historical habitat for the Roswell springsnail, is currently at 12 percent of the 1880s flow. However, during the mid-1970s, the areas currently occupied by the species continued to flow, even though groundwater pumping was at its highest rate and the area was experiencing extreme drought (McCord et al. 2007). This suggests these springs and seeps may be somewhat resilient to reduced water levels. (USFWS, 2010)

Stressor: Water contamination (USFWS, 2010)
Exposure:
Response:
Consequence:
Narrative: Water contamination, particularly from oil and gas operations, is a significant threat for these four invertebrates. In order to assess the potential for contamination, a study was completed in September 1999 to delineate the area that serves as sources of water for the springs on the Refuge (Balleau Groundwater, Inc. 1999). This study reported that the sources of water that will reach the Refuge's springs include a broad area beginning west of Roswell near Eightmile Draw, extending to the northeast to Salt Creek, and southeast to the Refuge. This area represents possible pathways from which contaminants may enter the groundwater that feeds the springs on the Refuge. This broad area sits within a portion of the Roswell Basin and contains a mosaic of Federal, State, City, and private lands with multiple land uses including expanding urban development. There are 378 natural gas and oil wells in the 12-township area encompassing the source-water capture zone for the Middle Tract of the Refuge that are

potential sources of contamination (Go-Tech 2010). The Bureau of Land Management (BLM) designated an area for protection of habitat from potential groundwater contamination by oil and gas well drilling operations (BLM 2002). This area, referred to as the habitat protection zone, includes a portion of the source-water capture area for the springs in the northern part of the Middle Tract of the Refuge, where the four invertebrate species occur. There are 17 oil and gas leases currently within this habitat protection zone. A lease does not necessarily represent a well; a lease may have approval for drilling but no wells, or it may have one or more wells. This habitat protection zone encompasses 12,585 acres (ac) (5,093 hectares [ha]) of the Federal mineral estate within the water resource area for the Refuge (Service 2005a). Twenty natural gas wells currently exist on these leases. The BLM has estimated a maximum potential development of 66 additional wells within the habitat protection zone, according to well spacing requirements established by the New Mexico Oil Conservation Division (New Mexico Statutes Annotated 1978, Chapter 70, Article 2). (USFWS, 2010)

Stressor: Fire (USFWS, 2010)
Exposure:
Response:
Consequence:
Narrative: Fire suppression efforts on the Refuge are largely restricted to established roads due to the safety hazards of transporting equipment over karst terrain. This severely limits the ability to quickly suppress fires that threaten fragile aquatic habitats on the Refuge. On March 5, 2000, the Sandhill Fire burned 1,000 ac (405 ha) of the western portion of the Refuge, including portions of Bitter Creek. The fire burned through Dragonfly Spring, a spring that feeds Bitter Creek, occupied habitat for Noel's amphipod and Koster's springsnail. The fire eliminated vegetation shading the spring and generated a substantial amount of ash in the spring system (Lang 2002, NMDGF 2005). This resulted in the formation of dense algal mats, increased water temperature fluctuations, increased maximum water temperatures, and decreased dissolved oxygen levels (Lang 2002). The prefire dominant vegetation of submerged aquatic plants and mixed native grasses within the burned area has also been replaced by the invasive common reed (Phragmites australis) (NMDGF 2005, 2008). Following the fire at Dragonfly Spring, a dramatic reduction in Noel's amphipod was observed, and Koster's springsnail presently occurs at lower densities than were observed prior to the fire (Lang 2002, NMDGF 2006a). The effects of wildfire to these four invertebrate species could be catastrophic and pose a threat to at least the Roswell and Koster's springsnails and Noel's amphipod. As such, strategically timed prescribed burns throughout their range significantly reduce fuel loads, limiting the risk of detrimental wildfires. (USFWS, 2010)

Stressor: Collection (USFWS, 2010)
Exposure:
Response:
Consequence:
Narrative: Roswell springsnail, Koster's springsnail, Pecos assiminea, and Noel's amphipod may occasionally be collected as specimens for scientific study, but these uses have a negligible effect on total population numbers. These species are currently not known to be of commercial value, and overutilization has not been documented. However, as their rarity becomes known, they may become more attractive to collectors. Although scientific collecting is not presently identified as a threat, unregulated collecting by private and institutional collectors could pose a threat to these locally restricted populations. Due to the small number of localities for the four

invertebrates, these species are vulnerable to unrestricted collection, vandalism, or other disturbance. There is no documentation of collection as a significant threat to any of the species. Therefore, we believe that collection of the animals is a minor but present threat. (USFWS, 2010)

Stressor: Predation (USFWS, 2010)
Exposure:
Response:
Consequence:
Narrative: Springsnails and amphipods are a food source for other aquatic animals. Juvenile springsnails appear vulnerable to a variety of predators. Damselflies (Zygoptera) and dragonflies (Anisoptera) have been observed feeding upon snails in the wild (Mladenka 1992). Damselflies and dragonflies are native and abundant on the Refuge and their aquatic larvae most likely prey upon both the springsnails and Noel's amphipod. The extent to which predation from nonnative fish affects population size of the three aquatic invertebrates is not known. (USFWS, 2010)

Stressor: Predation and competition (USFWS, 2010)
Exposure:
Response:
Consequence:
Narrative: Nonnative aquatic species such as crayfish, fish, and aquatic snails are also a potential threat to the four invertebrates. There are three native and three non-native species of crayfish in New Mexico, but their distributions do not overlap with that of the four invertebrates (Hobbs 1991; B. Lang, NMDGF, pers. comm., 2010). Crayfish are typically opportunistic generalists (they will eat anything and everything) (Hobbs 1991) and their predation on invertebrates is well documented (Hobbs 1991; Lodge et al. 1994; Charlebois and Lamberti 1996; Strayer et al. 1999). Additionally, because they also feed on organic debris and vegetation and reduce algal biomass (Charlebois and Lamberti 1996), they could potentially compete with Roswell springsnail, Koster's springsnail, and Noel's amphipod for food resources. Currently nonnative crayfish are not present on the Refuge or the sites in Texas. Diamond Y Springs Complex does have an undescribed native crayfish that we do not believe to be a concern for Pecos assiminea. However, crayfish have created major problems in aquatic systems in Arizona, and there is no physiological reason why some species of crayfish could not survive in the habitats that now support the four invertebrates. Eradication of crayfish once they are established is extremely difficult (Hyatt 2004). Should crayfish become established in habitats occupied by the four invertebrates, crayfish would pose a potential threat via predation and competition. Nonnative fish have had a major impact on native aquatic fauna in the southwest (Minckley and Douglas 1991; Desert Fishes Team 2003). Communities of animals evolved together and developed adaptations to deal with competition and predation from other members of the community (Meffe et al. 1994). When a nonnative species is introduced into this community, the native members often do not have defenses against predation or they may be less successful competitors. As a result, the nonnative species can have a major impact on native populations (Minckley and Douglas 1991; Meffe et al. 1994). Common carp, a nonnative species, is known to co-occur with the three aquatic invertebrates on the Refuge. Native to Asia, common carp was introduced into the United States in 1831, has become widely distributed (Sublette et al. 1990), and is present on the Refuge in habitats occupied by the invertebrates. It is an omnivore that feeds on aquatic invertebrates, fish eggs, algae, plants, and organic matter (Sublette et al. 1990). In addition, through spawning and feeding behavior it uproots vegetation and increases turbidity (Sublette et al. 1990). Because of its non-discriminatory diet and habitat disturbance, the

introduced common carp could have an impact on the three aquatic invertebrate species. (USFWS, 2010)

Stressor: Introduced species (USFWS, 2010)
Exposure:
Response:
Consequence:
Narrative: Introduced species are one of the most serious threats to native aquatic species (Williams et al. 1989, Lodge et al. 2000). Because the distribution of the four invertebrates is so limited and their habitat is so restricted, introduction of certain nonnative species into their habitat could be devastating. Building upon the list of nonnative aquatic species, such as crayfish, fish, and aquatic snails, discussed under Predation and competition in section 2.3.2.3, below is a discussion of additional nonnative plants and animals that could negatively impact the four invertebrates. Nonnative mollusks have affected the distribution and abundance of native mollusks in the United States. Of particular concern for three of the invertebrates (Noel's amphipod, Roswell springsnail, and Koster's springsnail) is the red-rim melania (Melanoides tuberculatus), a snail that can reach tremendous population sizes and has been found in isolated springs in the west. The red-rim melania has caused the decline and local extirpation of native snail species, and it is considered a threat to endemic aquatic snails that occupy springs and streams in the Bonneville Basin of Utah (Rader et al. 2003). It is easily transported on fishing boats and gear or aquatic plants, and because it reproduces asexually (individuals can develop from unfertilized eggs), a single individual is capable of founding a new population. It has become established in isolated desert spring ecosystems such as Ash Meadows, Nevada, and Cuatro Cienegas, Mexico, and within the last 15 years, the red-rim melania has become established in Diamond Y Springs Complex (Echelle 2001). It has become the most abundant snail in the upper watercourse of the Diamond Y Springs Complex (Echelle 2001). In many locations, this exotic snail is so numerous that it dominates the substrate in the small stream channel. The effect the species is having on native snails is not known; however, because it is aquatic it probably has less effect on Pecos assiminea than on the other endemic aquatic snails present in the spring. The New Zealand mudsnail tolerates a wide range of habitats, including brackish water. Densities are usually highest in systems with high primary productivity, constant temperatures, and constant flow (typical of spring systems). It has reached densities exceeding 500,000 per square meter (46,400 per square foot) (Richards et al. 2001) to the detriment of native invertebrates. Not only can it dominate the invertebrate assemblage (97 percent of invertebrate biomass), it can also eat nearly all of the algae and diatoms growing on the substrate, altering ecosystem function at the base of the food web (food is no longer available for native animals) (Hall et al. 2003). If the New Zealand mudsnail is introduced into the spring systems harboring the four invertebrates, control would most likely be impossible because the snails are so small and because any chemical treatment would also affect the native species. The impact could be devastating. (USFWS, 2010)

Stressor: Population dynamics (USFWS, 2010)
Exposure:
Response:
Consequence:
Narrative: Several biological traits have been identified as putting a species at risk of extinction (McKinney 1997, O'Grady et al. 2004). Some of these characteristics include having a localized range, limited mobility, and fragmented habitat (Noss et al. 2006, Fagan et al. 2002). The four

invertebrate species each have all of these characteristics. Having a small, localized range means that any perturbation (e.g., drought, water contamination) can eliminate the species. Having a high number of individuals at a site provides no protection against extinction. Noel (1954) noted that Noel's amphipod in Lander Spring, New Mexico was the most abundant animal present when she did her research. The species was extirpated from that site when the spring dried up (Cole 1985). Extremely limited dispersal capability effectively eliminated the ability of the amphipod to find and disperse to other suitable habitats or to move out of habitat that becomes unsuitable. Consequently, the amphipod and snails are unable to avoid pollution or other unfavorable changes to their habitat. Severe drought or wildfire, groundwater pollution and spring contamination, or spring development (impoundment, dredging, piping) could result in the extirpation or extinction of the species. (USFWS, 2010)

Stressor: Climate change (USFWS, 2010)
Exposure:
Response:
Consequence:
Narrative: The seeps and springs currently occupied by the four invertebrates have been perennial even through times of drought and increased groundwater pumping (such as in the 1970s), suggesting that these springs are relatively resilient to drought. However, climate change may test that resiliency. The Southwest may be entering a period of prolonged drought (McCabe et al. 2004, Seager et al. 2007). Seager et al. (2007) show that there is a broad consensus among climate models that the southwest will get drier in the twenty-first century and that the transition to a more arid climate is already under way. Only 1 of 19 models examined showed a trend toward a wetter climate in the southwest (Seager et al. 2007). An increase in average mean air temperature of just under 1°C (1.8 °F) has already been documented in New Mexico since 1976 (Lenart 2007). Udall and Bates (2007) found that multiple independent data sets confirm widespread warming in the west. Increased air temperatures lead to higher evaporation rates, which may reduce the amount of runoff, groundwater recharge, and consequently spring discharge. Increased temperatures across the southwest may also increase the extent of area influenced by drought (Lenart 2003), decreasing groundwater recharge regionally, thereby reducing spring discharge. Prolonged drought leading to diminishment or drying of the spring would have a negative impact on the four invertebrates. Springs would not have to dry out completely to have an adverse effect. Decreased spring flow could lead to a decrease in the amount of suitable habitat, increased water temperature fluctuations, lower dissolved oxygen levels, and an increase in salinity (MacRae et al. 2001). In addition, as water becomes increasingly scarce, conflict over its use becomes more intense. Human and cattle consumption of water would be expected to increase during drought. Any of these factors, alone or in combination, could lead to either the reduction or extirpation of the populations. Thus, climate change is a significant threat to these four invertebrate species into the foreseeable future. (USFWS, 2010)

Recovery

Reclassification Criteria:
Downlisting Criterion 1: Maintain the presence of each species in the occupied management units as of the start of this plan, with a stable or increasing average trend in density over 10 years at currently monitored management units (1 and 3). (USFWS, 2019)

Downlisting Criterion 2: Develop, implement, and fulfill a water management plan or equivalent conservation agreement, supported by the local irrigation district and other partners, that ensures adequate surface and groundwater levels to 1) sustain downlisting criteria measured by Criterion 1 above, and 2) meet or exceed BLNWR's minimum federally reserved water right flow (0.0042 m3 /s (0.15 cfs) for 10 years. (USFWS, 2019)

Downlisting Criterion 3a: Long-term commitments (Conservation Agreements etc) are in place and will continue to maintain sufficient water quality protections for 10 years, and water quality sustains each species as measured by Criterion 1 above. Downlisting Criterion 3b: Long-term commitments (Conservation Agreements etc) are in place that would specifically address the four invertebrates and reduce the risk of a catastrophic spill occurring within a drainage or recharge area occupied by any of the four invertebrates for 10 years. (USFWS, 2019)

Downlisting Criterion 4: A habitat management plan is developed and implemented that ensures that the environment remains as suitable habitat that sustains each species for 10 years. (USFWS, 2019)

The Implementation Schedule provides the estimated costs of implementing recovery actions for the first 5 years after the release of the recovery plan, as well as the total cost of recovery. Continual and ongoing costs, as well as the estimated total cost, are based on the projected timeframe of 20 years to recovery and delisting of the four invertebrates. The time estimated to downlist the four invertebrates from endangered to threatened status is 10 years, with an estimated cost of $830,000. The total cost to implement this plan through the year 2038, the estimated recovery (delisting) date for the four invertebrates, is $880,000. (USFWS, 2019)

Recovery Priority Number: 8

Delisting Criteria:
Delisting Criterion 1: Maintain the presence of each species in the occupied management units as of the start of this plan, with a stable or increasing average trend in density over 20 years in management units (1 and 3). (USFWS, 2019)

Delisting Criterion 2: Develop, implement, and fulfill a water management plan or equivalent conservation agreement, supported by the local irrigation district and other partners, that ensures adequate surface and groundwater levels to 1) sustain delisting criteria measured by Criterion 1 above, and 2) ensure that the flows in Bitter Creek as measured at the Bitter Creek Flume are greater than 0.007 m3 /s (0.25 cfs) for 20 years. (USFWS, 2019)

Delisting Criterion 3a: Long-term commitments (Conservation Agreements etc) are in place and will continue to maintain sufficient water quality protections for 20 years, and water quality sustains each species as measured by Criterion 1 above. Delisting Criterion 3b: Long-term commitments (Conservation Agreements etc) are in place that would specifically address the four invertebrates and reduce the risk of a catastrophic spill occurring within a drainage or recharge area occupied by any of the four invertebrates for 20 years. (USFWS, 2019)

Delisting Criterion 4: A habitat management plan is developed and implemented that ensures that the environment remains as suitable habitat that sustains each species for 20 years. (USFWS, 2019)

Recovery Actions:

- The actions needed to meet recovery criteria are organized below into six categories that are ranked in order of urgency: 1) ensure adequate water quantity, 2) protect and improve water quality, 3) protect and restore surface habitat, 4) design a long term monitoring strategy that will then become the post delisting monitoring plan, and 5) establish emergency captive rearing programs. These rankings are primarily based on our assessment of the scope, magnitude, and imminence of the threats impacting the four invertebrate species. Actions that address threats of higher magnitude and scope are considered more urgent compared to other actions. While this ranking will guide where we proactively focus our attention in the recovery process, it does not imply that these actions are restricted to being completed in this particular order. For example, 51 opportunities to address lower priority tasks will be considered if they arise before higher priority actions are completed (USFWS, 2018).
- Develop a recovery plan for these species. The State of New Mexico has a recovery plan that has helped guide conservation efforts; however, a recovery plan with measurable objectives and criteria needs to be developed by the Service to provide delisting goals. (USFWS, 2010)
- Continue investigation of Noel's amphipod population genetics to determine the species' status on the Refuge. (USFWS, 2010)
- Continue investigation of the effects of fire on the Pecos assiminea to determine methods of burning an occupied area while protecting the population. (USFWS, 2010)
- Secure conservation on additional lands surrounding occupied habitat to protect water quality and improve land management practices. (USFWS, 2010)
- Continue to manage Refuge lands to reduce invasive plants. (USFWS, 2010)

Conservation Measures and Best Management Practices:

- RECOMMENDATIONS FOR FUTURE ACTIONS (a) Continue investigations of survey and monitoring techniques for Pecos assiminea to better approximate density and distribution. (b) Further investigate to quantify the extent and implications gene flow between populations of Roswell and Koster's springsnail. (c) Understand the flow-ecology relationships between spring discharge and population dynamics to better understand snail movements and distribution, including seasonal variation. (d) Develop monitoring protocol for surveying for Gammarus lacustris or other amphipod species at Bitter Lake NWR. Create a field key for monitoring that will differentiate between Gammarus desperatus and other Gammarus species. (e) Identify potential translocation sites on and off Bitter Lake NWR. (f) Explore alternative conservation methods with landowners surrounding occupied habitat for the four listed invertebrates to protect water quantity/quality and improve habitat management. (g) Further investigate Noel's amphipod population genetics to determine the species status on the Bitter Lake NWR. (h) Monitor and assess the effects of fire on the Pecos assiminea to help determine the best methods of burning an occupied area while minimizing loss. (i) Reduce invasive plant species. (j) Continue monitoring springsnails and amphipods to determine abundance relationships among habitat characteristics, stream discharge, and groundwater levels. (USFWS, 2020)

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SPECIES ACCOUNT: *Lepidurus packardi* (Vernal pool tadpole shrimp)

Species Taxonomic and Listing Information

Listing Status: Endangered; September 19, 1994 (59 FR 48136).

Physical Description

Vernal pool tadpole shrimp (Lepidurus packardi), like other members of the Order Notostraca, are known as living fossils because they have changed little in appearance over roughly the last 2 million years, and resemble species found in the fossil record. The vernal pool tadpole shrimp is quite different in appearance from fairy shrimp. This species possesses a hard shell that is large, flattened, and arched over the back of the tadpole shrimp in a shield-like manner. This structure gives the tadpole shrimp its unique, tadpole-like appearance, which easily distinguishes it from the fairy shrimp. Vernal pool tadpole shrimp have 30 to 35 pairs of phyllopods, a segmented abdomen, paired cercopods or tail-like appendages, and fused eyes. Mature vernal pool tadpole shrimp range in size from 15 to 86 millimeters (0.6 to 3.3 inches [in.]) in length (USFWS 2005).

Taxonomy

The vernal pool tadpole shrimp was initially described as Lepidurus packardi. In a review of the order Notostraca, Longhurst (1955) reduced this and 18 other species to subspecies of L. apus, based primarily on the lack of apparent geographic boundaries between L. apus and L. packardi populations. Lynch (1972) resurrected L. packardi to full species status, based on further examination of specimens. This is the currently accepted taxonomic status of the vernal pool tadpole shrimp. Recent genetic analysis indicates L. packardi is a valid species (USFWS 2005). Species in the genus Lepidurus can be distinguished from members of the similar looking genus Triops by the presence of a supra-anal plate between their cercopods, which is lacking in Triops. Two other species of Lepidurus are found in California. One, the cryptic tadpole shrimp (Lepidurus cryptus), has recently been described. This species cannot be differentiated from the vernal pool tadpole shrimp by appearance, but the two species are genetically distinct. The cryptic tadpole shrimp occurs in the Great Basin and intermountain regions of northern California and southern and eastern Oregon, whereas the vernal pool tadpole shrimp occurs in the Central Valley, Delta, and eastern San Francisco Bay areas. The cryptic tadpole shrimp is not known to occur within the range of the vernal pool tadpole shrimp, as described in the listing rule. The other species, Lepidurus lemmonii, is distinguished from L. packardi by having more than 50 leg pairs (versus fewer than 40 in L. packardi), and the nuchal organ being placed behind the eyes (rather than between the eyes, as in all other Lepidurus) (USFWS 2005).

Historical Range

The vernal pool tadpole shrimp probably evolved in the Central Valley of California after colonizing large inland lakes during the Pliocene and Pleistocene, approximately 2 million years ago. From the end of the Pleistocene until the mid-1800s, the Central Valley still contained extensive seasonal wetlands, sometimes covering the entire valley. Prior to modern day agriculture, roughly 1.6 million hectares (ha) (4 million acres [ac.]) of vernal pool habitat existing in the Central Valley. Historically, the vernal pool tadpole shrimp was probably distributed over most of these vernal pool habitats. However, surveys in southern portions of California have never revealed vernal pool tadpole shrimp populations, and the species probably did not occur historically outside of the Central Valley and Central Coast regions (USFWS 2005).

Current Range

The vernal pool tadpole shrimp is currently distributed across the Central Valley of California and in the San Francisco Bay Area. The species' distribution has been greatly reduced from historical times as a result of widespread destruction and degradation of its vernal pool habitat. Vernal pool habitats in the Central Valley now represent only about 25 percent of their former area, and remaining habitats are considerably more fragmented and isolated than during historical times. Vernal pool tadpole shrimp are uncommon even where vernal pool habitats occur (USFWS 2005). The vernal pool tadpole shrimp has a patchy distribution across the Central Valley of California, from Shasta County southward to northwestern Tulare County, with isolated occurrences in Alameda and Contra Costa counties. The California Natural Diversity Database (CNDDB) currently reports 226 occurrences of vernal pool tadpole shrimp in the following 19 counties: Alameda, Butte, Colusa, Contra Costa, Fresno, Glenn, Kings, Merced, Placer, Sacramento, San Joaquin, Shasta, Solano, Stanislaus, Sutter, Tehama, Tulare, Yolo, and Yuba. Sacramento County contains 28 percent, the greatest amount, of the known occurrences (USFWS 2007).

Critical Habitat Designated

Yes; 8/6/2003.

Legal Description

On August 11, 2005, the Fish and Wildlife Service (Service), re-evaluated the economic exclusions made to the previous final rule (68 FR 46683; August 6, 2003), which designated critical habitat pursuant to the Endangered Species Act of 1973, as amended (Act), for 4 vernal pool crustaceans and 11 vernal pool plants. A total of approximately 858,846 acres (ac) (347,563 hectares (ha)) of land are now designated critical habitat. This reflects exclusion of lands from the final designation for economic reasons, pursuant to section 4(b)(2) of the Act. This designation also reflects the lands previously confirmed for exclusion under 4(b)(2) of the Act for noneconomic reasons (70 FR 11140; March 8, 2005). The non-economic exclusions include the boundaries of various Habitat Conservation Plans, National Wildlife Refuges and National fish hatchery lands (33,097 ac (13,394 ha)), State lands within ecological reserves and wildlife management areas (20,933 ac (8,471 ha)), Department of Defense lands within Beale and Travis Air Force Bases as well as Fort Hunter Liggett and Camp Roberts Army installations (64,259 ac (26,005 ha)), Tribal lands managed by the Mechoopda Tribe (644 ac (261 ha)), and the Santa Rosa Plateau Ecological Reserve (10,200 ac (4,128 ha)) from the final designation.

Critical Habitat Designation

Critical habitat for the vernal pool tadpole shrimp (Lepidurus packardi) consists of the following areas:

(1) Subunit 1A; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Shady Cove.

(2) Subunit 1B; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Shady Cove.

(3) Subunit 1C; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Shady Cove.

(4) Subunit 1D; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point and Shady Cove.

(5) Subunit 1E; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Boswell Mountain and Shady Cove.

(6) Subunit 1F; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point and Shady Cove.

(7) Subunit 1G; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point.

(8) Subunit 2A; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point.

(9) Subunit 2B; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Brownsboro and Eagle Point.

(10) Subunit 2C; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point.

(11) Subunit 2D; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point.

(12) Subunit 2E; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point.

(13) Subunit 3A; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point.

(14) Subunit 3B; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Eagle Point and Sams Valley.

(15) Subunit 3C; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Sams Valley.

(16) Subunit 4A; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Sams Valley.

(17) Subunit 4B; Jackson County, Oregon. From USGS 1:24,000 scale quadrangle Sams Valley.

(18) Subunit 5A; Siskiyou County, California. From USGS 1:24,000 scale quadrangle Timbered Crater.

(19) Subunit 5B; Modoc and Shasta County, California. From USGS 1:24,000 scale quadrangle Day, Timbered Crater.

(20) Subunit 5C; Shasta County, California. From USGS 1:24,000 scale quadrangle Dana, Burney Falls.

(21) Subunit 5D; Shasta County, California. From USGS 1:24,000 scale quadrangle Burney.

(22) Subunit 5E; Shasta County, California. From USGS 1:24,000 scale quadrangle Burney.

(23) Subunit 5F; Shasta County, California. From USGS 1:24,000 scale quadrangle Merken Bench.

(24) Subunit 5G; Shasta County, California. From USGS 1:24,000 scale quadrangle Murken Bench, Old Station.

(25) Subunit 5H; Lassen County, California. From USGS 1:24,000 scale quadrangle Poison Lake, Swains Hole.

(26) Subunit 5I; Lassen and Shasta County, California. From USGS 1:24,000 scale quadrangle Swains Hole.

(27) Subunit 5J; Lassen County, California. From USGS 1:24,000 scale quadrangle Harvey Mtn., Poison Lake, Pine Creek Valley, Bogard Buttes.

(28) Subunit 5K; Shasta County, California. From USGS 1:24,000 scale quadrangle Old Station, West Prospect Peak.

(29) Subunit 5L; Plumas County, California. From USGS 1:24,000 scale quadrangle Almanor.

(30) Subunit 6A; Shasta County, California. From USGS 1:24,000 scale quadrangle Enterprise.

(31) Subunit 6B; Shasta County, California. From USGS 1:24,000 scale quadrangle Enterprise, Cottonwood.

(32) Subunit 6C; Shasta County, California. From USGS 1:24,000 scale quadrangles Balls Ferry, Cottonwood, Enterprise, and Palo Cedro.

(33) Subunit 6D; Shasta County, California. From USGS 1:24,000 scale quadrangle Palo Cedro, Balls Ferry.

(34) Subunit 6E; Tehama County, California. From USGS 1:24,000 scale quadrangle Henleyville, Corning, West of Gerber, Gerber, Red Bluff West, Red Bluff East.

(35) Subunit 6F; Glenn and Tehama Counties, California. From USGS 1:24,000 scale quadrangle Black Butte Dam and Kirkwood.

(36) Subunit 7A; Shasta County, Tehama County, California. From USGS 1:24,000 scale quadrangle Balls Ferry.

(37) Subunit 7B; Shasta and Tehama County, California. From USGS 1:24,000 scale quadrangles Tuscan Buttes NE, Balls Ferry, Shingletown, Dales, Bend, Red Bluff East.

(38) Subunit 7C; Butte County, Tehama County, California. From USGS 1:24,000 scale quadrangles Acorn Hollow, Campbell Mound, Richardson Springs Northwest, and Vina.

(39) Subunit 7D; Butte County, California. From USGS 1:24,000 scale quadrangle Richardson Springs.

(40) Subunit 7E; Butte County, California. From USGS 1:24,000 scale quadrangle Richardson Springs.

(41) Subunit 7F; Butte County, California. From USGS 1:24,000 scale quadrangle Paradise West, Richardson Springs, Chico.

(42) Subunit 7G; Butte County, California. From USGS 1:24,000 scale quadrangle Hamlin Canyon, Chico.

(43) Subunit 7H; Butte County, California. From USGS 1:24,000 scale quadrangle Cherokee, Hamlin Canyon.

(44) Subunit 7I; Butte County, California. From USGS 1:24,000 scale quadrangle Hamlin Canyon, Shipee.

(45) Subunit 7J; Butte County, California. From USGS 1:24,000 scale quadrangle Cherokee, Oroville, Shippee.

(46) Subunit 7K; Butte County, California. From USGS 1:24,000 scale quadrangles Oroville, and Shippee.

(47) Subunit 7L; Butte County, California. From USGS 1:24,000 scale quadrangle Hamlin Canyon, Shippee.

(48) Subunit 7M; Butte County, California. From USGS 1:24,000 scale quadrangle Cherokee, Oroville, Shippee.

(49) Subunit 7N; Butte County, California. From USGS 1:24,000 scale quadrangle Oroville, Shippee.

(50) Subunit 8A; Mendocino County, California. From USGS 1:24,000 scale quadrangle Point Arena.

(51) Subunit 9A; Lake County, California. From USGS 1:24,000 scale quadrangle Kelseyville, The Geysers.

(52) Subunit 9B; Lake County, California. From USGS 1:24,000 scale quadrangle Middletown.

(53) Subunit 9C; Napa County, California. From USGS 1:24,000 scale quadrangle Capell Valley, Yountville.

(54) Subunit 10A; Colusa County, California. From USGS 1:24,000 scale quadrangle Meridian, Colusa.

(55) Subunit 10B; Yolo County, California. From USGS 1:24,000 scale quadrangles Davis, and Saxon.

(56) Subunit 10C; Solano County, California. From USGS 1:24,000 scale quadrangle Dozier.

(57) Subunit 10D; Solano County, California. From USGS 1:24,000 scale quadrangle Elmira.

(58) Subunit 10E; Solano County, California. From USGS 1:24,000 scale quadrangles Denverton, and Elmira.

(59) Subunit 10F; Solano County, California. From USGS 1:24,000 scale quadrangles Denverton, Elmira, and Fairfield South.

(60) Subunit 10G; Solano County, California. From USGS 1:24,000 scale quadrangle Fairfield South.

(61) Subunit 10H; Solano County, California. From USGS 1:24,000 scale quadrangle Fairfield South.

(62) Subunit 11A; Yuba County, California. From USGS 1:24,000 scale quadrangles Browns Valley, and Wheatland.

(63) Subunit 11B; Placer County, California. From USGS 1:24,000 scale quadrangle Lincoln.

(64) Subunit 11C; Placer County, California. From USGS 1:24,000 scale quadrangle Lincoln.

(65) Subunit 11D; Sacramento County, California. From USGS 1:24,000 scale quadrangle Folsom.

(66) Subunit 11E; Sacramento County, California. From USGS 1:24,000 scale quadrangle Carmichael.

(67) Subunit 11F; Sacramento County, California. From USGS 1:24,000 scale quadrangle Sloughhouse.

(68) Subunit 11G; Amador County, Sacramento County, California. From USGS 1:24,000 scale quadrangles Carbondale, Clay, Goose Creek, and Sloughhouse.

(69) Subunit 11H; Sacramento, San Joaquin County, California. From USGS 1:24,000 scale quadrangle Lockeford, Clay.

(70) Subunit 12A; Napa County, California. From USGS 1:24,000 scale quadrangle Napa, Cuttings Wharf.

(71) Subunit 12B; Napa County, California. From USGS 1:24,000 scale quadrangle Cuttings Wharf.

(72) Subunit 12C; Contra Costa County, California. From USGS 1:24,000 scale quadrangle Benicia, Mare Island.

(73) Subunit 13A; Contra Costa County, California. From USGS 1:24,000 scale quadrangle Antioch South, Brentwood.

(74) Subunit 13B; Contra Costa County, California. From USGS 1:24,000 scale quadrangle Byron Hot Springs, Clifton Court Forebay.

(75) Subunit 13C; Contra Costa County, California. From USGS 1:24,000 scale quadrangle Byron Hot Springs.

(76) Subunit 13D; Alameda County, California. From USGS 1:24,000 scale quadrangle Byron Hot Springs.

(77) Subunit 13E; Alameda County, California. From USGS 1:24,000 scale quadrangle Altamont, Livermore.

(78) Subunit 14A; Stanislaus County, California. From USGS 1:24,000 scale quadrangle Ripon.

(79) Subunit 14B; Merced County, California. From USGS 1:24,000 scale quadrangles Gustine, San Luis Ranch, and Stevinson.

(80) Subunit 14C; Merced County, California. From USGS 1:24,000 scale quadrangles San Luis Ranch, and Stevinson.

(81) Subunit 14D; Merced County, California. From USGS 1:24,000 scale quadrangles Arena, San Luis Ranch, Stevinson, and Turner Ranch.

(82) Subunit 14E; Merced County, California. From USGS 1:24,000 scale quadrangles Arena, and Turner Ranch.

(83) Subunit 14F; Merced County, California. From USGS 1:24,000 scale quadrangles Sandy Mush, and Turner Ranch.

(84) Subunit 14G; Merced County, California. From USGS 1:24,000 scale quadrangles Sandy Mush and Turner Ranch.

(85) Subunit 14H; Merced County, California. From USGS 1:24,000 scale quadrangle Sandy Mush.

(86) Subunit 14I; Merced County, California. From USGS 1:24,000 scale quadrangles El Nido, and Sandy Mush.

(87) Subunit 14J; Merced County, California. From USGS 1:24,000 scale quadrangle Sandy Mush.

(88) Subunit 14K; Merced County, California. From USGS 1:24,000 scale quadrangle El Nido.

[(89) omitted] (90) Subunit 14L; Merced County, California. From USGS 1:24,000 scale quadrangles El Nido, and Plainsburg.

(91) Subunit 14M; Kings County and Tulare County, California. From USGS 1:24,000 scale quadrangles Burris Park, Monson, Remnoy, and Traver.

(92) Subunit 14N; Tulare County, California. From USGS 1:24,000 scale quadrangles Alpaugh, Cocoran, and Taylor Weir.

(93) Subunit 14O; Tulare County, California. From USGS 1:24,000 scale quadrangles Alpaugh, and Pixley.

(94) Subunit 14P; Tulare County, California. From USGS 1:24,000 scale quadrangles Alpaugh, and Pixley.

(95) Subunit 14Q; Tulare County, California. From USGS 1:24,000 scale quadrangle Delano West.

(96) Subunit 15A; San Joaquin County, California. From USGS 1:24,000 scale quadrangle Peters, Farmington, Linden, Valley Springs SW.

(97) Subunit 15B; Tuolumne and Stanislaus County, California. From USGS 1:24,000 scale quadrangle Keystone, Knights Ferry.

(98) Subunit 15C; Stanislaus County, California. From USGS 1:24,000 scale quadrangles Paulsell, and Waterford.

(99) Subunit 15D; Stanislaus County, California. From USGS 1:24,000 scale quadrangle Paulsell.

(100) Subunit 15E; Stanislaus County, Tuolumne County, California. From USGS 1:24,000 scale quadrangles Cooperstown, Keystone, La Grange, and Paulsell.

(101) Subunit 15F; Stanislaus County, California. From USGS 1:24,000 scale quadrangle Paulsell.

(102) Subunit 15G; Stanislaus County, California. From USGS 1:24,000 scale quadrangles Montpelier, and Paulsell.

(103) Subunit 15H; Merced County, Stanislaus County, California. From USGS 1:24,000 scale quadrangles Cooperstown, La Grange, Merced Falls, Montpelier, Paulsell, and Turlock Lake.

(104) Subunit 15I; Merced County, California. From USGS 1:24,000 scale quadrangle Turlock Lake.

(105) Subunit 15J; Madera County, Mariposa County, Merced County, California. From USGS 1:24,000 scale quadrangles Haystack Mountain, Illinois Hill, Indian Gulch, Le Grand, Merced, Merced Falls, Owens Reservoir, Plainsburg, Planada, Raynor Creek, Snelling, Winton, and Yosemite Lake.

(105) Subunit 15J; Madera County, Mariposa County, Merced County, California. From USGS 1:24,000 scale quadrangles Haystack Mountain, Illinois Hill, Indian Gulch, Le Grand, Merced, Merced Falls, Owens Reservoir, Plainsburg, Planada, Raynor Creek, Snelling, Winton, and Yosemite Lake.

(107) Subunit 15L; Fresno County, and Madera County, California. From USGS 1:24,000 scale quadrangles Daulton, Friant, Gregg, Lanes Bridge, Little Table Mountain, and Millerton Lake West.

(108) Subunit 15M; Madera County, California. From USGS 1:24,000 scale quadrangles Millerton Lake East, and North Fork.

(109) Subunit 15N; Fresno County, California. From USGS 1:24,000 scale quadrangles Academy, and Millerton Lake East.

(110) Subunit 15O; Fresno County, California. From USGS 1:24,000 scale quadrangles Academy, Friant, and Round Mountain.

(111) Subunit 15P; Fresno County, California. From USGS 1:24,000 scale quadrangle Clovis.

(112) Subunit 15Q; Fresno County, California. From USGS 1:24,000 scale quadrangle Clovis.

(113) Subunit 15R; Tulare County, California. From USGS 1:24,000 scale quadrangles Ivanhoe, and Stokes Mountain.

(114) Subunit 15S; Tulare County, California. From USGS 1:24,000 scale quadrangles Auckland, Ivanhoe, Stokes Mountain, and Woodlake.

(115) Subunit 15T; Tulare County, California. From USGS 1:24,000 scale quadrangle Woodlake.

(116) Subunit 15U; Tulare County, California. From USGS 1:24,000 scale quadrangle Monson.

(117) Subunit 15V; Tulare County, California. From USGS 1:24,000 scale quadrangle Monson.

(118) Subunit 15W; Tulare County, California. From USGS 1:24,000 scale quadrangle Monson.

(119) Subunit 16B; Alameda County, California. From USGS 1:24,000 scale quadrangle Niles, Milpitas.

(120) Subunit 17A; San Benito, Monterey Counties, California. From USGS 1:24,000 scale quadrangle Llanada, San Benito, Hernandez Reservoir, Rock Springs Peak, Topo Valley, Hepsedam Peak, Lonoak, Pinalito Canyon, Monarch Peak, Nattrass Valley.

(121) Subunit 18A; Monterey County, California. From USGS 1:24,000 scale quadrangle Williams Hill, Jolon, Valleton, Bradley, San Miguel, Wunpost.

(122) Subunit 19A; Monterey County, California. From USGS 1:24,000 scale quadrangle Bradley, San Miguel, Wunpost, Valleton.

(123) Subunit 19B; Monterey, San Luis Obispo Counties, California. From USGS 1:24,000 scale quadrangle Bradley.

(124) Subunit 19C; Monterey, San Luis Obispo Counties, California. From USGS 1:24,000 scale quadrangle San Miguel.

(125) Subunit 19D; San Luis Obispo County, California. From USGS 1:24,000 scale quadrangle San Miguel.

(126) Subunit 19E; San Luis Obispo County, California. From USGS 1:24,000 scale quadrangle Paso Robles, and San Miguel.

(127) Subunit 19F; San Luis Obispo County, California. From USGS 1:24,000 scale quadrangle Paso Robles, Adelaida.

(128) Subunit 19G; Monterey and San Luis Obispo Counties, California. From USGS 1:24,000 scale quadrangle Creston, Paso Robles, Estrella, Ranchito Canyon, Cholame Hills.

(129) Subunit 20A; San Luis Obispo, California. From USGS 1:24,000 scale quadrangle Simmler.

(130) Subunit 21A; Santa Barbara County, California. From USGS 1:24,000 scale quadrangle Santa Ynez, Lake Cachuma, Los Olivos, Figueroa Mtn.

(131) Subunit 22A; Ventura County, California. From USGS 1:24,000 scale quadrangles Alamo Mountain, Lion Canyon, Lockwood Valley, San Guillermo, and Topatopa Mountains.

Primary Constituent Elements/Physical or Biological Features

The primary constituent elements of critical habitat for vernal pool tadpole shrimp (Lepidurus packardi) are the habitat components that provide:

(i) Topographic features characterized by mounds and swales and depressions within a matrix of surrounding uplands that result in complexes of continuously, or intermittently, flowing surface water in the swales connecting the pools described in paragraph (c)(4)(ii) of this section, providing for dispersal and promoting hydroperiods of adequate length in the pools;

(ii) Depressional features including isolated vernal pools with underlying restrictive soil layers that become inundated during winter rains and that continuously hold water for a minimum of 41 days, in all but the driest years; thereby providing adequate water for incubation, maturation, and reproduction. As these features are inundated on a seasonal basis, they do not promote the development of obligate wetland vegetation habitats typical of permanently flooded emergent wetlands;

(iii) Sources of food, expected to be detritus occurring in the pools, contributed by overland flow from the pools' watershed, or the results of biological processes within the pools themselves, such as single-celled bacteria, algae, and dead organic matter, to provide for feeding; and

(iv) Structure within the pools described in paragraph (c)(4)(ii) of this section, consisting of organic and inorganic materials, such as living and dead plants from plant species adapted to seasonally inundated environments, rocks, and other inorganic debris that may be washed, blown, or otherwise transported into the pools, that provide shelter.

Special Management Considerations or Protections

Once a vernal pool habitat has been protected from direct filling, it is still necessary to ensure that the habitat is not rendered unsuitable for vernal pool species because of factors such as altered hydrology, contamination, nonnative species invasions, or other incompatible land uses. Many of the factors that cause the decline and localized extirpation of vernal pool species can be avoided. Actions that should be avoided include the following: (1) Actions that increase competition from invasive species as many of the species addressed in this rule are threatened by invasion of nonnative species (CNDDB 2001). (2) Alteration of natural hydrology such as construction of dams or other structures that artificially increase the length of vernal pool inundation or construction of ditches that artificially drain vernal pools. (3) Human degradation of vernal pools such as off-road vehicle use, dumping, and vandalism that threatens many of the species addressed in this rule.

Life History

Feeding Narrative

Adult: Vernal pool tadpole shrimp consume aquatic invertebrates, including other species of fairy shrimp, detritus, and vegetation material. Vernal pool tadpole shrimp's food source is widely distributed throughout their environments, and vernal pool tadpole shrimp are opportunistic feeders. Growth rates are largely controlled by water temperature, and vary greatly (NatureServe 2015; USFWS 2005; USFWS 2007).

Reproduction Narrative

Adult: Vernal pool tadpole shrimp may be hermaphroditic (individuals have both male and female reproductive organs), and sex ratios can vary, perhaps in response to changes in water temperature (USFWS 2005; USFWS 2007). In response to environmental stimuli (e.g., winter rains), vernal pools and season wetlands fill with water and dormant vernal pool tadpole shrimp cysts may hatch in as little as 4 days (USFWS 2005; USFWS 2007). Vernal pool tadpole shrimp emerge from their cysts as metanauplii, a stage which lasts for 1.5 to 2 hours. They then molt into a larval form resembling the adult. Vernal pool tadpole shrimp generally take between 3 and 4 weeks, but may take nearly 2 months to mature. Reproduction begins after individuals reach 1 cm (0.4 in.) or more in carapace length, and fecundity increases with body size. Other studies have found the mean number of days to maturity to be 38.1, and the mean number of days to first reproduction to be 54.1 (NatureServe 2015). Large females, greater than 2 cm (0.8 in.) carapace length, can deposit as many as six clutches, ranging from 32 to 61 eggs per clutch, in a single wet season. Hatching of vernal pool tadpole shrimp eggs is temperature-dependent. Optimal hatching occurs between 10 to 15 degrees Celsius (°C) (50 to 59 degrees Fahrenheit [°F]), with hatching rates becoming significantly lower at temperatures above 20 °C (68 °F) (USFWS 2007). Vernal pool tadpole shrimp continue growing throughout their lives, periodically molting their shells, and have an average lifespan of 143.6 days (NatureServe 2015). Variation in growth and maturation rates may be a result of differences in water temperature, which strongly influences the growth rates of aquatic invertebrates.Additional cysts produced by adult tadpole shrimp during the wet season may hatch without going through a dormant period. Multiple hatching in the same wet season allows vernal pool tadpole shrimp to persist in vernal pools as long as these habitats remain inundated, sometimes for 6 months or more (USFWS 2005).

Geographic or Habitat Restraints or Barriers

Adult: Vernal pool tadpole shrimp are limited to their home pool. Cysts can be dispersed from dried-up pools, but survival is limited to the areas of vernal pools. Habitat destruction can remove known vernal pool occurrences.

Spatial Arrangements of the Population

Adult: Clumped according to resources.

Environmental Specificity

Adult: Narrow

Tolerance Ranges/Thresholds

Adult: Unknown (USFWS 2005)

Site Fidelity

Adult: High

Dependency on Other Individuals or Species for Habitat

Adult: Blank

Habitat Narrative

Adult: The vernal pool tadpole shrimp are found only in ephemeral freshwater habitats, including alkaline pools, clay flats, vernal lakes, vernal pools, vernal swales, and other seasonal wetlands in California (USFWS 2007). This species inhabits freshwater habitats containing clear to highly turbid water, with water temperatures ranging from 10 to 29°C (50 to 84 °F), pH ranging from 6.2 to 8.5, and surface areas ranging from 0.6 square meter to 36 ha (6.5 square feet to 88 ac.). Some of these vernal pools may be too small to remain inundated for the entire life cycle of the tadpole shrimp, but the vernal pool tadpole shrimp may be able tolerate temporary drying conditions.Throughout its range, more than 50 percent of vernal pool tadpole shrimp occurrences were on High Terrace (i.e., old terrace) landforms and Redding and Corning soils. The vernal pools that are classified as the old terrace type are located on soils associated with the Laguna geologic formation. Sacramento County represents important habitat for the vernal pool tadpole shrimp by providing large, nearly contiguous areas of relatively undisturbed, high-quality vernal pool habitat. Development in this area is leading to a loss of populations and cyst banks that act as sources of individuals to repopulate extirpated occurrences, increased urban runoff, and increased stormwater discharge into the system, which ultimately affect this entire old terrace system. Determining the vernal pool tadpole shrimp’s habitat requirements is not possible based on anecdotal evidence, and the tolerances of this species to specific environmental conditions have yet to be determined (USFWS 2005; USFWS 2007).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: Nonmigratory

Dispersal

Adult: Aquatic birds, overland flooding, rainstorms, and large mammals are also known distributors (USFWS 2007). Environmental requirements, rather than the ability or inability to disperse, are the likely limiting factor in the distribution of fairy shrimp (59 FR 48136).

Immigration/Emigration

Adult: No

Dispersal/Migration Narrative

Adult: Vernal pool tadpole shrimp are nonmigratory and have relatively little ability to disperse on their own. The primary historic dispersal mechanisms for the vernal pool crustaceans probably consisted of large-scale flooding resulting from winter and spring rains, and dispersal by migratory birds. As a result of widespread flood control and agricultural water diversion projects developed during the twentieth century, large-scale flooding is no longer a major form of dispersal for the vernal pool crustaceans. Aquatic birds are the most likely agents of dispersal. When being dispersed by migratory birds, the eggs of these crustaceans are either ingested and/or they adhere to the bird's legs and feathers, thereby being transported to new habitats. Large mammals are also known to act as distributors by wallowing in dirt, getting cysts caught in their fur, and transporting the cysts to another wallow. Because cysts can pass through the digestive systems, they can be ingested and then deposited in new habitats when the animal urinates. Cysts may also be dispersed by a number of other species, such as salamanders, toads, cattle, and humans (59 FR 48136; 68 FR 46684; USFWS 2005; USFWS 2007).Vernal pool crustaceans have low rates of gene flow between separated sites, between 0.02 and 2.61 individuals between sites per generation. The low rate of exchange between vernal pool tadpole shrimp populations is probably a result of the spatial isolation of their habitats, and their reliance on passive dispersal mechanisms (USFWS 2005).

Additional Life History Information

Adult: Vernal pool crustaceans have low rates of gene flow between separated sites, between 0.02 and 2.61 individuals between sites per generation. The low rate of exchange between vernal pool tadpole shrimp populations is probably a result of the spatial isolation of their habitats and their reliance on passive dispersal mechanisms (USFWS 2005).

Population Information and Trends

Population Trends:

Unknown (USFWS 2007)

Species Trends:

Unknown (USFWS 2007)

Number of Populations:

10 vernal pool regions (USFWS, 2024)

Population Size:

Several to several hundred individuals within any given water body (NatureServe 2015).

Resistance to Disease:

Unknown; possible parasitization by flukes (Trematoda) (USFWS 2007).

Adaptability:

Low

Additional Population-level Information:

Annual surveys have not occurred at all sites with known vernal pool tadpole shrimp occurrences. Where surveys have been conducted for vernal pool tadpole shrimp, they were designed for the purpose of determining the presence of species in the areas of proposed development or road projects, and have generally been limited in scope, focusing on a single parcel or occurrence. Surveys are generally not conducted in a manner to facilitate determination of the population trends of this species. No trends either downward or upward have been reported at any of the monitored sites; however, the accelerated loss and fragmentation of vernal pool tadpole shrimp habitat, particularly in the Southeastern Sacramento Valley Vernal Pool Region, is expected to result in markedly decreased long-term viability of this species (USFWS 2007).

Population Narrative:

Although vernal pool tadpole shrimp are spread over a wide geographic range, their habitat is highly fragmented and they are uncommon where they are found (USFWS 2007). Several to several hundred individuals can be found in any given water body (NatureServe 2015). At the time of listing in 1994, vernal pool tadpole shrimp were known from 18 populations, extending from east of Redding, Shasta County, southward to the San Luis NWR, Merced County, in the Central Valley, with a disjunct population at the San Francisco NWR, Alameda County (59 FR 48136). However, the precise location and extent of those populations and the number of counties occupied at that time are not known (USFWS 2005). There are 226 occurrences within 19 counties; however, the number of populations represented (species occurrences with a separation of greater than 0.25 mi.), is unknown. A given pool may support several to several hundred individuals within a given water body (NatureServe 2015). Annual surveys have not occurred at all sites with known vernal pool tadpole shrimp occurrences. Where surveys have been conducted for vernal pool tadpole shrimp, they were designed for the purpose of determining the presence of species in the areas of proposed development or road projects, and have generally been limited in scope, focusing on a single parcel or occurrence. Surveys are generally not conducted in a manner to facilitate determination of the population trends of this species. No trends either downward or upward have been reported at any of the monitored sites; however, the accelerated loss and fragmentation of vernal pool tadpole shrimp habitat, particularly in the Southeastern Sacramento Valley Vernal Pool Region, is expected to result in markedly decreased long-term viability of this species. Populations in the Vina Plains in Tehama County may be susceptible, as described in the 1994 final rule, to decreased fecundity due to parasitization by flukes (Trematoda) of an undetermined species (USFWS 2007). At the time of listing in 1994, the vernal pool tadpole shrimp’s distribution was described as consisting of 18 populations in the Central Valley from Shasta County in the north to Merced County in the south, as well as a single vernal pool complex on the Don Edwards San Francisco Bay National Wildlife Refuge (Figure 3). These occurrences were distributed across seven vernal pool regions. By the time of the first 5-year review in 2007, the known range of the vernal pool tadpole shrimp had been somewhat filled in throughout the Central Valley. This information does not indicate that the species is expanding its current range, but simply that greater study and surveys related to permitting pursuant to the Act have increased our knowledge of where the species can be found. In 2003, the vernal pool tadpole shrimp was documented in a single vernal pool in Contra Costa County, south of the City of Antioch. This is within the Livermore Vernal Pool Region, which brings the total number of vernal pool regions containing the vernal pool tadpole shrimp to eight. The previous 5-year review mentioned this new occurrence but did not note that this was within a new vernal pool region for the species. Also notable were the new occurrences in the southern San Joaquin Valley. The previous 5-year review discussed these occurrences as a 100-mile extension of the southern boundary of the known range. This was not quite correct as there had been two known occurrences of the vernal pool tadpole shrimp as far south as Tulare County from 1992, but the subsequent observations did sizably increase the known area occupied at the southern extent of the species range. Since the last 5-year review, the vernal pool tadpole shrimp has been identified in two new locations that are separated from previously known occurrences. One new occurrence is located in San Joaquin County near the northern border of the Southern Sierra Foothills Vernal Pool Region, and two new occurrences are located approximately 6 miles apart in Fresno and San Benito Counties in the vicinity of Mercey Hot Springs. The latter occurrences are not located within a vernal pool region, are 30 miles south of the nearest known occurrence (located along the San Luis Canal in the San Joaquin Vernal Pool Region), and the nearest vernal pool region is actually the Central Coast Region, which is approximately 7 miles north of the northernmost of the two new occurrences. Currently the only known occurrences of the vernal pool tadpole shrimp in the Central Coast Region are located 100 miles away in Alameda County. The Diversity Database notes that one of these occurrences is an unusual natural depression within otherwise steeply sloping hills, which differs from typical habitat for the vernal pool tadpole shrimp (USFWS, 2024).

Threats and Stressors

Stressor: Habitat destruction
Exposure: Conversion of habitat to agriculture, water conveyance, storage projects, population growth, and urbanization.
Response: Habitat elimination and degradation.
Consequence: Reduction in population numbers, and extirpation.
Narrative: Habitat destruction, degradation, and fragmentation are the primary threats to vernal pool tadpole shrimp. Loss of vernal pool habitat occurs due to development and lack of habitat management on lands that have been protected from development. The 1994 final listing rule stated that 14 of the 18 populations of vernal pool tadpole shrimp known at that time were imperiled by rapid urbanization, land conversion to agricultural use, off-road vehicle use, and changes in hydrologic patterns in the areas those populations occupy. Vernal pool tadpole shrimp continue to be threatened by all of the factors which led to the original listing of this species, primarily habitat loss and fragmentation through agricultural conversion and urban development, as well as by altered hydrology and inappropriate land management. The existing preserves may represent only a small percentage of the remaining vernal pool habitats, and may not be adequate to ensure the long-term viability of vernal pool tadpole shrimp. Many preserves are too small and disconnected from the larger vernal pool landscape to support hydrological function and are subject to numerous edge effects, including invasive plant species and altered site hydrology (USFWS 2007).

Stressor: Altered hydrology
Exposure: Dams, modification of watersheds surrounding pools, construction of roads, diversion of overland flow, urban development, and supplemental summer water.
Response: Shorter inundation periods, habitat elimination, vernal pool landscape reduction and fragmentation, and introduced predators.
Consequence: Mortality, reduction in population numbers, and decreased genetic diversity.
Narrative: Timing, frequency, and length of inundation of vernal pools are critical to vernal pool crustaceans. Modification of the watershed surrounding the pools can either disrupt the pools' ecosystem through allowing nonnative plants and/or opportunistic invertebrates to become

established, or eliminate the vernal pool habitat entirely. Hydrology can be altered through direct means, such as damming or construction of roads or canals, or by indirect means, such as diversions of overland flow. Either means can result in decreased runoff to vernal pool complexes, causing the pools to either not fill or to dry prematurely. Change in the upland hydrology that results in shorter inundation periods is of particular concern in vernal pools with vernal pool tadpole shrimp, because this species requires nearly 2 months to reach maturity.The hydrologic system of connectivity during flooding supports the metapopulation dynamic of recolonization of vernal pools that are subject to localized extirpation during drought years. The hydrological connectivity in this area comprises a functioning ecosystem, underlain by old terrace soils, that is characterized by one of the densest and highest quality vernal pools areas in California. As areas become increasingly urbanized, the vernal pool landscape is reduced and fragmented, and the hydrological connectivity is lost.Conversely, supplemental summer water outside of natural sources, such as from agricultural and urban development, can convert vernal pool habitats into permanent water sources, which are not appropriate for vernal pool crustaceans. Permanent water supports predators, such as bullfrog (Rana catesbeiana) adults and tadpoles, fish, and predatory insects, which can colonize vernal pool habitats. Urban runoff changes the hydroperiod of vernal pools, so that they become inundated during hot summer months when they would naturally have remained dry. Occasional summer rain does not saturate the soils overlaying hardpan and does not reduce the viability of cysts; however, chronic urban runoff does reduce the viability of vernal pool tadpole shrimp cysts and can extirpate vernal pool tadpole shrimp occurrences. Small changes in local land use, such as development of irrigated agriculture or parkland, may have considerable impacts on vernal pools, although the degree to which such changes affect pools is poorly understood (USFWS 2007).

Stressor: Inappropriate grazing regimes
Exposure: Lack of grazing and excessive grazing.
Response: See narrative.
Consequence: See narrative.
Narrative: Both lack of grazing and excessive grazing may cause an increase in organic matter in the habitat that can eliminate the natural vernal pool invertebrate community and promote opportunistic and invasive species, such as rye grass (Lolium spp.), that out-compete the obligate vernal pool species. Intensive grazing was listed as one of the threats to vernal pool tadpole shrimp in 1994, because cattle increase water turbidity, deplete the water levels in the pools, and may directly damage vernal pool tadpole shrimp cysts with their hooves. An additional threat related to grazing has been identified since the vernal pool tadpole shrimp was listed: the cessation of cattle grazing has been found to exacerbate the negative effects of invasive nonnative plants on the vernal pool inundation period. Appropriate levels of grazing may help maintain soil conditions and limit the amount of thatch accumulation near vernal pools. Increased grass cover in and around ungrazed pools may lead to an increase in evapotranspiration rates, resulting in a decreased hydroperiod. In areas where long-term grazing has been in effect, moderate grazing (in both stocking numbers and amount of time) may be an important tool in combating nonnative plant species, when burning is not an option (USFWS 2007).

Stressor: Predation
Exposure: Introduced predators in vernal pool habitat.
Response: Predation
Consequence: Mortality; population decline.

Narrative: Two introduced predators, bullfrogs (Rana catesbeiana) and mosquitofish (Gambusia affinis), are known to disperse into vernal pool habitat during the time of year when vernal pool tadpole shrimp are active. These predators are good dispersers and are found throughout the range of the shrimp. The 1994 final listing rule noted that predation of vernal pool crustaceans by nonnative bullfrogs potentially increased the threat of predation beyond that found naturally by waterfowl and other native animals. Opportunities for bullfrog dispersal into vernal pool habitats increase as additional permanent water sources are created by urban runoff and irrigated agriculture; however, the effect of such predation on the prey populations in these pools has not been determined. Vernal pool crustaceans lack predator-avoidance mechanisms, and are continuously moving their phyllopods, which may attract bullfrogs and other visual predators. Bullfrog predation of vernal pool tadpole shrimp has been documented.The use of mosquitofish to control mosquito larvae may be a new and emerging threat for the shrimp that was not identified at the time of the listing in 1994. Human diseases, including malaria, western equine encephalitis, and the West Nile Virus, are transmitted by mosquito species present within the range of the vernal pool tadpole shrimp. Mosquitofish are not native to California, but are introduced into permanent and temporary waters, including roadside ditches, rice fields, and vernal and woodland pools, to control larval mosquitoes. Small numbers of adult mosquitofish can significantly reduce abundance of fairy shrimp within 5 weeks, and could potentially be a substantial threat at sites where fairy shrimp abundance is low (USFWS 2007).

Stressor: Inadequacy of existing regulatory mechanisms
Exposure: See narrative.
Response: See narrative.
Consequence: See narrative.
Narrative: Endangered Species Act: The majority of the vernal pools covered under these biological opinions have not been surveyed, and the project proponents have simply assumed the presence of the vernal pool tadpole shrimp. Impacts to the vernal pool tadpole shrimp would not necessarily be addressed if the species were removed from protection under the federal Endangered Species Act (ESA).Similarly, if a federal agency is not involved in a proposed project, and federally listed species may be taken as part of the project, then project proponents may apply for an incidental take permit pursuant to Section 10(a)(1)(B) of ESA. The U.S. Fish and Wildlife Service (USFWS) may issue such a permit on completion of a satisfactory habitat conservation plan for the listed species that would be taken by the project.Clean Water Act: Section 404 of the Clean Water Act may afford some protection to vernal pool tadpole shrimp if it were to be delisted. The U.S. Army Corps of Engineers (USACE) interprets “the waters of the United States” expansively to include not only traditional navigable waters, but also other defined waters (including some types of wetlands) that are adjacent to or hydrologically connected to traditional navigable waters. Currently, USACE regulatory oversight of vernal pools is in doubt because of their “isolated” nature. If USACE loses its regulatory authority over vernal pools, unmitigated destruction of potential habitat for vernal pool tadpole shrimp may increase over the range of the species.National Environmental Policy Act: The National Environmental Policy Act (NEPA) (42 United States Code 4321 et seq.) requires all federal agencies to formally document, consider, and publicly disclose the environmental impacts of major federal actions and management decisions that have significant effects on the human environment. Additionally, NEPA applies only to actions by federal agencies, so private landowners are not required to comply with NEPA unless a federal agency is involved by funding or permitting a proposed project or action. Although NEPA requires public disclosure of the effects of federal actions, it does not afford direct protection to the vernal pool tadpole shrimp.Other Federal Lands:

Management plans may also provide direction for management of natural resources, including the vernal pool tadpole shrimp, on National Forests, Bureau of Land Management lands, and National Wildlife Refuge (NWR) lands. The vernal pool tadpole shrimp is present on the Sacramento NWR in Glenn and Colusa counties; the Sacramento River NWR, Llano Seco Unit, in Butte County; the Don Edwards San Francisco Bay NWR; the San Luis NWR; the San Joaquin River NWR; and the Merced NWR. The administrative draft Comprehensive Conservation Plan (CCP) for the Sacramento NWR addresses surveys and habitat management for the species. San Joaquin River NWR has completed their CCP, which addresses the vernal pool tadpole shrimp. CCPs for the Don Edwards, San Luis, and Merced NWRs, however, are either in the early stages of development or work is not yet slated to begin; therefore, on these refuges, it is not yet known how conservation of the tadpole shrimp will be addressed. On these federal lands, effects to vernal pool tadpole shrimp are addressed during Section 7 consultations with USFWS.California State Laws: The state’s authority to conserve wildlife includes the California Endangered Species Act (CESA) and the California Environmental Quality Act (CEQA). Although the vernal pool tadpole shrimp is not listed under CESA, it must be considered under CEQA as a rare species (Section 15380, Public Resources Code). CEQA (Chapter 2, Section 21050 et seq. of the California Public Resources Code) requires government agencies to consider and disclose environmental impacts of projects and to avoid or mitigate them where possible. Under CEQA, public agencies must prepare environmental documents to disclose environmental impacts of a project and to identify conservation measures and project alternatives. Through this process, the public can review proposed project plans and influence the process through public comment. However, CEQA does not guarantee that such conservation measures will be implemented (USFWS 2007).

Stressor: Random, naturally occurring events
Exposure: Random environmental fluctuations due to weather, food, or other environmental factors; fragmentation.
Response: Inbreeding depression.
Consequence: Increased risk of extinction, reduction in population numbers, and reduced fitness and fecundity.
Narrative: Stochastic (random or unpredictable) extinction and genetic bottlenecking due to the high degree of isolation and small population sizes of this species. Habitat for vernal pool tadpole shrimp continues to be highly fragmented throughout its range due to conversion of natural habitat for urban and agricultural uses. This fragmentation, along with the isolated nature of vernal pool tadpole shrimp occurrences, increases the chance of extinction for this species. Such isolated occurrences may be highly susceptible to extirpation due to chance events or additional environmental disturbance. If an extirpation event occurs in a location that is isolated or has been fragmented, the opportunities for recolonization will be greatly reduced due to physical isolation from other source occurrences (USFWS 2007).

Stressor: Contaminants
Exposure: Use of herbicides, fertilizers, and other chemicals.
Response: Water contamination, reduced dissolved oxygen, and reduction in habitat quality.
Consequence: Mortality, reduced fitness, reduction in population numbers, and behavior impairments.
Narrative: Petroleum products, pesticides, herbicides, and other chemicals can be conveyed into the vernal pool habitats by overland runoff during the rainy season, thereby adversely affecting water quality and altering the water chemistry of vernal pools (e.g., pH), which may make conditions unsuitable for vernal pool crustaceans. Many of these chemical compounds are

thought to have adverse effects on all of the listed vernal pool crustaceans and/or their cysts, with individuals being killed directly or suffering reduced fitness through physiological stress or a reduction in their food base due to the presence of these chemicals. Fertilizer contamination can lead to the eutrophication of vernal pools, which can kill vernal pool crustaceans by reducing the concentration of dissolved oxygen. Studies have shown that exposure to pesticides may include sub-lethal deleterious effects, including behavioral impairments related to foraging, movement, and predator avoidance (USFWS 2007).

Stressor: Nonnative plants
Exposure: Invasion and spread of nonnative species, proximity to residential development, and disturbed habitat.
Response: Changes in hydrology, increased thatch, oxygen depletion, and change in evapotranspiration.
Consequence: Reduction in population numbers, and reduced fitness.
Narrative: Nonnative grasses occur commonly in vernal pool complexes and have become a threat to native vernal pool species through their capacity to change pool hydrology. Nonnative grasses maintain dominance at pool edges, sequestering light and soil moisture. Italian ryegrass (Lolium multiflorum) and waxy mannagrass (Glyceria declinata) increase thatch buildup, which leads to increased oxygen depletion in the pools and contributes to the shortening of inundation periods through increased evapotranspiration, and reduces the amount of water entering the system through surface and subsurface flows.As vernal pool complexes become surrounded by residential development and disturbed habitat, the likelihood of invasion by nonnative plants increases. Nonnative plants are becoming an increasing threat to vernal pool communities. Nonnative plant species have been identified as a threat to vernal pool tadpole shrimp habitat at the Davis Communication Center Site, Yolo County; Vina Plains, Tehama County; Big Table Mountain, Fresno County; and the Sacramento Vernal Pool Preserve and Mather Field, Sacramento County (USFWS 2007).

Stressor: Climate change
Exposure: Rising global temperatures, and prolonged drought.
Response: Habitat degradation and decreased inundation periods, invasive species, fragmentation, and habitat isolation.
Consequence: Mortality, and reduction in population numbers and fitness.
Narrative: Climate change is expected to contribute to prolonged drought conditions in some part of California. The vernal pool tadpole shrimp is dependent on vernal pools that have sufficient volume to remain wet throughout the annual reproductive phase of the species, and is therefore dependent on vernal pools that hold water during drought years and especially during drought sequences. Climate change may also result in the alteration of vernal pool habitats through warmer temperatures, and greater winter precipitation and increased winter runoff, which would increase the periods and frequencies of inundation of vernal pools in the Central Valley of California. Drought-caused decreases in water depth and inundation period at vernal pools may also facilitate invasion of pools by nonnative plants and lead to altered competitive outcomes (USFWS 2007).

Recovery

Reclassification Criteria:

Accomplish habitat protection that promotes vernal pool ecosystem function sufficient to contribute to the population viability of the species, including: a. Protection of suitable vernal pool habitat in each prioritized core area for the species. For downlisting, 80 percent of the occurrences known at the time the Recovery Plan was signed should be protected. The Recovery Plan specifies criteria for protection of suitable vernal pool tadpole shrimp habitat in 24 core areas found in seven vernal pool regions; suitable habitat may be occupied or unoccupied by vernal pool tadpole shrimp. These criteria recommend that 95 percent of suitable habitat in zone 1 and 85 percent of suitable habitat in zone 2 core areas be protected range-wide. b. Protection of species localities distributed across the species geographic range and genetic range. Protection of extreme edges of populations protects the genetic differences that occur there. c. Permanent protection of additional localities, if determined essential to recovery goals. d. Habitat protection results in protection of hydrology essential to vernal pool ecosystem function, and monitoring indicates that hydrology that contributes to population viability has been maintained through at least one multi-year period that includes above-average, average, and below-average local rainfall as defined above, a multi-year drought, and a minimum of 5 years of post-drought monitoring (USFWS 2005; USFWS 2007).

Adaptive Habitat Management and Monitoring, including: a. Habitat management and monitoring plans that facilitate maintenance of vernal pool ecosystem function and population viability have been developed and implemented for all habitat protected, as previously discussed above. b. Mechanisms are in place to provide for management in perpetuity and long-term monitoring of items presented above, as previously discussed (funding, personnel, etc.). c. Monitoring indicates that ecosystem function has been maintained in the areas protected under items presented above for at least one multi-year period that includes above-average, average, and below-average local rainfall, a multi-year drought, and a minimum of 5 years of post-drought monitoring (USFWS 2005; USFWS 2007).

Status surveys, including: a. Status surveys, 5-Year status reviews, and population monitoring show that populations in each vernal pool region where the species occur are viable (e.g., evidence of reproduction and recruitment) and have been maintained (stable or increasing) for at least one multi-year period that includes above-average, average, and below-average local rainfall, a multi-year drought, and a minimum of 5 years of post-drought monitoring. b. Status surveys, status reviews, and habitat monitoring show that threats identified during and since the listing process have been ameliorated or eliminated. Site-specific threats identified through standardized site assessments and habitat management planning also must be ameliorated or eliminated (USFWS 2005; USFWS 2007).

Research, including: a. Research actions necessary for recovery and conservation of the covered species have been identified (these are research actions that have not been specifically identified in the recovery actions but for which a process to develop them has been identified). Research actions (both specifically identified in the recovery actions and determined through the process) on species biology and ecology, habitat management and restoration, and methods to eliminate or ameliorate threats, have been completed and incorporated into habitat protection, habitat management and monitoring, and species monitoring plans, and refinement of recovery criteria and actions. b. Research on genetic structure has been completed (for species where necessary – for reintroduction and introduction, seed banking) and results incorporated into habitat protection plans to ensure that in and among population genetic variation is fully representative by protected populations. c. Research necessary to determine appropriate parameters to measure population viability for each species has been completed (USFWS 2005; USFWS 2007).

Participation and outreach, including: a. Recovery Implementation Team is established and functioning to oversee range-wide recovery efforts. b. Vernal Pool Regional working groups are established and functioning to oversee regional recovery efforts. c. Participation plans for each vernal pool region have been completed and implemented. d. Vernal Pool Regional working groups have developed, and outreach and incentive programs that develop partnerships have been implemented (USFWS 2005; USFWS 2007).

Recovery Priority Number: 2C

Delisting Criteria:
The recovery plan for this species uses an ecosystem-level approach, because many of the listed species and species of concern co-occur in the same natural ecosystem and share the same threats. Major gaps in knowledge and understanding of vernal pool species and ecosystems hinder development of definitive recovery criteria. The preliminary recovery criteria in the recovery plan were designed to address these uncertainties, and strategies were developed to refine recovery criteria as recovery actions are implemented. Vernal pool branchiopod species reclassification/downlisting and delisting criteria are generalized (USFWS 2005). In addition to the reclassification criteria, delisting criteria recommend reintroduction of the species to vernal pool regions and soil types from which status surveys indicate the species has been extirpated, and requires that 100 percent of reintroduced populations be protected (USFWS 2005; USFWS 2007).

Recovery Actions:
- Protect vernal pool habitat in the largest blocks possible from loss, fragmentation, degradation, and incompatible uses (USFWS 2005).
- Manage, restore, and monitor vernal pool habitat to promote the recovery of listed species and the long-term conservation of the species of concern (USFWS 2005).
- Conduct range-wide status surveys and status reviews for all species addressed in this recovery plan to determine species status and progress toward achieving recovery of listed species and long-term conservation of species of concern (USFWS 2005).
- Conduct research and use results to refine recovery actions and criteria, and guide overall recovery and long-term conservation efforts (USFWS 2005).
- Develop and implement participation programs (USFWS 2005).
- Additional preservation of known extant occurrences is needed to reduce threats and reach recovery goals outlined in the Recovery Plan. Therefore, preservation of Zone 1 and 2 core areas should be pursued. The areas requiring the highest conservation action due to loss of habitat and/or lack of protected areas include the Northwestern Sacramento Valley (where there are limited protected areas, limited restoration possibilities, and rapid urban expansion, particularly in the Redding area); the Northeastern Sacramento Valley (where, despite the presence of some large preserves, there are limited protected areas in much of the region, a high number of sensitive species, and a high urban-conversion rate); the Southeastern Sacramento Valley (where there are limited protected areas and a high urban-conversion rate); the San Joaquin Valley (where greater emphasis on pool conservation is needed in the northeastern and southern portions of the valley); and the Southern Sierra

Foothills (where large areas of the region are being urbanized or converted to agriculture without vernal pool resource mitigation). USFWS should work with private landowners for the conservation of vernal pool tadpole shrimp through conservation easements or other methods (USFWS 2007).

- A standardized formal monitoring program should be developed and implemented to collect data in sufficient detail to evaluate species status, and examine changes in population dynamics and community composition. Monitoring should be conducted in areas with known occurrences throughout the range of this species, including revisiting historical survey sites. Many occurrences reported in the CNDDB (2007) have not been visited in more than a decade. An updated status-review of all known occurrences should be completed. In addition, a statewide vernal pool habitat mapping inventory should be implemented to quantify the actual acreage of vernal pools and acres protected (USFWS 2007).
- Research should be conducted on the extant distribution of the vernal pool tadpole shrimp, to better understand why it is absent from seemingly suitable vernal pools between areas that are known to be occupied by this species, and to understand the specifics of pools where this species occurs. Additional research should be conducted at regularly surveyed sites to incorporate research recommendations outlined in the Recovery Plan (USFWS 2007).
- Results from monitoring and research should be included in the management plans for protected sites supporting occurrences of this species. There is a need to develop management indicators for identifying potential problems and assessing ecosystem health as it pertains to vernal pool crustaceans. Requirements for appropriate management of vernal pool landscapes also must be established. Because of urban encroachment and resulting hydrological changes, conservation efforts should be focused on managing for unseasonable sources of water that infiltrate vernal pool preserves, resulting in changed site hydrology. Improved guidelines and success criteria also should be established for the monitoring of constructed and restored pools (USFWS 2007).
- Presence-absence survey guidelines should be improved. The current methodology is not always effective for documenting the presence of the species with confidence, given the species' adaptations to environmental fluctuations. Surveys, monitoring of conservation areas, and reporting should be standardized so that data can be systematically compared across sites (USFWS 2007).
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Conservation Measures and Best Management Practices:

- RECOMMENDATIONS FOR ACTIONS OVER THE NEXT 5 YEARS 1. Conduct large-scale mapping studies outside of the Central Valley to catalog all vernal pool complexes that were present in 2005 and how much still exists today. 2. Create a comprehensive database of all protected lands outside of the Central Valley and update the Central Valley database with newly protected lands since 2017. 3. Establish a Recovery Implementation Team and regional Vernal Pool Working Groups. 4. Assess how many occurrences of each species are still extant and how many are sufficiently protected to contribute to recovery criterion 1B. 5. Conduct genetics studies for the Conservancy fairy shrimp to assess the rangewide phylogeography of all known populations of the species. 6. Establish monitoring and management protocols on all protected lands to collect data that are necessary to assess if vernal pool hydrology, ecosystem function, and population viability of the three shrimp species are being maintained in perpetuity. Research may be needed to determine what data is needed to assess population viability for the three shrimp species (USFWS, 2024).

Additional Threshold Information:

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SPECIES ACCOUNT: *Lirceus usdagalun* (Lee County cave isopod)

Species Taxonomic and Listing Information

Listing Status: Endangered; 11/20/1992; Northeast Region (R5) (USFWS, 2015)

Physical Description

A small troglobytic isopod (NatureServe, 2015). Like all isopods, the Lee County cave isopod lacks a carapace, is dorsoventrally flattened, and possesses seven pairs of leg-like cephalothoracic appendages. It reaches a length of only 7.0 mm to 7.5 mm, and it lacks eyes and pigmentation (USFWS, 1997).

Taxonomy

A member of the Asellidae family. The family is represented in North America by several genera, including Caecidotea and Lirceus. Unlike most other species in this genus, Lirceus usdagalun is a troglobite (USFWS, 1997).

Historical Range

Endemic to 2 cave systems in Lee Co, VA (NatureServe, 2015).

Current Range

It has been documented as occurring in two cave systems and two springs (Surgener-Gallohan cave system, Thompson Cedar Cave, Sim's Spring, and the springs near Flanary Bridge) (USFWS, 2008).

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: Not available

Reproduction Narrative

Adult: Of 89 specimens collected between 1961 and 1971 by Dr. J.R. Holsinger and several colleagues, 72 were female and 16 were males, suggesting a female-biased sex ratio (Holsinger and Bowman 1973). Only five of the females were ovigerous or larviparous; these individuals were collected in July and August. Based on three females, the average number of eggs per female was estimated to be 27.5 (USFWS, 1997).

Geographic or Habitat Restraints or Barriers

Adult: Only occurs in subterranean environments (NatureServe, 2015)

Environmental Specificity

Adult: Very narrow (inferred from NatureServe, 2015)

Tolerance Ranges/Thresholds

Adult: Low (inferred from NatureServe, 2015)

Habitat Narrative

Adult: Found on submerged, small rocks in subterranean streams; sometimes among gravels. It is highly susceptible to water quality changes (NatureServe, 2015). The aquatic habitat of the isopod is a component of a karst ecosystem (USFWS, 1997).

Dispersal/Migration

Dispersal/Migration Narrative

Adult: Not available

Population Information and Trends

Population Trends:

Not available

Number of Populations:

4 (inferred from USFWS, 2008; see current range/distribution)

Population Size:

100,000 (USFWS, 2008)

Adaptability:

Low (inferred from NatureServe, 2015; see habitat narrative)

Population Narrative:

Based on available habitat where L. usdagalun predominated, the total population was estimated at 100,000 animals (Estes 1978) (USFWS, 2008). The LCCI had been documented from sites that occur within four discrete subterranean basins. The species is currently considered extant at nine sites within three basins including the Surgener-Gallohan Cave system, the Thompson Cedar Cave system, and the Flanary Bridge Springs system. The Sims Spring population is likely extirpated. (USFWS, 2021)

Threats and Stressors

Stressor: Development (USFWS, 2008)
Exposure:
Response:
Consequence:
Narrative: Residential and commercial development contributes sediment and contaminants to groundwater within the Cedars karst area. Several significant infrastructure developments have occurred in the Cedars, the cumulative effects of which have the potential to cause extinction (USFWS, 2008).

Stressor: Logging (USFWS, 2008)
Exposure:
Response:
Consequence:

Narrative: Logging occurs throughout the watersheds that feed into the Cedars karst area. With the exception of lands owned and protected by TNC and the DNH, all forest lands within the watersheds that feed the Cedars are in private ownership (USFWS, 2008).

Stressor: Sawmill operation (USFWS, 2008)
Exposure:
Response:
Consequence:
Narrative: A sawmill operation is located on top of the Thompson Cedar Cave system. The sawmill has operated for over twenty years within the karst watershed of Batie Creek, disposing massive amounts of sawdust in piles on its property. In 1987, the sinkhole and cave entrance of Thompson Cedar cave were completely filled with sawdust. As a result, the water quality in Thompson Cedar Cave and Batie Springs was extremely poor (USFWS, 2008).

Stressor: Agriculture (USFWS, 2008)
Exposure:
Response:
Consequence:
Narrative: Groundwater quality is clearly affected by poorly managed agricultural practices. As a result of nearby livestock activity, high levels of fecal coliform have been recorded in water from the Surgener Cave stream (USFWS, 2008).

Stressor: Vandalism (USFWS, 2008)
Exposure:
Response:
Consequence:
Narrative: Habitat for this species is particularly vulnerable to vandalism and/or unintentional disturbance from recreational cavers (USFWS, 2008).

Stressor: Toxic spills (USFWS, 2008)
Exposure:
Response:
Consequence:
Narrative: In this type of ecosystem, any single contamination event of land, surface streams, or underground caverns could rapidly contaminate springs and cave streams. Further, as development increases, the probability of unintentional toxic spills also increases (USFWS, 2008).

Recovery

Reclassification Criteria:
1. Delisting criterion 1 and 2 are completed (USFWS, 2008).

2. Monitoring programs in delisting criterion 3 and 4 have been underway for all four cave systems for at least 5 years with positive results (USFWS, 2008).

3. Delisting criterion 5 is accomplished for at least two sites (USFWS, 2008).

Recovery Priority Number: 8

Delisting Criteria:
1. Inventory work leads to a thorough delineation of the present and historic distribution for this species (USFWS, 2008).

2. The surface and subterranean hydrology within the known range of the isopod are understood sufficiently to monitor and manage the species (USFWS, 2008).

3. Populations in at least four subterranean systems are shown to be stable and persistent over a 10-year (minimal) monitoring period. For the three known extant populations, this monitoring period would begin when the following actions are completed: baseline data correlating habitat conditions with population status are gathered for the (No Suggestions) cave system; sampling techniques are finalized for the two springs at plenary Bridge and Sims Creek; and a monitoring protocol is established that provides for consistency among populations and allows inferences, if necessary, about the isopod's population status in the springs based upon comparative analysis of habitat conditions among the various cave systems. For the fourth population, the 10-year (minimal) monitoring period would begin when the previous criteria are met and either a new population is found or habitat restoration/return of a Thompson Cedar Cave population is achieved (USFWS, 2008).

4. A groundwater monitoring program is established in systems known to contain the Lee County cave isopod, with 10-year results demonstrating that groundwater quality and quantity are sufficient to ensure the survival of this species. For each system, groundwater monitoring would be conducted concurrently with the population monitoring period (USFWS, 2008).

5. Measures have been secured for the permanent protection from significant groundwater contamination of all four cave systems for the Lee County cave isopod (USFWS, 2008).

Recovery Actions:
- Conduct surveys to determine the location and extent of all areas supporting the Lee County cave isopod (USFWS, 1997).
- Monitor populations (USFWS, 1997).
- Conduct life history and other research to determine what constitutes a viable and stable population of the isopod (USFWS, 1997).
- Develop and understand the surface and subterranean drainage systems where the isopod occurs (USFWS, 1997).
- Monitor water quality and quantity and isopod habitat at selected sites, and eliminate or minimize environmental impacts on the species (USFWS, 1997).
- Implement habitat protection and, as needed, restoration measures for all populations of the isopod (USFWS, 1997).
- Conduct educational programs for the Lee County region that focus on protection of cave-karst resources (USFWS, 1997).
- If feasible and as needed, restore populations of the isopod to habitat within its historic range (USFWS, 1997).
- Implement a program to monitor recovery progress (USFWS, 1997).
- The 1997 recovery plan for the Lee County cave isopod should be revised for the following reasons: 1) More detailed information has been gathered about threats, habitat, and

populations that would inform a revised recovery strategy. 2) The Thompson Cedar Cave population has been re-re-established and is showing signs of recovery, providing significant information to modify current recovery criteria. 3) Recovery actions need to be adjusted because of new information and accomplishments. 4) Recovery criterion E needs to be re-worded to reflect a more realistic and attainable measure of recovery. 5) The five listing factors are not addressed in the recovery plan (USFWS, 2008).

- Establish and implement a population and water quality monitoring protocol that provides for consistency among populations and allows inferences, if necessary, about the isopod's population status in the springs based upon comparative analysis of habitat conditions among the various cave systems (USFWS, 2008).
- Conduct an investigation of karst resources southwest of the known populations and survey accessible cave streams to thoroughly delineate the present and historic distribution of this species (USFWS, 2008).
- Conduct a quantitative assessment of the Thompson Cedar Cave and Gallohan Cave populations and compare with historic data to evaluate the current status of the two populations (USFWS, 2008).
- Conduct a presence/absence assessment of L. usdagalun to verify its continued presence at Sim's Spring and the Flanary Bridge springs (USFWS, 2008).
- Conduct a Geographic Information System analysis to identify and quantify land cover and potential threats within each of the conservation sites identified by the DNH (USFWS, 2008).
- Continue to assist with and support land acquisition and establishment of conservation easements in The Cedars karst area, particularly with regard to expanding the Cedars State Natural Area Preserve (USFWS, 2008).
- Continue to work with partners to bate impacts to the Thompson Cedar Cave population from sawdust waste (USFWS, 2008).
- Continue to educate and work with landowners and managers to implement BMPs (USFWS, 2008).
- Continue working with the Lee County planning commission to plan development so as to minimize threats to the Lee County cave isopod (USFWS, 2008).

Conservation Measures and Best Management Practices:

- RECOMMENDATIONS FOR FUTURE ACTIONS: To address recovery Criterion D and continue recovery efforts, which include protection of habitat (Criterion E), in order to delist the LCCI, we continue to endorse recommendations 1 and 2 from our 2014 5-year review with modifications to 1. Two new recommendations (3 and 4) will provide additional information to help inform our understanding of the species' status: 1. Continue implementing recovery actions 1.1, 2.1, 5.4, 6.2 and 9 to monitor water quality and populations of the LCCI, and track recovery progress with additional focus on the following: • Conduct a presence/absence assessment of the LCCI to verify presence/extirpation at Little Sims Spring, or develop a method to test for presence in blind tributaries to Sims Spring proper. • Continue to monitor the Thompson Cedar Cave population and water quality. Recovery actions 1.1, 5.4 and 6.2 • Continue to monitor Flanary Bridge Springs system water quality. Recovery action 5.4 • Conduct qualitative monitoring of extant populations. Recovery actions 2.1 2. Continue to pursue permanent land protection for key autogenic areas. Recovery action 6.2 3. Coordinate with Dr. Julian Lewis and the 1'Université Lyon in France to analyze additional specimens from all basins, and specifically individuals from Thompson Cedar (east of Hardy Creek) and Surgener-Gallohan (west of Hardy Creek), for the ongoing molecular phylogenetics project. 4. If the Sims Spring population is extirpated, reassess the species' status using our current understanding of the populations, threats, and viability across the range. (USFWS, 2021)

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SPECIES ACCOUNT: *Orconectes shoupi* (Nashville crayfish)

Species Taxonomic and Listing Information

Listing Status: Endangered; 9/26/1986; Southeast Region (Region 4) (USFWS, 2015)

Physical Description

A pigmented crayfish with well-developed eyes. Pigmented; eyes well developed. First pleopod of male ending in two rami; central projection clearly longer. Rostral margins thickened; areola 9-10 times longer than broad and with 3-4 punctations across narrowest part. The length is 2 cm and the width is 1 cm. (NatureServe, 2015)

Taxonomy

Not Available

Historical Range

Barrociere (1986) listed 19 historical records from literature (4 rivers, many duplicate records resampled at later dates) and compiled 11 of his own survey records in Williamson and Davidson Cos. (NatureServe, 2015)

Current Range

Known from limited number of localities in Mill Creek and its tributaries in the vicinity of Nashville, Tennessee. Records outside of the Mill Creek system are thought to be 'bait bucket' introductions or misidentifications. (NatureServe, 2015)

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: As all crawfishes, essentially an opportunistic feeder that can and does act as piscivore, browsing herbivore, etc. Barrociere (1986) analyzed stomach contents and found 40.8% contained materials identifiable as plant fragments and 25.9% parts of arthropods. They are also detrivitores. Sharp increase in circadian rythym with onset of crepuscular PM. (NatureServe, 2015).

Reproduction Narrative

Adult: Late spring oviposition, probably after Fall amplexus; female broods eggs and first 3 instars below abdomen; young released early summer. Maximum life span three years with females occasionally found in greater numbers than males (Stark, 1987) (NatureServe, 2015). Reproductive activity begins in late summer and early fall (USFWS, 1989).

Geographic or Habitat Restraints or Barriers

Adult: Hydrological discontinuity (NatureServe, 2015)

Spatial Arrangements of the Population

Adult: Linear (inferred from NatureServe, 2015)

Environmental Specificity

Adult: Narrow to moderate (NatureServe, 2015)

Tolerance Ranges/Thresholds

Adult: Moderate (inferred from NatureServe, 2015)

Habitat Narrative

Adult: Inhabits moderately flowing streams with firm, usually rocky bottoms. Requires nonturbid, well-oxygenated water and clean substrate. Although it is found in freshly silted areas, Hartfield feels strongly that this is stress response because the rocky cover of riffles is covered by silt, causing more individuals to move to open water. Creeks have slope of 0.95 m/km-2.46 m/km. Study by Corps of Engineers emphasizes "living in silty areas" to permit dam and other construction. Badly needs unbiased study to eliminate Hartfield's reservation or to support it. Stark (1987) found it preferably selected large stones to hide under more often than smaller stones and inhabited non-moving water more frequently than moving water. Need for clean, high quality water strongly indicated, despite the fact that it can exist in polluted-by-silt situations. The environmental specificity is narrow to moderate. Separation barriers are based on hydrological discontinuity (NatureServe, 2015). Canopy cover appears important, as O'Bara et al. (1985) reported that all sites they sampled had canopy cover of 60 to 90 percent (USFWS, 1989).

Dispersal/Migration

Motility/Mobility

Adult: Moderate (inferred from NatureServe, 2015)

Migratory vs Non-migratory vs Seasonal Movements

Adult: Non-migratory (NatureServe, 2015)

Dispersal

Adult: Low to moderate (inferred from NatureServe, 2015)

Dispersal/Migration Narrative

Adult: This species is a good benthic walker and a good swimmer. It is non-migratory (NatureServe, 2015).

Population Information and Trends

Population Trends:

Decline of <30% (NatureServe, 2015)

Resiliency:

We measured resiliency at the population segment level for this assessment, but also report resiliency in total stream miles across the range. There are ten population segments across the range of the Nashville crayfish. Currently, six of these population segments display high resilience (145 stream miles); two moderate resilience (20 stream miles); and two low resilience (26.5 stream miles) (USFWS, 2017b).

Representation:

We lack genetic and ecological diversity data to characterize representation for Nashville crayfish. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics across the geographical range. Thus, we characterized representative units (MC-A, MC-B, and MC-C) by using physical stream hydrology. Differences in hydrology in these three areas could result in differences in the species to adapt to changing environmental conditions. Because the mainstem population segment crosses representative unit boundaries, we report representation as the percentage of stream miles categorized as low, moderate, and high, within each representative unit. Current representation is high because the majority of stream mileage in each representative unit is of high resilience (USFWS, 2017b).

Redundancy:

There are 10 population segments distributed across the range of the Nashville crayfish within all representative units. Six of these population segments are highly resilient; two population segments are moderately resilient; and two population segments are low resilience. Currently, there appears to be adequate redundancy for Nashville crayfish to withstand catastrophic events, although the species range is relatively small (i.e. limited to Mill Creek watershed) (USFWS, 2017b).

Number of Populations:

1 - 20 (NatureServe, 2015)

Population Size:

2500 - 100,000 individuals (NatureServe, 2015)

Adaptability:

Moderate (inferred from NatureServe, 2015)

Population Narrative:

Seems to be a 'hardy beast' (Fridell, J. pers. comm. 1995), with a broad niche (Stark, 1987). Despite the dominance of this species in its limited range, there exists vast expanses of bedrock in the Mill Creek basin which do not support any crayfish, so available habitat is limited. The area exists in an urban region that continues to grow and expand southward around the main stem of the creek (Bouchard, 1984). Although it may appear that the species is extremely hardy, persisting in a drainage that is undergoing increasing development pressure, it is likely that it is being concentrated into the remaining areas of suitable habitat left in the Mill Creek drainage. There has been no documented decline of the Nashville crayfish since it was located in the early eighties. Seems to be maintaining itself in areas of the main channel of the Mill Creek that are not heavily polluted and where it is the dominant species. This species has experienced a long-term decline of <30% to increase of 25%. The range extent of this species is 100 - 400 square miles, with an estimated population size of 2,500 - 100,000 individuals. There may be up to 20 occurrences, with 4 - 12 having good viability/integrity. It is moderately vulnerable (NatureServe, 2015).

Threats and Stressors

Stressor: Water quality deterioration (USFWS, 1989)
Exposure:
Response:
Consequence:
Narrative: The Nashville crayfish is endangered by water quality deterioration from development within the watershed. According to a U.S. Army Corps of Engineers' (Corps) report (Corps 1984), about 40 percent of the Mill Creek watershed has been developed. The lower watershed lies within the highly urbanized Nashville, Tennessee, metropolitan area. The Corps (1981) concluded that the uppermost segment of Mill Creek was degraded by organic enrichment and had very poor water quality. Threats to the species could also come from other activities in the watershed such as road and bridge construction, stream channel modifications, impoundments, land use changes, and other projects, if such activities are not planned and implemented with the survival of this geographically restricted species in mind. The Nashville crayfish's restricted range makes it very vulnerable to a single catastrophic event such as a chemical spill. The Corps (1984) reported that occasional spills and discharges have occurred along Mill Creek in the past (USFWS, 1989).

Recovery

Reclassification Criteria:
3. The species and its habitat in the Mill Creek system and one other system are protected from human-related and natural threats that would be likely to cause the species' extinction in the foreseeable future (USFWS, 1989).

1. Through protection of the existing Mill Creek basin population and by reintroduction of the species into some as yet unknown historic habitat or by discovery of an additional distinct population, there exist two distinct viable populations (USFWS, 1989).

2. A newly discovered or reintroduced population must (a) have been established or be self-sustaining for a minimum of 10 years without augmentation from an outside source, (b) represent a significant component of the crayfish fauna throughout most of that creek, and (c) be stable or increasing in numbers and range (USFWS, 1989).

Recovery Priority Number: 11C

Delisting Criteria:
Not available

Recovery Actions:
- Preserve Mill Creek population and presently occupied habitat of the Nashville crayfish (USFWS, 1989).
- Search for additional populations and/or historic habitat suitable for reintroduction efforts (USFWS, 1989).
- Develop a reintroduction plan and reintroduce the Nashville crayfish into suitable stream reaches that are determined to have been historic habitat (USFWS, 1989).
- Develop and implement a program to monitor population levels and habitat conditions of the presently established population as well as any introduced or newly discovered populations (USFWS, 1989).

- Annually assess overall success of the recovery program and recommend such actions as changing recovery objectives, delisting, continuing to protect, implementing new measures, and initiating other studies (USFWS, 1989).
- RECOMMENDATIONS FOR FUTURE ACTIONS: 1. Develop objective, and measurable recovery criteria, taking into account evidence that the Nashville crayfish is endemic to the Mill Creek drainage and highly resilient to perturbation. 2. Conduct studies to determine the extent to which Nashville crayfish can survive and perpetuate itself in man-made ponds similar to habitats where the species has been previously collected. If the results of such research indicate that the species could utilize such habitat, investigate the feasibility of establishing Nashville crayfish in man-made retention ponds adjacent to streams in the Mill Creek drainage. If implemented, the ponds should be protected from water quality degradation and other human intrusion to the maximum extent possible. 3. Continue to work with the USACE, TDEC, and municipal and county governments to incorporate protective measures for the Nashville crayfish and its habitat into permits issued for development activities in the Mill Creek drainage. 4. Continue working with representatives at the Nashville Zoo and other partners to develop outreach and educational programs to promote pride in Mill Creek and protection of the Nashville crayfish among the residents in the drainage. 5. Continue support for partners implementing a long-term monitoring program for the species. Track trends in numbers, distribution, and recruitment of the species in relation to development in the drainage. In addition to providing trend data, this would provide the basis for post-delisting monitoring should the species reach recovery. 6. Investigate the extent to which the Nashville crayfish is being exploited for food and bait. 7. Conduct research to determine if urbanization in the Mill Creek drainage is resulting in elevated numbers in populations of potential predator species (e.g., raccoons, muskrats). Determine if predation on Nashville crayfish is increasing as a result. 8. Work with developers in the Mill Creek drainage to reduce indirect impacts to the streams during development and encourage them to include protection of riparian zones and establishment of green space in future developments in the drainage. 9. Evaluate lands critical to the survival of the species in priority segments of the watershed and work with land trusts and similar organizations to provide incentives for conservation. 10. Evaluate underutilized, previously developed riparian areas for restoration and enhancement. 11. Work directly with MNAA regarding potential enhancements to lands and streams under its control but outside the regular EPA and TDEC regulatory framework. 12. Work directly with Metro Nashville Parks to ensure that uses associated with their lands in the Mill Creek watershed are conducive to protection of the Nashville crayfish, and assist evaluation of additional land parcels that could be brought under their stewardship (USFWS, 2017a).
- Not available

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SPECIES ACCOUNT: *Pacifastacus fortis* (Shasta crayfish)

Species Taxonomic and Listing Information

Listing Status: Endangered; October 31, 1988 (53 FR 38460).

Physical Description

Shasta crayfish (Pacifastacus fortis) are small- to medium-sized crayfish that may reach 25 to 50 millimeters (mm) (1 to 2 inches [in.]) in total length of the carapace (the shell covering the back over the walking legs). The color is variable and may range from dark brownish-green to dark brown on the topside and bright orange on the underside. Occasional blue-green to light blue individuals are found in isolated populations. These blue crayfish have a light salmon color on their undersides. Members of the Fall River population are dark orange-brown on the topside and bright red on the underside, especially on the chelae (pinchers). These colors (except the blue) provide camouflage for the crayfish among the volcanic rubble substrates of its habitat. Shasta crayfish adults are sexually dimorphic and can easily be distinguished because the males have narrower abdomens and larger chelae than the females. The first two pairs of swimmerets (tiny swimming legs) of the males are hard and modified for sperm transfer to the female during mating. These notable sexual characteristics can be seen in young larvae that are less than 11 mm (0.4 in.) in total carapace length (53 FR 38460; USFWS 1998).

Taxonomy

The Shasta crayfish is a decapod (ten-footed) crustacean of the family Astacidae. Shasta crayfish have a toothed (denticulate) margin on the rostrum (anterior prolongation of the head). In signal crayfish (Pacifastacus leniusculus), the rostrum has three parts or protrusions (tripartite rostrum). The inside margin of the chelae (claw) of the Shasta crayfish is smooth, while the chelae of the signal crayfish is notched. The absence of patches of bristles (setal patches) on their claws separate Shasta crayfish from Pacifastacus connectens (native to Idaho, northern Nevada, northern Utah, and eastern Oregon) and Pacifastacus gambelii (a northern Rocky Mountains/Great Basin species). Shasta crayfish have shorter and thicker claws than the sooty crayfish (Pacifastacus nigrescens), whose claws are long and narrow (USFWS 1998).

Historical Range

The historical range of the Shasta crayfish is assumed to have been restricted to cold, clear spring water with rocky substrate found in the Pit River drainage in northeastern Shasta County, California, with its distribution more or less continuous throughout Fall River, Tule River, Hat Creek, Rising River, and the segment of the Pit River that joins these drainages (upstream of Fall River Mills) (USFWS 2009). It was described in 1898 from the Fall River at Fall River Mills and Hat Creek at Cassel, with subsequent collections from the Fall River system in 1934, 1964, and 1973 to 1974; with collections in 1975 from all three river systems (headwaters of the Fall River, Sucker Springs Creek on the Pit River, Crystal Lake on Hat Creek). In 1978 to 1980 it was found in numerous locations in the Fall River system, including the type locality as well as Sucker Springs Creek and the Pit River, and in Crystal, Baum, and Rising River lakes in the Hat Creek system (NatureServe 2015).

Current Range

Shasta crayfish is found only in Shasta County, California, in the Pit River drainage and two tributary systems—the Fall River and Hat Creek subdrainages. The limits of its current range appear to be relatively unchanged from its historical range, though its distribution within its range is considered more fragmented than it was historically (USFWS 2009). In the Hat Creek subdrainage, populations have been found in Lost Creek and in Crystal, Baum, and Rising River Lakes. In the Fall River subdrainage, populations occur in the following bodies of water: Fall River; Big Lake (Horr Pond); Bit Tule River; Spring, Mallard, Squaw, and Lava creeks; and Crystal, Thousand and Rainbow springs (53 FR 38460; USFWS 2009).

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: Shasta crayfish are opportunistic detritivores, grazers, and carnivorous feeders that may consume aquatic invertebrates, periphyton, and dead fish as well as other possibly unknown food sources. Other potential food resources include trout, sucker, and sculpin eggs, which are seasonally abundant. The species needs cold, clear, well-oxygenated water with lava rocks in slow-flowing water and lakes. They probably feed mostly at night, with individuals only appearing during the day when their hiding location has been disturbed or when they are ill. Two nonnative invasive crayfish species, signal crayfish (Pacifastacus leniusculus) and virile crayfish (Orconectes virilis), compete with the Shasta crayfish for food resources and are a major threat to the survival of the species. Although some of the items Shasta crayfish will consume are known, nothing is known about their actual nutritional requirements. Individuals grow approximately 1 to 3 mm (0.04 to 0.12 in.) per molt, which is substantially slower than both invasive crayfish species (53 FR 38460; NatureServe 2015; USFWS 1998).

Reproduction Narrative

Adult: Mating occurs in September and October, when the male deposits a capsule containing sperm (spermatophore) on the underside of the female near her genital opening at the base of the fourth pair of walking legs. The female lays 10 to 70 eggs, which she fertilizes with sperm from the spermatophores and then attaches to the underside of her abdomen or tail. The fertilized eggs are extruded from October to November, and then incubated on the female for 1 to 2 months (at latest until late May). When they hatch into immature larval forms, the first instars remain attached to the underside of her abdomen by threads to the inner egg membrane. These molt into second instars, miniatures of the adult that clasp the female with their tiny claws. After a second molt, the third instars reach a total carapace length of 5 to 7 mm (0.20 to 0.27 in.) and gradually become free-living in mid to late July. The sex ratio for the species is 1:1, and their lifespan is from 10 to 15 years. Individuals mate once per season. Females do not reach sexual maturity until their fifth year, at a size of 27 mm (1 in.) (USFWS 1998; NatureServe 2015).

Geographic or Habitat Restraints or Barriers

Adult: Separation barriers are based on hydrological discontinuity. Additional physical barriers, particularly for secondary and tertiary burrowers, include the presence of upland habitat between water connections of a distance greater than 30 meters (m) (98.5 feet [ft.]) (NatureServe 2015).

Spatial Arrangements of the Population

Adult: Clumped

Environmental Specificity

Adult: Narrow/specialist.

Tolerance Ranges/Thresholds

Adult: Low

Site Fidelity

Adult: Moderate

Habitat Narrative

Adult: Shasta crayfish are benthic (bottom-living) invertebrates that occur in cool, clear, spring-fed lakes, rivers, and streams, usually at or near a spring inflow source, where waters show relatively little annual fluctuation in temperature and remain cool during the summer. Most are found in lentic and slowly to moderately flowing waters such as at Tule River, Little Tule River, and lower Fall River (below the mouth of Tule River)—variable-temperature, slow-moving, low-gradient rivers, characterized by seasonal variations in temperature (5 to 23 degrees Celsius [41 to 73 degrees Fahrenheit]) and turbidity, with warm eutrophic water (nutrient-rich and low in oxygen) in the summer. These rivers are moderately wide, with an average depth of 2.5 to 3.0 m (8 to 10 ft.). The substrate in these rivers is predominantly silt and fine organic matter. Although there is little to no natural lava substrate, some lava was imported into these rivers for levee maintenance and bridge construction. Although Shasta crayfish have been observed in groups under large rocks situated on clean, firm sand or gravel substrates, they also have been observed on a fine, probably organic, material 1 to 3 cm (0.4 to 0.5 in.) thick, on the bottom of Crystal Lake. Shasta crayfish is most abundant where plants are absent. Another important habitat requirement appears to be the presence of adequate volcanic rock rubble to provide escape cover from predators. Habitat for these creatures is primarily separated according to each species' burrowing ability, with exotic crayfish being more adept than Shasta crayfish and therefore having a greater habitat range (53 FR 38460; NatureServe 2015).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: Nonmigratory

Dispersal

Adult: Limited; not known to move great distances.

Immigration/Emigration

Adult: No; populations are geographically isolated (USFWS 1998).

Dependency on Other Individuals or Species for Dispersal

Adult: Typically solitary, but will tolerate other crayfish if habitat is limited. The expansion of nonnative crayfish has increased, causing stretches of unsuitable habitat and creating hostile barriers to Shasta crayfish movement (USFWS 2009).

Dispersal/Migration Narrative

Adult: Although Shasta crayfish are not known to move great distances from their habitat and are not strong swimmers, they have dispersed into and colonized new areas when habitat was created by the addition of lava substrate, such as around bridge abutments and the levees in the upper Tule River subdrainage (upper Tule River refers to the section of river that widens around Horr Pond and continues to Big Lake). Many of the disjunct populations of Shasta crayfish are isolated not only by distance, but by natural barriers or by manmade barriers, such as hydroelectric development. Individuals are typically solitary, but will tolerate other crayfish if habitat is limited. The expansion of nonnative crayfish has increased, causing stretches of unsuitable habitat and creating hostile barriers to Shasta crayfish movement (USFWS 1998).

Additional Life History Information

Adult: Shasta crayfish do not migrate and are not strong swimmers (NatureServe 2015).

Population Information and Trends

Population Trends:

Most populations in decline, some are relatively stable.

Species Trends:

Decline; determined to be at least 50 percent in the last 10 years, and continuing to decline (NatureServe 2015).

Population Growth Rate:

Decline of at least 50 percent (NatureServe 2015).

Number of Populations:

Six to 20 (NatureServe 2015). At the time of listing in 1988, the Shasta crayfish was separated into eight geographically isolated subpopulations (USFWS 2009).

Population Size:

~610 (USFWS, 2023)

Adaptability:

Low

Additional Population-level Information:

The first genetic study on Shasta crayfish was initiated in 2004. Preliminary findings indicate that there is a fair amount of variation among subpopulations. Three different genetic clusters were identified: Crystal Lake; the Big Lake group, which includes Big Lake Springs, Ja She, Lava, and Springs creeks; and Thousand Springs (USFWS 2009).Overall, Shasta crayfish populations have declined since listing. The first systematic survey for the species documented crayfish occupation in 14 of 16 locations that were surveyed. The approximate population size of fewer than 6,000 individuals was estimated for the 14 locations. At the time of listing, Shasta crayfish occupied approximately 80 percent of the sites surveyed; this occupation rate is down to 58 percent. The sex ratio for the species remains essentially equal, but the age class distribution is now biased toward adults, indicating a decreased survival of smaller age class crayfish (USFWS 2009).

Population Narrative:

The distribution of Shasta crayfish has become patchier because large areas of lava substrate have become unavailable to Shasta crayfish during this century as a result of habitat alterations (e.g., excavations, impoundments, water diversions, and sedimentation) and the colonization of lava substrate by introduced crayfish. The overall species is in severe decline, with approximately 50 percent of the species lost in the last decade and the population continuing to decline. At the time of listing in 1988, the Shasta crayfish was separated into eight geographically isolated subpopulations. It is estimated that 2,500 to 100,000 individuals remain. The first systematic survey for the species documented crayfish occupation in 14 of 16 locations that were surveyed. The approximate population size of fewer than 6,000 individuals was estimated for the 14 locations. At the time of listing, Shasta crayfish occupied approximately 80 percent of the sites surveyed; this occupation rate is down to 58 percent. The sex ratio for the species remains essentially equal, but the age class distribution is now biased toward adults, indicating a decreased survival of smaller age class crayfish (USFWS 2009).Based on surveys from the mid 1990's the species is most abundant in the spring tributaries to the Fall River, with lower densities at springs feeding Big Lake and Horr Pond, and Pit River and Hat Creek tributaries. As of 2008, the Thousand Springs above barrier (greater than 200) and Rainbow Spring (fewer than 10) populations in the upper Fall River were stable. Populations in the upper (greater than 100) and lower (greater than 10) coves in Spring Creek were possibly stable. Lava Creek's population (fewer than 20) was in decline. The Ja She Creek headwaters population (greater than 50) was possibly stable, and the Crystal Springs Cove inlet (fewer than 10) and Tule Coves (fewer than 10) in upper Tule River (Ja She Creek) populations were in decline. All of upper Tule River (upper Big Lake) was in decline, with Big Lake Springs having fewer than 50 individuals, north Big Lake having fewer than 10 individuals, and northeast and northwest Big Lake each having one individual. The populations of the upper Tule River (levee system) varied in status, the south shore of Big Lake (fewer than 10) and northeast upper Tule River (0) were both in decline, and the population in the south shore upper Tule River (fewer than 20) was stable. All of the Pit River is in decline, with only Sucker Springs (10) having any individuals. In Hat Creek, the population in southwest Crystal Lake (greater than 100) was possibly stable, in Crystal Lake outflow (fewer than 10) was declining, and both Crystal Lake middle cove (0) and Baum Lake at Crystal Lake inflow (0) were in decline. The Rising River has not been surveyed since 1995, with the midstream, footbridge, and southern populations having fewer than 10 individuals and the outflow population having fewer than 30 individuals. The first genetic study on Shasta crayfish was initiated in 2004. Preliminary findings indicate that there is a fair amount of variation among subpopulations. Three different genetic clusters were identified: Crystal Lake; the Big Lake group, which includes Big Lake Springs, Ja She , Lava, and Springs creeks; and Thousand Springs (USFWS 1998, 2009; NatureServe 2015). In 2022, it was estimated only 610 Shasta crayfish remain and most of the Shasta crayfish populations are declining as signal crayfish populations continue to invade Shasta crayfish habitat (see Table 1). In the past, Spring Creek had the largest Shasta crayfish population and supported 4,500–5,000 individuals (Forestry Department 1993, p. 30). Currently, the Spring Creek population has roughly 300 individuals and will likely continue to decline in the future (see Table 1; Urlie in litt. 2023, p. 1). Shasta crayfish subpopulations such as the ones in Tule River, Big Lake, or Fall River Pond, for example, do not have recent Shasta crayfish sightings and may be extirpated. However, it is possible Shasta crayfish still exist within these locations, thus, these locations are not considered extirpated (see Table 1; Ellis in litt. 2023 p. 20). Translocating Shasta crayfish to refugia free of signal crayfish may increase the overall abundance of Shasta crayfish and prevent extinction (Service 2015a, p. 3). Furthermore, current access to suitable habitat is limited, thus future access to private property to survey for Shasta crayfish may provide a more accurate evaluation of species abundance (USFWS, 2023).

Threats and Stressors

Stressor: Development/agriculture
Exposure: Development and agriculture destroy and fragment crayfish habitat.
Response: Populations are fragmented and become disjunct.
Consequence: Reduction in population/population extirpation.
Narrative: Development and agriculture pose a major threat to Shasta crayfish and their habitat. These activities include diking, dredging, water diversion projects, hydroelectric projects, agricultural development, water impoundments, and increased residential development. All these habitat modifications seem to favor the two exotic species, which have a great reproductive advantage over the Shasta crayfish. Continued habitat loss and degradation present substantial threats to the existence of this crayfish. The loss of lava substrate in historic times has restricted the dispersal of Shasta crayfish, isolated subpopulations, and created disjunct populations (USFWS 1998).

Stressor: Predation
Exposure: Nonnative and native species may prey on Shasta crayfish.
Response: Shasta crayfish are removed from the population through predation.
Consequence: Reduction in population/population extirpation.
Narrative: Two of the three native aquatic mammals, river otters (Lontra canadensis) and mink (Neovison vison), are known to prey on crayfish. Muskrats (Ondatra zibethicus), which prey on crayfish, were introduced into the drainage in the early 1930s. Raccoons (Procyon lotor) are also known to eat crayfish. Furthermore, many species of nonnative gamefish were intentionally introduced into the midsections of the Pit River drainage to provide sport fishing opportunities. Some of these introductions were without the sanction of California Department of Fish and Wildlife and other agencies. Brown trout (Salmo trutta), largemouth bass (Micropterus salmoides), smallmouth bass (Micropterus dolomieu), black crappie (Pomoxis nigromaculatus), green sunfish (Lepomis cyanellus), black bullhead (Ameiurus melas), brown bullhead (Ameiurus nebulosus), and channel catfish (Ictalurus punctatus) have all been introduced within the range of the Shasta crayfish and are all known to prey on crayfish (USFWS 1998).

Stressor: Regulatory mechanisms
Exposure: Inadequacy of existing regulatory mechanisms.
Response: Loss of habitat or habitat degradation from populations and potential populations not being properly identified and maintained.
Consequence: Reduction in population; extirpation; and habitat loss and degradation.
Narrative: The Shasta crayfish was listed as an endangered species by the California State Fish and Game Commission in 1988, thus offering protection from take, possession, or sale in the State of California. Other state regulations prohibit the take, possession, or use for bait of any crayfish species within the range of the Shasta crayfish. These regulations were enacted to protect the Shasta crayfish and prevent the accidental spread of exotic crayfish; however, enforcement is difficult because of the large size and remoteness of the area. The California

Water Resources Control Board issues both waste discharge permits for liquid waste discharges and 401 Water Quality Certifications for discharges to navigable waters, which require a federal permit or license. The California Department of Fish and Wildlife issues Stream and Lake Alteration Agreements under Sections 1600-1605 of the California Fish and Game Code for the alteration of any stream or water course depicted as a blue-line channel on U.S. Geological Survey topographic maps (USFWS 1998).

Stressor: Competition
Exposure: Nonnative crayfish species introduced.
Response: Nonnative crayfish can outcompete native Shasta crayfish.
Consequence: Reduction in population/population extirpation.
Narrative: Signal crayfish have all the characteristics of a classic invading species; they are larger and more aggressive, are faster growing and earlier maturing, produce more offspring, and have a larger native range than Shasta crayfish. Signal crayfish also have a broader diet, greater physical tolerance (e.g., to water temperature and quality), and a higher daytime activity rate than Shasta crayfish. The more aggressive signal crayfish males may mate with female Shasta crayfish where they occur together. The absence of hybrid individuals, however, would indicate that only nonviable eggs are produced from matings between the two species, which could effectively reduce the reproductive output of female Shasta crayfish to zero for the year (reproductive interference). This type of reproductive interference can be costly to Shasta crayfish because they are slow-growing, late-maturing, and have low fecundity (produce fewer offspring). As the exotic crayfish populations increase in size and distribution, Shasta crayfish populations reduce in number and become more isolated (USFWS 1998; USFWS 2009).

Stressor: Small population size
Exposure: Smaller populations are vulnerable to sudden natural and manmade changes.
Response: Loss of individuals and continued reduction in population, inbreeding depression, and genetic drift.
Consequence: Population extirpation.
Narrative: Shasta crayfish is threatened by small population size. Of the 29 sites surveyed between 2004 and 2006, 12 no longer have Shasta crayfish, eight have fewer than 10 individuals, and only three have more than 100 individuals. Small populations may be subject to inbreeding depression and genetic drift, and also to chance extinction from stochastic environment and demographic incidents. Genetic analyses show that in general there is a great deal of genetic variation in the remaining Shasta crayfish populations, despite the demographic data showing a severe reduction in population size. Shasta crayfish are also threatened with an increase in fragmented populations (further threat of genetic drift and isolation). Fragmented populations often exhibit poor metapopulation connectivity where the dispersal distance between populations is outside the capability of the species, making the species less likely to disperse to other population sites or recolonize sites that may have been extirpated (USFWS 2009).

Stressor: Global climate change
Exposure: Changes in climate.
Response: Loss of individuals and continued reduction in population.
Consequence: Reduction and/or loss of habitat, reduction in population, and population extirpation.
Narrative: Impacts to the Shasta crayfish under predicted future climate change are unclear. A trend of warming in the mountains of western North America is expected to decrease snowpack,

hasten spring runoff, and reduce summer stream flows; and increased summer heat may increase the frequency and intensity of wildfires. Although it appears reasonable to assume that the species may be affected, we lack sufficient certainty regarding how and how soon climate change will affect the species, the extent of average temperature increases in California/Nevada, or potential changes to the level of threat posed by increased drought or fire. The most recent literature on climate change includes predictions of hydrological changes, higher temperatures, and expansion of drought areas, resulting in a northward and/or upward elevation shift in range for many species. We have no knowledge of more detailed climate change information specifically for the species' range (USFWS 2009).

Stressor: Poor Water Quality from Flushing Flows (USFWS, 2023)
Exposure:
Response:
Consequence:
Narrative: Pursuant to the Federal Energy Regulatory Commission (FERC) License Article 401 for the Pit 1 Project (FERC No. 2687), PG&E began implementing an annual flushing flow requirement in 2003 to control surface aquatic vegetation in Fall River Pond during the summer. After several years of monitoring, it was found that the flushing flows were not needed for vegetation control and that they were reducing cold water habitat, resulting in negative impacts to the Shasta crayfish (Service 2009b, entire). The Service informed FERC that the effects from the flushing flow requirement were not analyzed in the biological opinion for the Pit 1 Project and that they needed to reinitiate consultation. As a result, PG&E has temporarily suspended the flushing flows annually since 2010 (Spring Rivers 2021, p. 29; Service 2023, entire). The final amended Water Quality Certification to permanently remove the flushing flow requirement has not yet been formally approved by FERC (USFWS, 2023)

Recovery

Reclassification Criteria:
The 20 major subpopulations within five Shasta crayfish populations that are currently free of nonnative crayfish species are protected to ensure that they remain isolated from nonnative crayfish species, and that these subpopulations are stable (i.e., self-sustaining and comprising representatives of all age classes) (USFWS 1998).

The Crystal Lake and Sucker Springs Creek subpopulations, which have been invaded by signal crayfish, are protected and stable due to elimination, reduction, or management of signal crayfish (USFWS 1998).

Over a 5-year period, population sizes remain constant at Upper Fall River, Spring Creek, and Rising River; and population sizes increase at Lava Creek, upper Tule River, Crystal Lake, and Sucker Springs (USFWS 1998).

Signal crayfish are eradicated in lower Lava Creek so that Shasta crayfish are free of signal crayfish throughout the entire Lava Creek subdrainage (USFWS 1998).

The major subpopulations in each of the seven Shasta crayfish populations are protected from disturbances related to land use practices (USFWS 1998).

Recovery Priority Number: 5

Delisting Criteria:
Delisting criteria require meeting the reclassification criteria and the following additional criteria:

Nonnative crayfish species, in particular signal crayfish, have been eliminated, reduced, or managed in all Shasta crayfish subpopulations, so that they no longer threaten the continued existence of Shasta crayfish at these sites (USFWS 2009).

All Shasta crayfish subpopulations are stable, with population sizes that are increasing over a 5-year period (USFWS 2009).

Recovery Actions:
- Protect Shasta crayfish populations by eradicating or preventing invasions by nonnative crayfish, restoring habitat, and eliminating impacts from land management practices (USFWS 1998).
- Determine the status, distribution, and relative abundance of Shasta crayfish in the mainstem of the Pit River (USFWS 1998).
- Conduct research on the ecology, behavior, and pathology of Shasta crayfish (USFWS 1998).
- Monitor and assess Shasta crayfish populations, and determine population targets for a sustainable and well-distributed population (USFWS 1998).
- Develop effective watershed and ecosystem management plans for all drainages supporting Shasta crayfish populations (USFWS 1998).
- Provide public education on Shasta crayfish (USFWS 1998).
- Substrate additions to create habitat and stabilize levees; levee bank stabilization with native grasses; and elimination of dredging (USFWS 1998).
- Continue removal of exotic crayfish, especially at Sucker Springs and Thousand Springs barrier sites, and expand removal efforts to protect at least one population in each of the eight subpopulation areas (USFWS 2009).
- Continue to explore options for constructing barriers to crayfish movement, followed by intensive exotic crayfish eradication upstream of the barrier, to create Shasta crayfish refugia that are free of exotic crayfish. Areas to consider are Rock Creek, Lava Creek, and Rising River (USFWS 2009).
- Establish a population of Shasta crayfish above the natural barrier (USFWS 2009).
- Develop a genetic management plan to help determine source populations for potential reintroduction of Shasta crayfish into Rock Creek and elsewhere (USFWS 2009).
- Conduct mitochondrial DNA work on existing Shasta crayfish genetic samples (USFWS 2009).
-

Conservation Measures and Best Management Practices:
- RECOMMENDATIONS FOR FUTURE ACTIONS: In this section we propose recommendations which will aid in the recovery and conservation of Shasta crayfish. We recognize that conservation of this taxon will require cooperation and coordination with partners (federal, state, and local) to minimize impacts from current threats, aid future restoration, and maximize the effectiveness of limited funding. 1. Continue removal of nonnative crayfish, especially at the Sucker Springs and Thousand Springs crayfish barrier sites and expand removal efforts to protect at least one population in each

of the 8 geographical regions. 2. Continue to identify potential refugia. 3. Work with private landowners to conduct surveys and restore habitat as needed. 4. Conduct studies to evaluate Shasta crayfish diet during different life stages to support captive breeding and head-starting activities. 5. Construct/identify the Shasta crayfish captive breeding/head-starting facility and implement the translocation program to populate refuge areas such as Rock Creek and areas identified as a result of the efforts described in recommendation 2 above. 6. Supplement cobble substrate in Rock Creek to expand the amount of suitable habitat for the translocated population in that location. 7. Continue to develop methods to determine translocation success and assess the efficacy and accuracy of using eDNA as a conservation tool (USFWS, 2023).

Additional Threshold Information:

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SPECIES ACCOUNT: *Palaemonetes cummingi* (Squirrel Chimney Cave shrimp)

Species Taxonomic and Listing Information

Commonly-used Acronym: SCCS

Listing Status: Threatened; 6/21/1990; Southeast Region (Region 4) (USFWS, 2015)

Physical Description

Florida cave shrimp, Palaemonidae. (NatureServe, 2015). It measures about 30 millimeters (1.2 inches) in total length and Is transparent. The body and eyes are unpigmented. and the eyes are reduced in size In comparison to surface dwelling species of Polaemonetes (USFWS, 1990).

Taxonomy

The Squirrel Chimney cave shrimp (Palaemonetes cummingi), is a decapod crustacean of the family Palaemonidae (USFWS, 1990).

Historical Range

Not available

Current Range

Known only from the type locality: Squirrel Chimney, Alachua County, Florida, USA. (NatureServe, 2015)

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: This species is dependent upon detrital flow (NatureServe, 2015)

Reproduction Narrative

Adult: No information available.

Geographic or Habitat Restraints or Barriers

Adult: Cave boundaries (inferred from NatureServe, 2015)

Environmental Specificity

Adult: Very narrow (NatureServe, 2015)

Tolerance Ranges/Thresholds

Adult: Low (inferred from NatureServe, 2015)

Habitat Narrative

Adult: Obligate carvernicole; known only from one water-filled cave contiguous with a deep sinkhole. The sinkhole has vertical walls that lead down to groundwater and two small holes open in the face of the sink slightly above the water and lead into a wide fissure (Deyrup and Franz, 1994). The environmental specificity is very narrow and as a cave species dependent upon detrital flow as well as the quantity and quality of water in the aquifer, it is presumably delicate (NatureServe, 2015).

Dispersal/Migration

Migratory vs Non-migratory vs Seasonal Movements

Adult: Non-migratory (NatureServe, 2015)

Dispersal/Migration Narrative

Adult: This species is non-migratory (NatureServe, 2015).

Population Information and Trends

Population Trends:

Decline of >70%, possibly extirpated (NatureServe, 2015)

Species Trends:

Unknown (USFWS, 2008)

Number of Populations:

1 (USFWS, 2021)

Population Size:

Zero to 1000 individuals (NatureServe, 2015)

Adaptability:

Low (inferred from NatureServe, 2015)

Population Narrative:

As a cave species dependent upon detrital flow as well as the quantity and quality of water in the aquifer, it is presumably delicate. Also vulnerable to fish predation. Possibly has been extirpated, but can not be certain. This species is known only from one water-filled cave contiguous with a deep sinkhole and has experienced a long-term decline of >70%. The range extent is 40 - 100 square miles, with an estimated population size of 0 - 1,000 individuals (NatureServe, 2015). The species status is unknown, based on the 2007 Recovery Data Call. It was last observed in 1973 (Franz 1982). (USFWS, 2008). The Squirrel Chimney cave shrimp, Florida’s only cave shrimp, is known from one location, the Squirrel Chimney near Gainesville, Alachua County. There are no more than 12 records of this species dating from its discovery in 1953 to and its last collection in 1973. The last status survey of the Squirrel Chimney and several nearby cave systems (1994-1996) did not document the SCCS or find evidence of the SCCS. A 1992 survey documented the presence of a new fish species within the Squirrel Chimney, the redeye chub. This fish is a small predator capable of eating crustaceans the size of SCCS larvae and may explain the apparent absence of the SCCS from the Squirrel Chimney. In 1997, the Service was petitioned to reconsider the federal listing of the SCCS due to its potential extinction. The Service found that the petition did not present substantial information indicating that delisting this species due to extinction was warranted. The Service based its finding on the inadequacy of the existing information, as the status surveys did not include a number of sink and cave systems within 5 miles that are ecologically similar to the Squirrel Chimney. These caves and sinks are all characteristic of the karst topography of this area and are likely interconnected through underground features. These features likely provided the travel corridors that allowed the redeye chub to establish a population within the Squirrel Chimney. Such passageways could also provide shelter and travel corridors for dispersal of the SCCS (USFWS 1998) (USFWS, 2021)

Threats and Stressors

Stressor: Aquifer degradation (NatureServe, 2015)
Exposure:
Response:
Consequence:
Narrative: Presumably sensitive to degradation of aquifers (pollution), alteration (especially reduction) of detrital flow, and saltwater intrusion that may accompany excessive water withdrawal (for agriculture, industry, and human consumption) or sea level rise. Owner of only known site is aware, but may not be able to provide protection over a large enough area or long enough time period (NatureServe, 2015).

Stressor: Redeye chub (NatureServe, 2015)
Exposure:
Response:
Consequence:
Narrative: A 1992 survey documented continued presence of the redeye chub, Notropis harperi, a potential predator of the shrimp (NatureServe, 2015).

Stressor: Stochastic events (USFWS, 2008)
Exposure:
Response:
Consequence:
Narrative: Natural droughts and water withdrawals for human use can impact cave water levels. Contaminant spills in the recharge area or a single act of vandalism could seriously damage the only known site of occurrence (USFWS, 2008).

Recovery

Reclassification Criteria:
Not available - this species does not have a recovery plan (USFWS, 2008).

Recovery Priority Number: 5C

Delisting Criteria:
Not available - this species does not have a recovery plan (USFWS, 2008).

Recovery Actions:

- RECOMMENDATIONS FOR FUTURE ACTIONS: Work with private landowners regarding the protection and conservation of the Squirrel Chimney and other nearby ecologically similar caves and sink systems. Acquire or obtain a conservation easement on Squirrel Chimney and other nearby ecologically similar caves and sink systems. Conduct a survey to determine the status of the SCCS. Evaluate and consider establishing a captive breeding program for the SCCS as a recovery tool if deemed appropriate after the recommended survey. Monitor groundwater quality and water levels of Squirrel Chimney and other nearby ecologically similar caves and sink systems. Determine the origin (age, source and recharge area) of the Squirrel Chimney and other nearby ecologically similar caves and sink systems. Use existing regulatory mechanisms to protect the SCCS and its groundwater habitat. Develop and distribute educational and technical information materials essential for cave, sink, and recharge area stewardship. Evaluate potential use of eDNA to detect the presence of SCCS at the Squirrel Chimney and other nearby similar caves. Environmental DNA (eDNA) is a surveillance tool used to monitor for the genetic presence of an aquatic species. Provide best management practices for the conservation of aquatic caves and the species dependent upon them to public and private land owners. Provide assistance, funding and conservation easements to landowners who participate. Per Walsh (2001), all counties with aquatic caves should be targeted with a priority on Alachua (47 caves), Suwannee (43), Jackson (34) and Marion (27) (Walsh 2001) (USFWS, 2016).
- Work with private landowners regarding the protection and conservation of the Squirrel Chimney and other nearby ecologically similar caves and sink systems (USFWS, 2008).
- Acquire or obtain a conservation easement on Squirrel Chimney and other nearby ecologically similar caves and sink systems (USFWS, 2008).
- Conduct an intensive survey to determine the status of the SCCS (USFWS, 2008).
- Evaluate and consider establishing a captive breeding program for the SCCS as a recovery tool if deemed appropriate after the recommended intensive survey (USFWS, 2008).
- Monitor groundwater quality and water levels of the Squirrel Chimney and other nearby ecologically similar caves and sink systems (USFWS, 2008).
- Determine the origin (age, source and recharge area) of the Squirrel Chimney and other nearby ecologically similar caves and sink systems (USFWS, 2008).
- Use existing regulatory mechanisms to protect the SCCS and its groundwater habitat (USFWS, 2008).
- Develop educational and technical information materials essential for cave, sink and recharge area stewardship (USFWS, 2008).

Conservation Measures and Best Management Practices:

- RECOMMENDATIONS FOR FUTURE ACTIONS Work with private landowners regarding the protection and conservation of the Squirrel Chimney and other nearby ecologically similar caves and sink systems. Acquire or obtain a conservation easement on Squirrel Chimney and other nearby ecologically similar caves and sink systems. Conduct a survey to determine the status of the SCCS. See Appendix B for prioritization table and GIS map pertaining to most suitable areas. Evaluate and consider establishing a captive breeding program for the SCCS as a recovery tool if deemed appropriate after the recommended survey. Monitor groundwater quality and water levels of Squirrel Chimney and other nearby ecologically similar caves and sink systems. Determine the origin (age, source and recharge area) of the Squirrel Chimney and other nearby ecologically similar caves and sink systems. Use existing regulatory mechanisms to protect the SCCS and its groundwater habitat. Develop and distribute educational and technical information materials essential for cave, sink, and recharge area stewardship. Evaluate potential use of eDNA to detect the presence of SCCS at the Squirrel Chimney and other nearby similar caves. Environmental DNA (eDNA) is a surveillance tool used to monitor for the genetic presence of an aquatic species. Provide best management practices for the conservation of aquatic caves and the species dependent upon them to public and private land owners. Provide assistance, funding and conservation easements to landowners who participate. Per Walsh (2001), all counties with aquatic caves should be targeted with a priority on Alachua (47 caves), Suwannee (43), Jackson (34) and Marion (27) (Walsh 2001). (USFWS, 2021)

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SPECIES ACCOUNT: *Palaemonias alabamae* (Alabama cave shrimp)

Species Taxonomic and Listing Information

Commonly-used Acronym: ACS

Listing Status: Endangered; 9/7/1988; Southeast Region (Region 4) (USFWS, 2015)

Physical Description

Cave shrimp; Atyidae; Albinistic; eyes unpigmented and unfaceted; lacking branchiostegal and hepatic spines on carapace. First and second pereiopods chelate and fingers with tufts of setae. Rostrum with <15 dorsal teeth and none ventrally. The length is 2 cm. (NatureServe, 2015)

Taxonomy

Not Available

Historical Range

Not Available

Current Range

Known only from Shelta Cave and another 13 km distant, both in Madison Co., Alabama. (NatureServe, 2015)

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: Probably, as most troglobites, totally opportunistic. This species is a detritivore and exhibits a circadian phenology (NatureServe, 2015). The base of the food web in the five shrimp caves appears to be organic material, detritus, and other food items carried in by flowing water. Cooper (1975) observed Alabama cave shrimp ingesting silt and other bottom debris in shallow pools of Shelta Cave. Cooper also observed shrimp apparently feeding on suspended organic particles on the surface of the water. During a study in Mammoth Cave, Kentucky, Leithauser (1988) found that a complex assemblage of bacteria, protozoans, and minute crustaceans fed on detritus particles in cave stream sediments, and observed that the Kentucky cave shrimp fed on these organisms by nonselective grazing (USFWS, 1997).

Reproduction Narrative

Adult: Ovigerous females occur August-January; Shelta Cave females with fewer eggs than Bobcat Cave females. (NatureServe, 2015). Life span has not been documented for the ACS, however the closely related P. ganteri is reported to live between 10 and 15 years (Leithhauser 1988) (USFWS, 2006). The number of eggs carried by gravid females ranged from 4 to 30 (Cooper 1975). McGregor et al. (1994) concluded that shrimp require at least one growing season to reach sexual maturity. Cooper (1975) estimated sex ratios of the Alabama cave shrimp to approach a 1:1 ratio. (USFWS, 1997).

Habitat Narrative

Adult: Found in subterranean aquatic pools with fine silt bottoms. Usually occur near bottom until disturbed; they then swim to surface (NatureServe, 2015). The use of cave windows by Alabama cave shrimp was documented by Cooper (1975) and McGregor et al. (1994). They observed shrimp near windows, swimming in and out of windows, or using windows to escape when disturbed (USFWS, 1997).

Dispersal/Migration

Motility/Mobility

Adult: Moderate (inferred from NatureServe, 2015)

Migratory vs Non-migratory vs Seasonal Movements

Adult: Non-migratory (NatureServe, 2015)

Dispersal/Migration Narrative

Adult: Good swimmers. This species is non-migratory (NatureServe, 2015).

Population Information and Trends

Population Trends:

Declining (USFWS, 1997)

Species Trends:

Stable (USFWS, 2006)

Number of Populations:

6 (USFWS, 2023)

Population Narrative:

Available information indicates the overall population may be declining, and the shrimp is apparently extirpated from Shelta Cave (USFWS, 1997). The species status is stable, based on the 2005 Data Recovery Call. It currently survives in two of the three known locations (USFWS, 2006). The range extent is less than 40 - 100 square miles (NatureServe, 2015). The Alabama cave shrimp is an albinistic troglobitic (cave-dwelling) shrimp known to be found in cave systems in Madison and Jackson counties in Alabama (Figure 1). The cave shrimp was first collected in Shelta Cave in 1958 (Cooper 1975); but has not been seen there since the early 1970s. A second population of cave shrimp was discovered in Bobcat Cave in 1973. Populations of cave shrimp have also been discovered in Hering/Glover (1991), Brazelton Cave (1994) (Rheams et al. 1994), Muddy Cave (2005) (Kuhajda, pers. comm. 2006), and Fern Cave (2018) (Niemiller et al. 2019). Until 2018 the total range of the species previously extended approximately 20 km (12 miles) east-southeast across the Flint River and the Huntsville, Green, and Monte Sano mountains and southward to near the Tennessee River (McGregor et al. 1994), but with the discovery of four cave shrimp in Fern Cave, its known distribution has been expanded into the Lower Paint Rock River watershed (Niemiller et al. 2019; Figure 1) (USFWS, 2023).

Threats and Stressors

Stressor: Groundwater contamination (USFWS, 2006)
Exposure:
Response:
Consequence:
Narrative: Groundwater contamination is likely the greatest threat to ACS populations. Recent monitoring data (McGregor and O'Neil 2004) show a continual increase in maximum lead concentrations in Bobcat Cave. Pollutants may originate from residential development and enter caves during periods of runoff (USFWS, 2006).

Stressor: Stochastic events (USFWS, 2006)
Exposure:
Response:
Consequence:
Narrative: Droughts and water withdrawal for human use can impact cave water levels. Toxic spills and urban development can accelerate pollutant delivery to caves during surface runoff (USFWS, 2006).

Recovery

Reclassification Criteria:
1. Identification and protection of reproductively viable populations of Alabama cave shrimp in five groundwater basins (or aquifers) (USFWS, 1997).

2. Reproductive viability, defined as reproducing populations which are stable or increasing in size, should be demonstrated for all five populations for a 20-year period (USFWS, 1997).

Recovery Priority Number: 5

Delisting Criteria:
The Alabama cave shrimp will be considered for delisting when: 1. A minimum of five (5) populations in five distinct groundwater systems (determined by hydrologic studies that can distinguish different systems), show a stable or increasing trend, evidenced by natural recruitment, and multiple size classes (addresses Factors A, C, andE). 2. Threats have been addressed and/or managed to the extent that the species will remain viable into the foreseeable future (addresses Factors A and E). 3. A minimum of three (3) populations occur in groundwater systems protected via a conservation mechanism (addresses Factors A and E) (USFWS, 2019).

Recovery Actions:
- Protect Alabama cave shrimp populations and their groundwater habitat (USFWS, 1997).
- Develop technical information and educational material essential for cave and recharge area stewardship (USFWS, 1997).
- Monitor Alabama cave shrimp populations (USFWS, 1997).
- Conduct life history and other needed research (USFWS, 1997).
- Continue searching for additional populations (USFWS, 1997).
- Modify or replace the gated entrance to Shelta Cave (USFWS, 1997).
- Assess suitability of re-introduction of Alabama cave shrimp into Shelta Cave (USFWS, 1997).

- Continue monitoring Alabama cave shrimp populations in Bobcat Cave to develop long-term trends (USFWS, 2006).
- Continue monitoring ground-water quality and water levels in Bobcat Cave. Special attention should be placed on the levels and trends of potential toxins, such as lead and cadmium, persistent current-generation pesticides, and other parameters associated with urban runoff (see McGregor and O'Neil 2004 for more details) (USFWS, 2006).
- Determine the origin (age, source, and recharge area) of deep ground water in the Bobcat Cave aquifer (USFWS, 2008).
- Work with private landowners to confirm shrimp populations and develop water quality monitoring plans for the HGB system, Muddy Cave, and in the unnamed cave in western Jackson County, Alabama (USFWS, 2008).
- Work with EPA to determine the source of, and remediate, TCE and other contaminants plumes that will affect Bobcat Cave population (USFWS, 2006).
- Implement all other recovery actions (USFWS, 2006).

Conservation Measures and Best Management Practices:

- RECOMMENDED FUTURE ACTIVITIES A detailed discussion of recovery actions and criteria are presented in the Recovery Plan (Service 1997) and Alabama Cave Shrimp Recovery Plan Amendment (Service 2019). During the course of this status review new and/or targeted potential recovery activities were identified and are included below. Recovery Activities 1. The Service should continue working with landowners to protect Alabama cave shrimp populations, their groundwater habitat, and surrounding recharge zones. 2. Assess the suitability of re-introductions of Alabama cave shrimp into Shelta Cave. Monitoring and Research Activities 1. Population monitoring should be conducted to assess the response of the Alabama cave shrimp to continued threats, determine the current population size and viability, and determine other biological relationships within the known cave ecosystems where the Alabama cave shrimp is found. 2. Continue water quality monitoring within Bobcat Cave. 3. Additional studies should be conducted to determine if other populations of the Alabama cave shrimp exist in other locations. This could be accomplished utilizing traditional methods, eDNA monitoring, or other novel methods not yet considered. 4. Additional studies of the recharge area surrounding caves where the Alabama cave shrimp is known to occur should be conducted to get an updated understanding of current hydrological conditions and how groundwater impacts karst environments. 5. Conduct life history and other needed research such as assessment of genetic diversity within and among populations. 6. Conduct hydrologic studies to determine if Muddy and Bobcat caves are in separate groundwater recharge systems (USFWS, 2023)

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SPECIES ACCOUNT: *Palaemonias ganteri* (Kentucky cave shrimp)

Species Taxonomic and Listing Information

Listing Status: Endangered; Southeast Region (R4) (USFWS, 2015)

Physical Description

The Kentucky cave shrimp, P. ganteri, is a small, blind, freshwater crustacean (Order Decapoda, Family Atyidae) reaching a maximum total length of 30 mm (1.2 inches [in]). The species has a translucent body and is characterized by rudimentary eyestalks lacking facets of pigmentation, subequal first and second chelae, and terminal tufts of setae on each of the chelae. Palaemonias ganteri is distinguished from its closest relative, P. alabamae (Alabama cave shrimp), by having more than 15 dorsal teeth on the rostrum (shelf-like structure on the top and front of the head) and more than 15 spine-like setae on the appendix masculina (lobe or rod-like structure on the second swimmeret) (Hobbs et al. 1977; USFWS 1988). Hatchlings are approximately 3 mm (0.12 in) total length and adults up to 30 mm (1.2 in) in total length (Leitheuser and Holsinger 1983). The Service listed the Kentucky cave shrimp as endangered and designated the Roaring River passage of Mammoth Cave (Flint Mammoth Cave System, Echo River groundwater basin) as critical habitat on October 12, 1983 (48 FR 46337). The Roaring River passage is a base level cave passage characterized by abundant quantities of organic matter and sediments of coarse silt and very coarse to very fine sand. The total designated Critical Habitat area encompasses about one mile of cave passage.

Taxonomy

Not Available

Historical Range

Other potential habitat in the upstream Graham Springs Basin might well exist, as well as adjacent areas along the escarpment area. Although there were no historic records of the species from the Graham Springs Basin, Lewis and Lewis (2005) hypothesized that the species could have occurred historically in the basin but was now extirpated due to the extensive habitat degradation (e.g., sedimentation, illegal dumps) observed during their survey. (USFWS, 2010)

Current Range

The Kentucky cave shrimp is endemic to the MCNP region of central Kentucky. At the time of listing, the species' known distribution was limited to five localities in the Mammoth Cave system (Holsinger and Leitheuser 1982a and 1982b, Leitheuser 1984) within the boundaries of MCNP, including four within the Echo River Spring groundwater basin and one within the Pike Spring groundwater basin (Quinlan and Ray 1981). Since that time, the species' distribution has been extended to include most of the base level passages in the Echo River Spring groundwater basin; five localities in the Pike Spring groundwater basin; and one each in the Mile 205.7 Spring, Suds Spring, and McCoy Blue Spring groundwater basins. In addition, previously unreported and recently discovered habitat includes Sandhouse Cave in the Double Sink groundwater basin; Ganter Cave and Lee Cave in the Turnhole Spring groundwater Basin; and Running Branch Cave. The current known distribution of the shrimp includes nine distinct Groundwater Basins in the MCNP region (USFWS 2010, Figure 1). Three of these basins (the Echo River Spring, Ganter Cave, and Running Branch Cave Groundwater Basins) are located more or less entirely within MCNP.

Two other basins (Mile 205.7 Spring and Pike Spring) extend well beyond the east boundary of the park. Approximately one-third of the Mile 205.7 Spring and one-half of the Pike Spring Groundwater Basins are located on private lands. Although Sandhouse Cave is located in Mammoth Cave National Park, the majority of the Double Sink Groundwater Basin is located on private lands southwest of the park. The only locality known to contain shrimp in the Turnhole Spring Groundwater Basin, Snake River in Lee Cave, is located within MCNP. The majority of this basin, however, is located on private lands south of the park. The remaining basins known to contain shrimp (McCoy Blue Spring and Suds Spring Groundwater Basins) are both entirely on private lands east of MCNP. Ganter Cave, Running Branch Cave, and McCoy Blue Spring are all on the north side of the Green River, which bisects MCNP, while remaining basins are on the south side of the river.

Critical Habitat Designated

Yes; 10/12/1983.

Legal Description

On October 12, 1983, the U.S. Fish and Wildlife Service designated critical habitat for the Kentucky cave shrimp under the Endangered Species Act of 1973, as amended (48 FR 46337 - 46342).

Critical Habitat Designation

Critical habitat for the Kentucky cave shrimp is designated in Edmonson county, Kentucky: the Roaring River pasage of the Flint-Mammoth Cave system in Mammoth cave National Park. The total designated critical habitat amounts to about 1 mile of cave passages.

Primary Constituent Elements/Physical or Biological Features

Known constituent elements include a stream in a base level cave passage with abundant organic material and sediments consisting of coarse silt and very coarse to very fine sand.

Special Management Considerations or Protections

Not available

Life History

Feeding Narrative

Adult: The Kentucky cave shrimp is a non-selective grazer. Studies of fecal pellets indicated the presence of sand grains, generally amorphous mucus or other cementing material that may be either sedimentary or microbial in nature, exoskeletons of protozoans, insects, and other unidentified organisms, fungal hyphae (filaments) and spores, algal cells, and miscellaneous other unidentified material. The surface layers of cave sediments contain a complex association of bacteria, fungi, protozoans, and minute crustaceans. Shrimp use the terminal setal tufts on their chelae to trap these organisms, which are moved toward the mouthparts where they are scraped off and ingested (Holsinger and Leitheuser 1982a, 1982b; Leitheuser and Holsinger 1983; Lisowski 1983; Leitheuser and Holsinger 1985; Leitheuser et al. 1986; and USFWS 1988).

Reproduction Narrative

Adult: The Kentucky cave shrimp hatches from oblong eggs, approximately 1.0 by 1.2 mm (0.04 to 0.05 in), which are carried by mature females under the abdomen. Up to 33 eggs have been counted from a single female shrimp. The eggs may hatch at varying times, so it is normal to observe female shrimp carrying only a few eggs at a time. Larval development is completely unknown. The age at sexual maturity and both minimum and maximum breeding ages are unknown. Mature females carrying eggs range in size from 18 to 26 mm (0.71 to 1.02 in) total length. The maximum observed size for the species is 30 mm (1.12 in) total length, but individuals in excess of 25 mm (1.02 in) are uncommon. Hatchlings are approximately 3 mm (0.12 in) total length and adults up to 30 mm (1.2 in) in total length (Holsinger and Leitheuser 1982a, 1982b; Leitheuser and Holsinger 1983; Lisowski 1983; Leitheuser and Holsinger 1985; Leitheuser et al. 1986; and USFWS 1988). Female shrimp with eggs have been observed at all times of the year. Reproduction probably occurs continuously, but there is some evidence that suggests seasonal reproduction in response to flooding events. Flood events are thought to bring in additional food supplies that "trigger" reproduction. Oocytes (eggs) may be resorbed during periods of low food availability and later develop as conditions improve. Females may reproduce more than once during their lifetime. Aquarium studies have resulted in life span estimates of up to 10 to 15 years. Females which are at some stage of reproductive development account for approximately 28 percent of individuals in some populations (Holsinger and Leitheuser 1982a, 1982b; Leitheuser and Holsinger 1983; Lisowski 1983; Leitheuser and Holsinger 1985; Leitheuser et al. 1986; and USFWS 1988).

Habitat Narrative

Adult: The Roaring River passage is a base level cave passage characterized by abundant quantities of organic matter and sediments of coarse silt and very coarse to very fine sand.

Dispersal/Migration

Migratory vs Non-migratory vs Seasonal Movements

Adult: Non-migratory

Dispersal/Migration Narrative

Adult: Usually slow walkers on bottom, but when disturbed quickly swim to top. (NatureServe, 2015)

Population Information and Trends

Number of Populations:

Occurs in 11 groundwater basins (USFWS, 2022)

Population Narrative:

Localities from which shrimp have been collected, observed, or reported have not been mapped with sufficient precision to allow the direct calculation of population densities. It is, however, possible to estimate relative population densities over a section of passage known to contain shrimp. The resulting "population density estimate" is based upon only one dimension, that of length of the passage. Population densities appear to be highly variable. Shrimp density has been reported to vary from 0.007 shrimp/meter (m) (0.002 shrimp/foot [ft]) to 0.7 shrimp/m (0.2 shrimp/ft) (Holsinger and Leitheuser 1982b, 1983). It has also been noted that population densities appear to vary over time in each specific locality (Holsinger and Leitheuser 1983). For example, one locality varied from a density of 0.07 shrimp/m (0.022 shrimp/ft) to 0.5 shrimp/m (0.148 shrimp/foot) (Holsinger and Leitheuser, 1983). The passages from which these data were obtained were approximately 0.9 m to 10.8 m (3 to 12 ft) wide and 0.3 to 0.9 m (1 to 3 ft) deep. Pearson and Jones (1998) conducted faunal inventories and habitat analyses at 10 sites within the Mammoth Cave System over a three-year period from 1993 to 1995. They observed individuals of P. ganteri at 6 of 10 historic sites, with the greatest abundances observed in 1995. Individuals of P. ganteri were observed at Colossal River in 1994 (1 shrimp); Mystic River in 1993 (8), 1994 (33), and 1995 (233); Golden Triangle Area in 1994 (25) and 1995 (45); Roaring River in 1994 (32) and 1995 (34); Shrimp Pools at Roaring River in 1995 (4); and Echo/Styx River in 1994 (6) and 1995 (2). Tentative population estimates for each groundwater basin were provided in the recovery plan (USFWS 1988). These included Echo River Spring (750 individuals), Ganter Spring (150), Running Branch Spring (300), Mile 205.7 Spring (50), Pike Spring (5,000 to 10,000), Double Sink (unknown), Turnhole Spring (unknown), McCoy Blue Spring (unknown), and Suds Spring (500). More-recent population estimates are unavailable. The species is restricted to 11 groundwater basins in the Mammoth Cave National Park region of central Kentucky. The region's sinkholes, sinking streams, and other karst features allow pollutants to quickly enter groundwater systems and travel downstream to where they can adversely affect cave shrimp populations. Population estimates have not been revised since 1988; however, the perceived low abundance of Kentucky cave shrimp in each of its groundwater basins makes these populations vulnerable to catastrophic contamination events that could lead to extirpation. Due to the varied sources and unpredictable nature of these contaminants, current regulatory mechanisms have been ineffective in preventing these impacts. The species is afforded some protection from groundwater pollution and habitat disturbance because 4 of the 11 occupied groundwater basins occur entirely within federal land that is managed in a way to protect underground resources (USFWS, 2022).

Threats and Stressors

Stressor: Poor water quality/habitat deterioration
Exposure:
Response:
Consequence:
Narrative: Poor water quality and habitat deterioration resulting from groundwater contamination, siltation caused by poor land use practices, and other nonpoint-source pollutants.

Stressor: Limited distribution
Exposure:
Response:
Consequence:
Narrative: Limited distribution resulting in (a) vulnerability to toxic chemical spills and (b) limiting the natural genetic exchange between and within populations.

Recovery

Reclassification Criteria:
Protection of viable, reproducing populations in five groundwater basins currently known to support the species or found to support it in the future.

Recovery Priority Number: 5

Delisting Criteria:
Protection of viable, reproducing populations in nine groundwater basins currently known to support the species or found to support it in the future.

Recovery Actions:

- Determine the current status and distribution of the Kentucky cave shrimp by completing a new, comprehensive inventory of groundwater basins surrounding Mammoth Cave National Park. All historic basins should be searched along with adjacent basins (e.g., Graham Springs) that could potentially support the species.
- Conduct research to determine the factors that are adversely impacting the species and the means to eliminate or reduce such impacts. Determine the effects of sediment, pesticides, herbicides, and other contaminants.
- Maintain adequate water quality within basins known to support cave shrimp. Develop region-wide habitat protection methods or best management practices that would prevent groundwater contamination and habitat disturbance of cave shrimp habitats. Conduct routine monitoring of water quality to determine if pollutants are present.
- Determine the level of genetic exchange between populations. Information on cave shrimp movements within the basin would provide important information on the long-term viability of the species.
- Recovery Priority Number: 5

Conservation Measures and Best Management Practices:

- RECOMMENDATIONS FOR FUTURE ACTIVITIES A list of recovery actions is provided in the recovery plan (Service 1988) and additional items were included in the 2016 5-year review (Service 2016). The following activities are added to support and promote recovery of Kentucky cave shrimp. • Determine the level of genetic exchange between populations. Information on cave shrimp movements within the basin would provide important information on the long-term viability of the species. • As indicated in Stump (2019), eDNA has shown to be a useful method for determining presence of the species in areas that are difficult to sample; therefore, continue eDNA sampling to determine if the the species could be present in Mammoth Cave National Park staff have identified the Buffalo Creek, Floating Mill, Sand Cave, Grinstead Mill, Big Spring, Ugly Creek, Lawler Bluehole, Gorin Mill, and Graham Spring groundwater basins. • Continue to refine the delineation of known groundwater basins and assess the potential threats associated with each basin. • Obtain a revised population estimate. (USFWS, 2022)

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SPECIES ACCOUNT: *Procambarus econfinae* (Panama City crayfish)

Species Taxonomic and Listing Information

Commonly-used Acronym: PCC

Listing Status: Threatened

Physical Description

The PCC is a small crayfish, growing to about two inches (body length minus claws). Detailed morphological descriptions of the PCC are provided by Hobbs (1942), Keppner and Keppner (2001), and Breinholt and Moler (2016)(Figure 2.6). The color pattern consists of a medium-dark brown background color, lighter brown mid-dorsal stripe, and darker brown dorsolateral stripes (Figure 2.1). The lower lateral carapacial surfaces are lighter brown with reddish-brown spots (USFWS, 2017; USFWS, 2022).

Taxonomy

The currently accepted classification is (Integrated Taxonomic Information System 2017): Phylum: Arthropoda Subphylum: Crustacea Class: Malacostraca Order: Decapoda Family: Cambaridae Subfamily: Cambarinae Genus: Procambarus Subgenus: Procambarus (Leconticambarus) Species: Procambarus econfinae (Hobbs 1942) (USFWS, 2017)

Historical Range

The PCC's historic range is located in south-central Bay County, Florida and is estimated to cover a 56 square mile area (FWS GIS 2017). It's range, on a peninsula, is bounded by Callaway Bayou to the southeast, Callaway Creek to the east, Bayou George Creek and the headwaters of Callaway Creek to the northeast, North Bay to the north, West Bay to the west, and St. Andrew Bay and East Bay to the south (Figure3.1).The PCC range overlaps jurisdictional boundaries of four cities (Panama City, Lynn Haven, Callaway, Springfield) and Bay County proper (Figure 3.2) (USFWS, 2017).

Current Range

FL; Using November 2016 Bay County, Florida Department of Revenue (DOR) parcel layers, we estimated undeveloped acres remaining in core and secondary soils (Table 3.1). "Undeveloped" parcels include lands labeled cropland, improved agriculture, vacant industrial, vacant commercial, vacant residential, grazing, urban, utilities rights-of-way, and timberland (FWS GIS 2017). Sixty-one (61%) or 9,180 acres of historic core soils remain undeveloped and 46% or 5,646 acres or secondary soils remain undeveloped (Figure 3.4)(Table 3.1). Averaging the losses of both core and secondary soils, we estimate that 54% of the original lands historically available to the PCC remains potentially available for use by the PCC. If we remove hardwood swamps from the core and secondary soils, then 6,287 acres (42%) of core, and 5,325 acres (43%) remain undeveloped from historic levels, or 43% overall. A 2013 aerial photo shows the undeveloped areas remaining within the PCC's range (Figure 3.5) (USFWS, 2017; USFWS, 2022).

Critical Habitat Designated

Yes; 2/4/2022.

Legal Description

We, the U.S. Fish and Wildlife Service (Service), list the Panama City crayfish (Procambarus econfinae), a terrestrial crayfish species native to Bay County, Florida, as a threatened species with a rule issued under section 4(d) of the Endangered Species Act of 1973 (Act), as amended. We also designate critical habitat for the species under the Act. In total, approximately 4,138 acres (1,675 hectares (ha)) in Bay County, Florida, fall within eight units of critical habitat. This rule extends the Act’s protections to the species and its designated critical habitat (USFWS, 2022).

Critical Habitat Designation

We, the U.S. Fish and Wildlife Service (Service), list the Panama City crayfish (Procambarus econfinae), a terrestrial crayfish species native to Bay County, Florida, as a threatened species with a rule issued under section 4(d) of the Endangered Species Act of 1973 (Act), as amended. We also designate critical habitat for the species under the Act. In total, approximately 4,138 acres (1,675 hectares (ha)) in Bay County, Florida, fall within eight units of critical habitat. This rule extends the Act’s protections to the species and its designated critical habitat (USFWS, 2022).

Unit 1: 19th Street, Bay County, Florida. (i) Unit 1 consists of 23.2 acres (9.4 ha) and is composed of lands in State, county, or city ownership (3.7 ac (1.5 ha)), and private ownership (19.5 ac (7.9 ha))

Unit 2: Talkington, Bay County, Florida. (i) Unit 2 consists of 37.2 acres (15.1 ha) and is composed of lands in State, county, or city ownership (4.09 ac (1.7 ha)), and private ownership (33.08 ac (13.4 ha)). (ii) Map of Unit 2 is provided at paragraph (6)(ii) of this entry. (8) Unit 3: Minnesota, Bay County, Florida

Unit 3 consists of 49.0 acres (19.8 ha) and is composed of lands in State, county, or city ownership (30.0 ac (12.1 ha)), and private ownership (19.1 ac (7.7 ha)). (ii) Map of Unit 3 is provided at paragraph (6)(ii) of this entry

Unit 4: Transmitter West, Bay County, Florida. (i) Unit 4 consists of 181.8 acres (73.6 ha) and is composed of lands in State, county, or city ownership (2.2 ac (0.9 ha)), and private ownership (179.6 ac (72.7 ha))

Unit 5: Deer Point, Bay County, Florida. (i) Unit 5 consists of 278.8 ac (112.8 ha) and is composed of lands in State, county, or city ownership (4.5 ac (1.8 ha)), and private ownership (274.3 ac (111.0 ha))

Unit 6: High Point, Bay County, Florida. (i) Unit 6 consists of 36.8 ac (14.9 ha) and is composed of lands in State, county, or city ownership (0.5 ac (0.2 ha)), and private ownership (36.3 ac (14.7 ha)). (ii) Map of Unit 6 is provided at paragraph (10)(ii) of this entry

Unit 7: Star, Bay County, Florida. (i) Unit 7 consists of 1,424.3 ac (576.4 ha) and is composed of lands in State, county, or city ownership (6.5 ac (2.6 ha)), and private ownership (1,417.8 ac (573.8 ha))

Unit 8: Transmitter East, Bay County, Florida. (i) Unit 8 consists of 2,107.4 ac (852.8 ha) and is composed of lands in State, county, or city ownership (49.9 ac (20.2 ha)), and private ownership

(2,057.5 ac (832.6 ha))

Primary Constituent Elements/Physical or Biological Features

Panama City Crayfish (Procambarus econfinae) (1) Critical habitat units are depicted for Bay County, Florida, on the maps in this entry. (2) Within these areas, the physical or biological features essential to the conservation of Panama City crayfish consist of the following components:

(i) Undeveloped lands, including cropland, utilities rights-of-way, timberlands, and grazing lands, that support open wet pine flatwoods and wet prairie habitats that contain the following: (A) Appropriate herbaceous ground cover vegetation; (B) Permanent or temporary pools of shallow (usually less than 1 foot) freshwater locations; and (C) Gently sloped ground-level swales with a 3:1 or shallower slope ratio along ecotonal or transitional areas.

(ii) Soil types within undeveloped lands that provide sediment structure needed for burrow construction and that support mostly native herbaceous vegetation needed for additional food and shelter, and where the ground water is always within 3 feet of the ground surface and surface waters occur on occasion. These soil types include: (A) Core soils for Panama City crayfish, including Pamlico-Dorovan Complex, Rutlege Sand, Plummer Sand, Pelham Sand, Pantego Sandy Loam, and Rutledge-Pamlico Complex; (B) Secondary soils within 50 feet (15 meters) of core soils: Albany Sand, Leefield Sand, Leon Fine Sand, Osier Fine Sand, and Alapaha Loamy Sand; and (C) Soils that currently, or can eventually, support native herbaceous vegetation such as, but not limited to, wiregrass (Aristida beyrichiana), redroot (Lachnanthes caroliniana), beakrushes (Rhynchospora spp.), pitcher plants (Sarracenia spp.), sundews (Drosera spp.), butterworts (Pinguicula spp.), and lilies (Hymenocallis spp.).

(iii) Undeveloped lands that contain surface and groundwater of sufficient quality to support all life stages of the Panama City crayfish and the herbaceous vegetation on which they rely, specifically surface waters with: (A) Oxygen levels that range between 2 and 9 milligrams per liter; (B) pH levels between 4.1 and 9.2; and (C) Temperatures between 42 and 94 degrees Fahrenheit (°F) (5 and 34.4 degrees Celsius (°C)), although optimum temperatures are thought to be in the range of 68 to 79 °F (20 to 26 °C). (3) Critical habitat does not include manmade structures (such as buildings, aqueducts, runways, roads, and other paved areas) and the land on which they are located existing within the legal boundaries on February 4, 2022. (4) Data layers defining map units were created based on known occurrences and habitat requirements. Critical habitat units were mapped in ArcMap (ESRI, Inc.) using the U.S. Department of Agriculture, Natural Resources Conservation Service, Soil Survey Geographic Database dataset. The maps in this entry, as modified by any accompanying regulatory text, establish the boundaries of the critical habitat designation. The coordinates or plot points or both on which each map is based are available to the public at https://www.regulations.gov at Docket No. FWS–R4–ES–2020–0137 and at the field office responsible for this designation. You may obtain field office location information by contacting one of the Service regional offices, the addresses of which are listed at 50 CFR 2.2

Life History

Food/Nutrient Resources

Food Source

Adult: Herbaceous vegetation

Reproductive Strategy

Adult: Oviparity

Lifespan

Adult: 1.5 - 3.5 years (USFWS, 2017)

Breeding Season

Adult: April-August (USFWS, 2017)

Reproduction Narrative

Adult: The life history of this species is not well known. Surveys conducted to date were focused on finding locations where the PCC currently survives and attempting to characterize those habitats and to begin management on easements when possible. Quantitative studies of population densities and the life history were not part of the surveys, although abundance records were captured during certain years. As a result, there are only fragments of information regarding breeding seasons, seasonal occurrence of juveniles, fecundity, and population density. Butler et al. (2003) provides an overview of crayfish of North America and generalities obtained from the study of a few of the many species of cambarid crayfishes: 1) Generally in the southern United States, crayfish mate in the spring and the fertilized eggs adhere to the female's swimmerets while she sequesters herself in a safe place while "in berry" (her egg mass resembles berries). Upon hatching, the young remain with the female for the first three molts before leaving for an independent existence. Brown and Gunderson (1997) stated crayfish are ectothermic, meaning their body temperature is the same as the environmental temperature. Reproduction is cued by seasonal changes (particularly temperature) and growth of juveniles tends to be during the period of maximum availability of food and optimum temperature. This is in response to seasonal changes, also. Optimum temperature for crayfish, regardless of species, is generally thought to be in the range of 68-79o F (20- 26o C). 2) Molting or shedding of the exoskeleton provides a period for growth before the new exoskeleton hardens. This is a critical time for crayfish due to increased vulnerability to predation and pollutants. 3) Many crayfish species have a maximum life span of 1.5 to 3.5 years. According to Hobbs (2001), cambarid crayfishes live about 2.5-3 years. The majority breed more than once, with mating among mature yearlings frequent; however, many individuals do not become sexually active until late summer or fall. 4) Crayfish can be keystone predators in some situations. Some species of crayfish are omnivorous and feed on a wide variety of food items, including plant material, detritus, carrion, and live prey (Smith et al. 2011). Information summarized below is more specific to the PCC and depicted in a life cycle in Figure 2.8: 1) Males alternate between reproductively mature forms (Form I) and nonreproductive forms (Form II) through a continuous series of molts (Taylor et al. 1996, p. 27). Most breed more than once, with mating among mature yearlings frequent. PCC Form I males have been captured in April and June (Hobbs 1942, Keppner and Keppner 2014) 2) There are multiple instances of females captured from burrows with eggs or young and even adult males in the presence of females with young (Hobbs 1942, Keppner and Keppner 2002, FWC 2017 dataset) (Table 2.2). Female PCC have been found with eggs and/or young from March through September. Juveniles are most frequently found in the summer and have been observed through December, so young appear to be produced from at least March to December. Juveniles can be carried overland by sheet flow during rainy periods, which aids in dispersal (Keppner and Keppner 2002) (Table 2.2). Juveniles about the size that just detached from the females (from 15-25 mm in length) were netted a number of times in December 2003 (Keppner and Keppner 2004). However, the number of juveniles encountered decreased from September through December (seasonal dry period)(Table 2.2). During the normal, seasonal dry conditions experienced from April through May, captures are challenging due to limited surface water. We developed a conceptualized life cycle diagram for the PCC based on available life history information but when information was lacking we relied on data available regarding another semi-terrestrial crayfish, Procambarus hayi (Figure 2.8) and general crayfish life history information (Butler et al. 2003; Longshaw and Stebbing 2016). 3) Adult and juvenile PCC crayfish held in captivity have often died during molting phases where neither predation nor pollutants were issues, but perhaps they lacked certain minerals to successfully complete the process (Patty Kelly pers. comm. 2017). Almost all specimens held in aquaria molted at least once during their captivity if captivity was of sufficient duration (Keppner and Keppner 2014). One juvenile molted twice within a span of two months in captivity (Patty Kelly, USFWS, pers. comm. May 2017) (USFWS, 2017).

Habitat Type

Adult: Wet pine flatwoods and wet prairie habitats

Dependencies on Specific Environmental Elements

Adult: The Panama City crayfish needs freshwater wetlands that support herbaceous vegetation, which is important to the Panama City crayfish for food, shelter, and detritus formation. The species needs core or secondary soils to provide the proper sediment structure for burrow construction and to support the herbaceous vegetation. The Panama City crayfish needs access to groundwater (through burrowing) or surface water to prevent desiccation of individuals and populations. The species needs both adequate water quality and quantity to fulfill its life history (USFWS, 2018).

Environmental Specificity

Adult: Narrow (inferred from USFWS, 2018)

Habitat Narrative

Adult: The Panama City crayfish is endemic to specific soil types in Bay County, Florida (Figure 1). The species inhabits shallow, ephemeral, freshwater wetlands. Ideal habitat is dominated by herbaceous vegetation with little to no shrub or tree cover. Due to this species' need to burrow when there is an absence of surface water, specific soil types are required to support Panama City crayfish during the dry season and droughts (Figure 1). The core soil types support herbaceous vegetation and provide adequate sediment structure for burrow construction that allows the species to access the water table during droughts. Secondary soils, adjacent to core soils, provide similar requirements when the water table is high enough but also support dispersal during sheet flow rain events. Refer to the SSA table 2.3 for more information on soil types that support this species (USFWS, 2024). Historically, the PCC inhabited natural and often temporary bodies of shallow fresh water within open pine flatwoods and prairie-marsh communities (Hobbs 1942). However, most of these communities have been cleared for residential or commercial development or replaced with slash pine plantations. Thus, the PCC currently is known to inhabit the waters of grassy, gently-sloped ditches and swales, slash pine plantations, and utility rights-of-way (Keppner and Keppner 2001). Several conservation easements within their range are under management for the PCC. These easements are largely wet pine flatwoods and wet prairie habitats. Other private lands are inaccessible to surveyors although, lacking significant disturbance, are likely occupied by PCC given the appropriate soil types discussed further below (USFWS, 2017).

Dispersal/Migration

Motility/Mobility

Adult: Low (USFWS, 2022)

Dispersal

Adult: Low (USFWS, 2022)

Population Information and Trends

Population Trends:

Unknown (USFWS, 2019)

Number of Populations:

A genetic analysis describes eight localized populations occurring in a western grouping and four localized populations occurring in an eastern grouping (Duncan et al. 2017, entire). The 12 populations are described in more detail in the SSA report (USFWS, 2022).

Population Size:

Currently, we have estimated population sizes at three sites (19th Street, Transmitter West, Talkington). Abundance ranges from 34 to 623 (USFWS, 2022)

Minimum Viable Population Size:

The conservation strategy identifies goals that may need to be met in order to ensure recovery of the Panama City crayfish and states that a minimum viable population size (MVP) for Panama City crayfish of 5,137 individuals and 2,200 acres of actively managed habitat across the range that is permanently protected and managed across at least seven population units should ensure the Panama City crayfish maintains viability for the future (USFWS, 2022).

Population Narrative:

The Panama City crayfish historically ranged throughout south-central Bay County, Florida, within a 56-squaremile area (14,504 ha; see figure, below). The historical range likely created one population connected by core and secondary soils. As urban growth came to Panama City, the range of the Panama City crayfish became fragmented into isolated patches. Today, the species has 12 localized (i.e., isolated) populations that can be divided into two groups, based on patterns in fragmentation from urban development: The western group and eastern group, using Transmitter Road as the primary division. Localized populations were delineated using a landscape genetic analysis based on a pattern of isolation-by-distance, where increasing geographic separation tends to reflect increasing genetic differentiation (Duncan et al. 2017, entire) (USFWS, 2022).

Threats and Stressors

Stressor: The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range
Exposure:
Response:
Consequence:
Narrative: Development projects and land conversion can result in direct loss of habitat, as well as fragmentation and isolation of populations. The effects of development may also include alterations to water quality and quantity. Historically, the Panama City crayfish inhabited natural and often temporary bodies of shallow fresh water within open pine flatwoods and wet prairie-marsh communities (Hobbs 1942). The Panama City crayfish's natural habitat (wet pine flatwoods) has been lost or degraded through residential, commercial, and industrial development, as well as conversion to intensive pine silviculture and for ranching and farming uses. It is likely that no unaltered natural pine flatwoods remain within the Panama City crayfish's current range. Most known Panama City crayfish occurrences are in human-altered habitats and are vulnerable to further loss or alteration. Although artificial habitats such as roadside ditches and rights-of-way have allowed the Panama City crayfish to persist in areas from which they would otherwise likely have been extirpated, human activities can alter the hydrology and configuration of these sites, making them unsuitable for long-term Panama City crayfish persistence. For example, roadside ditch maintenance and construction activities have resulted in the destruction of several crayfish sites. While ditch maintenance activities may have temporary negative impacts on the species, if conducted using conservation management principles, they may provide long-term habitat improvements that support Panama City crayfish presence. For example, the design of the ditch helps determine whether it can support Panama City crayfish. Swales and ditches with herbaceous vegetation and a 3:1 or shallower slope are more likely to support Panama City crayfish than ditches with a steeper slope (FWC 2017, p. 22). Infrastructure development has impacted, or is anticipated to impact, several crayfish sites (Keppner and Keppner 2001, pp. 13–14, 2004, p. 9). For example, several proposed road construction or expansion projects, such as the widening of Star Avenue and Kern Avenue and the widening and hardening of Tram Road, may impact Panama City crayfish habitat in the future. Infrastructure development can eliminate suitable Panama City crayfish habitat by removing the required herbaceous vegetation and digging up the surrounding soils. Silvicultural practices such as ditching and bedding, roller chopping, installing fire breaks, and constructing roads can alter the hydrology of Panama City crayfish sites, create physical barriers to crayfish movement, and destroy underground burrows (Hobbs 2001, p. 988; Keppner and Keppner 2001, p. 13, 2004, p. 10; FWC 2006, p. 10). These activities may contribute to the isolation of Panama City crayfish populations. Fire suppression and high tree density on silvicultural sites can reduce herbaceous groundcover necessary for suitable crayfish habitat (Keppner and Keppner 2001, p. 13, 2004, p. 10; FWC 2006, p. 27). Similarly, removal of tree canopy cover, changes in ground cover vegetation, and associated changes in water quality and surface water availability are all possible changes associated with the effects of conversion to farming and ranching practices, such as cattle grazing (e.g., Jansen and Robertson 2001, pp. 71–73). These activities negatively impact the habitat of the Panama City crayfish. Although minimal changes are expected to occur due to farming and ranching practices, conversion from silviculture to grazing use has occurred on lands adjacent the crayfish's range (USFWS, 2018).

Stressor: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes
Exposure:
Response:

Consequence:
Narrative: Crayfish may be recreationally harvested for fish bait. Within the range of the Panama City crayfish, several of the areas where the species occurs are known to be utilized by locals collecting fish bait (FWC 2016, p.11; Keppner and Keppner 2001, 2005). However, although harvesting individual crayfish at these sites has been documented, the actual species collected are unknown. Therefore, while harvesting crayfish may be impacting individual Panama City crayfish, we find that it is not having a species-wide impact (USFWS, 2018).

Stressor: Habitat Degradation, Loss, and Fragmentation
Exposure:
Response:
Consequence:
Narrative: Development projects and land conversion can result in direct loss of habitat, leading to fragmentation and isolation of populations. Historically, the Panama City crayfish inhabited natural and often temporary bodies of shallow fresh water within open pine flatwoods and wet prairiemarsh communities. The Panama City crayfish's natural habitat (wet pine flatwoods) has been lost or degraded through residential, commercial, and industrial development, as well as conversion to intensive pine silviculture, and for ranching and farming uses. No unaltered natural pine flatwoods remain within the Panama City crayfish's current range. Most known Panama City crayfish current occurrences are in human-altered habitats and are vulnerable to further loss or alteration. Although artificial habitats such as roadside ditches and rights-of-way have allowed the Panama City crayfish to survive in areas from which they would otherwise likely have been extirpated, human activities can alter the hydrology and configuration of these sites, making them unsuitable for long-term Panama City crayfish survival. For example, roadside ditch maintenance and construction activities have resulted in the destruction of several crayfish sites. Infrastructure development has impacted, or is anticipated to impact, several known crayfish sites. For example, several road construction or expansion projects, such as the widening of Star Avenue and Kern Avenue and the widening and hardening of Tram Road, may impact Panama City crayfish habitat in the future. Infrastructure development can eliminate suitable Panama City crayfish habitat by removing the required herbaceous vegetation and digging up the surrounding soils. Silvicultural practices such as ditching and bedding, roller chopping, installing fire breaks, and constructing roads can alter the hydrology of Panama City crayfish sites, create physical barriers to crayfish movement, and destroy underground burrows. These activities may contribute to the isolation of Panama City crayfish populations. Fire suppression and high tree density on silvicultural sites can reduce herbaceous groundcover necessary for suitable crayfish habitat. Similarly, removal of tree canopy cover, changes in ground cover vegetation, and associated changes in water quality and surface water availability are all possible changes associated with the effects of conversion to farming and ranching practices, such as cattle grazing. These activities reduce the suitability of the habitat for the Panama City crayfish. Although minimal changes to habitat in the future are expected to occur from farming and ranching practices, conversion from silviculture to grazing use has historically occurred on lands adjacent the crayfish's range. Ditching and draining urban areas is a common practice in efforts to control local flooding events and reduce mosquito outbreaks but could have accidental impacts, especially to populations with small amounts of available habitat, by artificially draining or decreasing the amount of time that surface waters are available. The majority of known Panama City crayfish occurrences, particularly in the western part of the range, are in roadside ditches and swales and thus are vulnerable to impacts from ditching and draining activities. Additionally, nearly all populations are isolated from other Panama City crayfish populations by

roads and development. Fragmentation and isolation can increase vulnerability to local extirpation due to adverse genetic, demographic, and environmental events. Further, when Panama City crayfish are extirpated from an area, lack of habitat connections between sites can prevent Panama City crayfish from recolonizing (FWC 2016, p. 10). Recent genetic work indicates the isolation throughout the range has resulted in inbreeding and drift (Duncan et al. 2017, p. 17) (USFWS, 2022).

Stressor: Water Quality
Exposure:
Response:
Consequence:
Narrative: Freshwater crayfish may be sensitive to declines in water quality, and these water quality declines have been identified as a threat to the Panama City crayfish. Water quality declines can range from oxygendeficient conditions resulting from algal blooms or sewage spills to pollution originating from roadway runoff, pesticide applications, or chemical spills. Given the level of development throughout the range of the Panama City crayfish and the occurrences of Panama City crayfish adjacent to private properties, runoff from roads or incompatible application of chemicals, such as pesticides or fertilizers, negatively impacts water quality and has direct impacts on the species. Mosquitocides are used within the range of the Panama City crayfish to treat both larval and adult mosquitos. The mosquitocides registered for use within the range of the Panama City crayfish do not pose known threats to water quality if applied per label directions (FWC 2016, p. 10). If incorrectly applied, however, the consequences to the Panama City crayfish can be fatal. Similarly, fertilizers, insecticides, and herbicides may pose a risk to Panama City crayfish if applied inappropriately. Many substances commonly used around the home or business can be toxic to Panama City crayfish and other wildlife if used or disposed of improperly. Since Panama City crayfish often inhabit ditches and swales close or adjacent to private properties, they are at risk if landowners do not ensure that fertilizers, insecticides, and herbicides are applied and disposed of properly per label directions. Potentially toxic substances such as petroleum products and paint should be properly disposed of at hazardous waste disposal facilities. Accidental spills of large volumes of toxic substances such as petroleum products and acids occasionally occur in urban areas. If spills overflow into ditches, swales, or other areas inhabited by Panama City crayfish, substantial localized impacts to the population are possible (USFWS, 2022).

Stressor: Bait Collection
Exposure:
Response:
Consequence:
Narrative: Collecting Panama City crayfish for fish bait or other uses may have long-term effects on populations if large numbers of adults are taken from a population. Several lines of evidence indicate that current occupied sites are used as sources for catching crayfish for fish bait. Although this activity is occurring, the magnitude of the impact of recreational harvest on the Panama City crayfish is unknown (Keppner and Keppner 2001, p. 14; Keppner and Keppner 2005, p. 11) (USFWS, 2022).

Recovery

Reclassification Criteria:

Recovery Priority Number: 2

Delisting Criteria:
Recovery Criterion 1. At least five Panama City crayfish populations, distributed across its range, with evidence of natural recruitment, and multiple age classes over a ten-year monitoring period (USFWS, 2024).

Recovery Criterion 2. At least 2,200 acres of suitable Panama City crayfish habitat are protected and managed such that threats are abated to the extent that the species will maintain resiliency into the foreseeable future (USFWS, 2024).

Recovery Criterion 3. All five populations mentioned in Criterion 1 are within the actively managed habitat specified in Criterion 2 (USFWS, 2024).

Recovery Actions:
- Several private lands within the Panama City crayfish's range are being managed under conservation easements for the species. These easements largely cover wet pine flatwoods and wet prairie habitats. Other private lands are inaccessible to surveyors, but if they lack significant disturbance and have suitable habitat for the species, they are likely occupied by Panama City crayfish. Areas in silviculture adjacent to human-altered habitats may serve as refuges for Panama City crayfish, and silvicultural BMPs require operators to minimize impacts to Panama City crayfish. Use of BMPs for agriculture and grazing can also help minimize impacts to aquatic species (e.g., Florida Department of Agriculture and Consumer Services 2008, p. 1). Gulf Power Company manages rights-of-way along approximately 114 acres of land that is populated by the Panama City crayfish. The Service and FWC have a management agreement that provides recommended BMPs to Gulf Power Company; the management practices through this agreement have proven effective as the crayfish continue to thrive within the easement areas (USFWS, 2018).

References

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SPECIES ACCOUNT: *Procambarus milleri* (Miami Cave crayfish)

Species Taxonomic and Listing Information

Listing Status: Proposed Threatened

Physical Description

In contrast to the sexual dimorphism exhibited by many crayfish species, females and males of the Miami cave crayfish do not demonstrate any significant size differences and adults of both sexes bear relatively large claws (Loftus and Trexler 2004, p. 47; Loftus and Bruno 2006, p. 135; Radice and Loftus 1995, pp. 113-114). The carapace lengths reported in wild adults range from 0.3 inch (8 millimeters (mm)) up to 1.1 inches (27.4 mm) (Hobbs 1971, p. 121; Loftus and Trexler 2004, p. 45; Loftus and Bruno 2006, p. 135; Cook et al. 2018, suppl.). Captive-bred adults are larger than are those sampled from wild populations, most likely due to the increased food availability and reduced predatory and competitive pressures in captive settings. The average carapace length of captive adult Miami cave crayfish is 0.05 inch (1.25 mm) longer than that of wild adults (Loftus and Trexler 2004, pp. 46-47; Loftus and Bruno 2006, p. 135). Although first described as unpigmented by Hobbs (1971, p. 115), adult Miami cave crayfish have black eye spots and are most commonly dark orange in color with a distinctive reddish stripe extending medially on the dorsal surface from the first abdominal segment to the sixth (Loftus and Trexler 2004, pp. 45-47; Loftus and Bruno 2006, p. 135; Radice and Loftus 1995, pp. 114, 116) (Figure 2.2.2). Approximately 83 percent of 2,451 adult, captive-reared Miami crayfish exhibited this color pattern, while 8.8 percent displayed a more muted orange coloration ((Loftus and Trexler 2004, pp. 45-47; Loftus and Bruno 2006, p. 135). Less common color variations demonstrated by captive-born individuals included hues of pink, blue, red, green, beige, and brown, accounting for a combined total of 8.5 percent of the adults inspected (Loftus and Trexler 2004, pp. 45-47; Loftus and Bruno 2006, p. 135; Radice and Loftus 1995, pp. 114, 116). Egg masses are pigmented, and the majority of captive-bred juveniles bear red pigmentation upon hatching (Loftus and Trexler 2004, pp. 46-47) (Figure 2.2.2). However, 10 percent of the captive juveniles examined in 1994 were albino, a trait lost in the captive population following this generation as a result of disease-related die-off (Loftus and Trexler 2004, pp. 46-47). The presence of pigmentation in the majority of wild and captive Miami cave crayfish suggests that the species is still in the process of adapting to its subterranean environment (i.e., stygophilic (adapted to living in both surface and subterranean habitats) versus stygobitic (strictly subterranean)) (Hobbs 1971, pp. 121-122; Caine 1974, pp. 490-491; Loftus and Trexler 2004, p. 50; Loftus and Bruno 2006, p. 135) (USFWS, 2022).

Taxonomy

Encompassing 178 described species worldwide and nearly half of all American crayfish taxa, the genus Procambarus is the largest genus of freshwater crayfish. Although the monophyly of this New World genus has been called into question by recent molecular analyses, the taxon has historically been subdivided into 15-17 distinct subgenera, which include Acucauda, Austrocambarus, Capillicambarus, Distocambarus, Girardiella, Hagenides, Leconticambarus, Lonnbergius, Mexicambarus, Ortmannicus, Remoticambarus, Paracambarus, Pennides, Procambarus, Scapulicambarus, Tenuicambarus, and Villalobosus (Hobbs 1984, entire; Owen et al. 2015, pp. 4-5; Longshaw and Stebbing 2016, p. 206). The distinguishing feature of the genus Procambarus is the presence of four terminal elements of the male gonopod. Although the majority of the diversity in this genus is within the southeastern United States, representatives extend throughout much of the eastern portion of North America, along the eastern seaboard and the coastal regions of the Gulf of Mexico, up the Mississippi River drainage as far as Wisconsin, and south through Texas into Mexico. Several species of Procambarus extend through Central America to Honduras, while three are endemic to Cuba (Hobbs 1984, entire; Longshaw and Stebbing 2016, p. 206). The Miami cave crayfish (Procambarus milleri; assigned to the subgenus Leconticambarus) was first described from specimens collected from a 22 foot (ft) (6.7 meter (m)) deep well drilled into the Biscayne Aquifer in Miami-Dade County, Florida (Hobbs 1971, entire). The species has recently adapted to the subterranean environment as is indicated by the presence of both pigment and eye facets in individuals (Hobbs 1971, pp. 121-122; Caine 1974, pp. 490-491; Loftus and Trexler 2004, p. 50; Loftus and Bruno 2006, p. 135). The Miami cave crayfish is considered a valid taxon and meets the ESA definition of a species. The currently accepted classification is (Integrated Taxonomic Information System 2021): Phylum: Arthropoda Class: Malacostraca Order: Decapoda Family: Cambaridae Genus: Procambarus Species: Procambarus milleri (USFWS, 2022)

Historical Range

The historical and current range of the Miami cave crayfish is restricted to areas of the Biscayne Aquifer along the Atlantic Coastal Ridge in southern and central Miami-Dade County, Florida east of the Everglades wetland ecosystem (Figure 2.6.1) (Hobbs 1971, pp. 114, 121; Loftus and Trexler 2004, p. 45; Loftus and Bruno 2006, p. 135; Radice and Loftus 1995, pp. 112, 114; Cook et al. 2018, suppl.; P. Moler pers. comm. 2021). Hobbs (1971, entire) first described the species based on specimens recovered from a well trap on the grounds of a nursery south of Miami in 1968. The next confirmed report of the species was from a fish farm in Homestead in 1992. Two individuals were initially discovered during a well blowout, followed by seven additional specimens captured over two months in a baited trap placed 24.9 ft (7.6 m) down the well hole (USFWS, 2022).

Current Range

The historical and current range of the Miami cave crayfish is restricted to areas of the Biscayne Aquifer along the Atlantic Coastal Ridge in southern and central Miami-Dade County, Florida east of the Everglades wetland ecosystem (Figure 2.6.1) (Hobbs 1971, pp. 114, 121; Loftus and Trexler 2004, p. 45; Loftus and Bruno 2006, p. 135; Radice and Loftus 1995, pp. 112, 114; Cook et al. 2018, suppl.; P. Moler pers. comm. 2021). Hobbs (1971, entire) first described the species based on specimens recovered from a well trap on the grounds of a nursery south of Miami in 1968. The next confirmed report of the species was from a fish farm in Homestead in 1992. Two individuals were initially discovered during a well blowout, followed by seven additional specimens captured over two months in a baited trap placed 24.9 ft (7.6 m) down the well hole (USFWS, 2022).

Critical Habitat Designated

No;

Life History

Food/Nutrient Resources

Reproductive Strategy

Adult: Oviparous (USFWS, 2022)

Lifespan

Adult: Unknown

Breeding Season

Adult: continuous reproduction throughout the year, peaking in the late summer through early winter. (USFWS, 2022)

Reproduction Narrative

Adult: Miami cave crayfish begin life as fertilized black eggs (~0.08 inch (~2 mm) in diameter) adhering to the pleopods underneath a female's abdomen (Figure 2.3.1). Mature females produced up to 100 eggs in captivity, averaging 50 eggs across the 37 females measured (Radice and Loftus 1995, p. 114; Loftus and Trexler 2004, pp. 47-48; Loftus and Bruno 2006, p. 135). Gravid females are larger than non-gravid females, and larger Miami cave crayfish produce more eggs per clutch (Loftus and Trexler 2004, pp. 47-48). Miami cave crayfish lay fewer and larger eggs in comparison to the closely-related, surface-dwelling Everglades crayfish (Procambarus alleni), a general reproductive pattern predicted by life-history theory. In order to optimize reproductive success over a lifetime, the food-resource-limited subterranean crayfish species benefits from investing in less, but larger offspring in a clutch, while the surface crayfish with more extensive food resources maximizes its success with more eggs of smaller size per clutch (Loftus and Trexler 2004, p. 48; Loftus and Bruno 2006, p. 135). After hatching, the young of crayfish species attach to the female by a "telson thread," a ropelike structure binding the eggshell attached to the last segment of the abdomen of the female to the abdomen of the hatchling (Vogt and Tolley 2004, pp. 569-571). Young crayfish undergo a series of molts (a process of shedding, or molting, their old exoskeleton, and growing and hardening the new exoskeleton) while still attached to the female (Jezerinac et al. 1995, p. 17; Taylor et al. 1996, pp. 26-27). During this time, females will care for and protect their young (Vogt and Tolley 2004, p. 573). Juveniles then leave the female to begin life as free-living individuals. At water temperatures of 75.2 degrees Fahrenheit (˚F) (24˚Celsius (C)) in captivity, Miami cave crayfish juveniles are released by the female in approximately three to four weeks. In captivity, Miami cave crayfish exhibit continuous reproduction throughout the year, peaking in the late summer through early winter. In captive conditions, gravid females were present in every month with the highest annual abundance recorded in January through March (Loftus and Trexler 2004, pp. 47-48; Loftus and Bruno 2006, p. 135). Similarly, captive free-living juveniles were sampled in every month, becoming most numerous in summer through winter counts (Loftus and Trexler 2004, p. 47). Females of this species have the capacity to breed more than once a year as demonstrated by a captive female who produced two successful summer broods in just 3 ½ months. On average, throughout the year, 91 percent of gravid females in a captive population of Miami cave crayfish had fertile eggs, while the remaining 9 percent had attached juveniles (Loftus and Trexler 2004, pp. 47-48). (USFWS, 2022)

Habitat Type

Adult: Subterranean Aquifer

Habitat Narrative

Adult: The Miami cave crayfish is a relatively small, freshwater, subterranean crustacean endemic to southern and central Miami-Dade County, Florida. The species has recently adapted to the belowground aquifer environment as is indicated by the presence of both pigment and eye facets in some individuals. The species has been collected from wells 7.9-36 ft (2.41-11 m) deep in the Miami Limestone and Fort Thompson limestone formation within the Biscayne Aquifer along the Atlantic Coastal Ridge in southern and central Miami-Dade County, Florida. Hobbs first described the species based on specimens collected south of Miami in 1968. Additional confirmed reports of the species followed in 1992, 2000-2004, 2009, and most recently in 2018. Despite significant sampling effort, no specimens have been recovered from groundwater wells of similar depths within Everglades National Park, even those sampled along the western-most, isolated segment of the Atlantic Coastal Ridge at Long Pine Key (USFWS, 2022)

Dispersal/Migration

Population Information and Trends

Number of Populations:
1 (USFWS, 2022)

Threats and Stressors

Stressor: Development
Exposure:
Response:
Consequence:
Narrative: We use the term “development” to refer to urbanization of the landscape, including (but not necessarily limited to) land conversion for urban and commercial use, infrastructure (roads, bridges, utilities), and urban water uses (water supply reservoirs, wastewater treatment, etc.). As of April 1, 2020, Miami-Dade County was one of the most populous counties in the United States with a population of 2,701,767, an increase of 8.8 percent since 2010 (U.S. Census Bureau 2021, unpaginated). The majority of Miami-Dade county’s residents are concentrated in urban sprawl stretching across approximately 598 square miles (1,550 square kilometers), mostly along the Atlantic Coastal Ridge (Bradner et al. 2005, p. 3) (Figure 3.1.2). Development in the county is anticipated to rise into the future in conjunction with burgeoning human populations, and approximately 6,718 acres (27 square kilometers) that overlay Miami cave crayfish habitat have already been identified to accommodate the urban expansion for the approximately 3,343,700 people who will be residing in the county within the next twenty years (Carr and Zwick 2016, p. 30; Miami-Dade County Department of Regulatory and Economic Resources 2021, pp. 2-5) (Table 3.1.1). Accordingly, the direct and indirect threats associated with development affect the viability of not only current populations of Miami cave crayfish, but future ones as well.

Stressor: Agriculture
Exposure:
Response:
Consequence:
Narrative: Land use directly related to agricultural activities accounts for approximately 36,825 acres (14,902.5 hectares (ha)) of surface cover extending across the endemic range of Miami cave crayfish (Miami-Dade County. 2021a) (Figure 3.1.3; Appendix B). The vast majority of this agriculture (~97 percent) falls into the category of plant agriculture, which is dominated by winter vegetables, nursery ornamentals, and citrus and other tropical fruits. Animal agriculture

(e.g., poultry, livestock, horses), aquaculture, and farm storage areas supporting agricultural activities only cover about 3 percent of the total agricultural acreage overlying Miami cave crayfish habitat (Figure 3.1.4; Appendix B). Although all populations of the species experience the effects of agricultural land use, analysis units 1, 2, and 3 are the most affected with total agricultural surface coverages of 12,074.30 acres (4,886.3 ha), 16930.41 acres (6,851.5 ha), and 7,651.41 acres (3,096.4 ha), respectively

Stressor: Anthropogenic Modification of Detrital Input
Exposure:
Response:
Consequence:
Narrative: Anthropogenic land use further serves to curtail the amount and quality of detrital influx into the Biscayne Aquifer by altering the type, quantity, and temporal distribution of vegetation that remains as surface cover in agricultural and developed regions. Post-colonial introductions of non-native plants have led to the spread of alien invasive species throughout south Florida (Stys et al. 2017, p. 363). For the purposes of this SSA, we define "alien invasive species" as an alien species (i.e., a taxon occurring outside of its natural range and dispersal potential) that becomes established in natural or semi-natural ecosystems, is an agent of change, and threatens native biological diversity per the Invasive Species Specialist Group (ISSG; 2000, pp. 5-6). There are dozens of terrestrial alien invasive plants that range across the surface area above Miami cave crayfish habitat. Over twenty species are on the U.S. Department of Agriculture's federal and state noxious weeds list (Hunsberger and Peña 2019, p. 1), while two taxa of alien invasive trees (Australian pine (Casuarina equisetifolia) and portia tree (Thespesia populnea)) that are not on the state noxious weeds list are widespread in Miami-Dade County (EDDMapS 2021, unpaginated). In their replacement of the native floral community, these alien invasive species alter not only the quantity but the type of detrital input that filters into subterranean ecosystems.

Stressor: Climate Change
Exposure:
Response:
Consequence:
Narrative: The Intergovernmental Panel on Climate Change (IPCC) concluded that the evidence for warming of the global climate system due to human influence is unequivocal (IPCC 2014, p. 2; IPCC 2021, pp. 5-8). Numerous long-term and rapid climate changes have been observed in the atmosphere, cryosphere, oceans, and biosphere, including but not limited to widespread changes in precipitation amounts, global sea level rise, elevated ocean salinity and acidification, and increases in the number and intensity of extreme weather events (e.g., droughts, heat waves, tropical cyclones) (IPCC 2014, pp. 2–4; IPCC 2021, pp. 5-11). The general climate trend for South Florida includes increases in mean annual temperatures, fluctuations in precipitation patterns, and the increased likelihood of extreme weather events by the mid-21st century

Recovery

Conservation Measures and Best Management Practices:

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Additional Threshold Information:

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References

USFWS. 2022. Species status assessment report for the Miami Cave Crayfish (Procambarus milleri). Version 1.2. September 20, 2023. Atlanta, GA. 167 pages.

SPECIES ACCOUNT: *Procambarus pictus* (Black Creek crayfish)

Species Taxonomic and Listing Information

Listing Status: Proposed Endangered

Physical Description

Black Creek crayfish (Fig. 2.1) is a small to medium sized crayfish species with dark claws (chelae) and a dark carapace that is bisected by a white to light yellow dorsal stripe. Individuals average 7.6 cm (3 in) in total body length but can be found up to 8.9 cm (3.5 in) long in late summer (Franz 1994, p. 212). The abdomen is rust colored with black banding and there are white spots, streaks or flecking present on its sides, which is a pattern unique to live Black Creek crayfish; no other cambarid crayfish look similar (Franz et al. 2008, p. 1). Black Creek crayfish have a series of ten bumps present on their claws, a rostrum with lateral spines, a broad areola with 7-10 punctuations in the narrowest part, and ridges behind the eyes terminating forward in sharp spines (Florida Natural Areas Inventory [FNAI] 2001, p. 1). Black Creek crayfish have small gill chambers, which are an adaptation for using highly oxygenated streams (USFWS, 2024).

Taxonomy

The Black Creek crayfish was first described in 1940 by Horton H. Hobbs, Jr. (Hobbs 1940, p. 419) and was further refined taxonomically by Hobbs in 1958 (Hobbs 1958, entire). It belongs to the family Cambaridae, order Decapoda, and has no recognized subspecies. Black Creek crayfish are closely related to some cave crayfish in peninsular Florida and, though distantly related, similar in form to ancestral cave crayfishes in the subgenus Procambarus (Lonnbergius) in Putnam, Orange, and Seminole counties (P. Moler 2020, pers. comm.). Propictus crayfish that colonized peninsular Florida are believed to be a “relict” from an insular landmass, which persisted through higher sea levels during the Pleistocene (Hobbs 1958, p. 87). Hobbs (1972, p. 9) placed Black Creek crayfish in the subgenus Ortmannicus. The subgeneric classifications were eliminated by Crandall and De Grave (2017, p. 619) in their updated classification of the freshwater crayfishes due to lack of evidence for phylogenetic uniqueness. (USFWS, 2024)

Historical Range

The historical range of this species is largely unknown. Prior to 1976, Black Creek crayfish were only known from two streams, Governors Creek and Peters Creek, in Clay County (Fig. 2.5; Hobbs 1942a). Comprehensive fieldwork for the species did not occur until the late 1970s, when the species was found to inhabit the extensive Black Creek basin originating in western Clay County. The current range of the Black Creek crayfish is restricted to the Lower St. Johns River Basin in four northeastern Florida counties (Figs 1.1 and 2.5). Black Creek crayfish currently occupies 19 subwatersheds across its range (Fig. 2.5). Two subwatersheds where Black Creek crayfish were located historically do not have any recent detections (Clapboard Creek [Raleys Creek] (1984) and Little Black Creek (1979) Fig. 2.5) (USFWS, 2024)

Current Range

See Historical Range

Critical Habitat Designated

No;

Life History

Food/Nutrient Resources

Reproductive Strategy

Adult: Oviparity

Breeding Season

Adult: Jan - Sept

Reproduction Narrative

Adult: Black Creek crayfish hatch in late summer and likely live a maximum of 16 months (Franz 1994, p. 212), limiting a female to one clutch of eggs in her lifetime. Male Black Creek crayfish alternate between a reproductively ready form (Form I), observed from January to September, and a non-reproductive form (Form II). Reproductive female Black Creek crayfish, observed from June to August, carry between 47 and 146 eggs on the underside of their abdomen (Fig. 2.2; Franz 1994, p. 212). Eggs stay attached to the female for 2 to 3 weeks (Fig. 2.3). Hatching begins in July and young are recruited into the population in August (Franz 1994, p. 212). (USFWS, 2024)

Habitat Type

Adult: Stream

Environmental Specificity

Adult: Narrow

Site Fidelity

Adult: High

Habitat Narrative

Adult: Black Creek crayfish rely on cool, flowing, sand-bottomed, and tannic-stained streams that are highly oxygenated (Franz and Franz 1979, p. 14; Franz 1994, p. 212). These high-quality streams typically originate in sandhills and may flow through swampy terrain (Franz and Franz 1979, p. 14; Brody 1990, pp. 8-11; FNAI 2001, pp. 102; Nelson and Floyd 2011, p.1). Preliminary data suggest that Black Creek crayfish are not found in water with temperatures over 30°C (86°F; Warren et al. 2019b, unpublished data). Locations that fulfill the species' habitat requirements are typically headwater sections of streams that maintain a constant flow; however, the species is found in small and large tributary streams that fulfill other habitat criteria (e.g., high oxygen levels, sandy bottom) (Franz and Franz 1979, p. 14). Within these streams, Black Creek crayfish require cover – such as, aquatic vegetation, detritus packs, woody debris, tree roots, or undercut banks – for shelter. Black Creek crayfish are primarily found in forested stream reaches but also occupy areas with more open canopies. In forested sections of habitat (Fig. 2.4a), surrounding riparian areas provide shade which cools the air and water temperature, and provides woody detritus which serves as refuge and a food source (Franz et al. 2008, p. 16; FWC 2013, pp. 2, 19). In open stretches of habitat (Fig. 2.4b), Black Creek crayfish rely on aquatic vegetation or other sources for cover. (USFWS, 2024)

Dispersal/Migration

Dispersal/Migration Narrative

Adult: Home range sizes and dispersal distances for Black Creek crayfish are not well known, but they are believed to be small based on observations of other native, non-invasive crayfish (Bubb et al. 2006, p. 1363). Based on these presumed small home range sizes, unknown dispersal distances, and stream habitat heterogeneity, it is possible that multiple crayfish populations exist within an analysis unit. However, we do not have adequate data to support delineating smaller populations at this time; additional research could inform a change in population delineations in the future. We considered all analysis units with Black Creek crayfish observations from 2008 to 2023 for current condition. Two analysis units, Clapboard Creek and Little Black Creek, have not had detections of Black Creek crayfish since 1984 and 1979, respectively. These two units were considered historical populations and were not assessed in current condition. (USFWS, 2024)

Population Information and Trends

Number of Populations:

found in 14 of 19 HUCs (USFWS, 2024)

Population Narrative:

Black creek crayfish is found in 14 of 19 Habitat Units (USFWS, 2024)

Threats and Stressors

Stressor: White tubercled crayfish (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: The white tubercled crayfish (WTC), a pioneering crayfish from an adjacent watershed was introduced to the Black Creek crayfish's range and is likely influencing Black Creek crayfish through competition for food and shelter and possibly through direct predation. Crayfish introductions are one of the leading threats to native crayfish and there are numerous case studies of introduced crayfish replacing native species (Light et al. 1995, entire; Olden et al. 2006, entire; Distefano and Westhoff 2011, entire; Imhoff et al. 2012, entire). Competition is the most studied mechanism for crayfish replacements (Capelli and Munjal 1982, entire; Chucholl et al. 2008, entire), but introduced crayfish can also affect disease spread (Gherardi 2007, p. 515-517) or hybridization (Perry et al. 2002, p. 262-267). Although studies have found no direct predation of white tubercled crayfish on Black Creek crayfish (Reisinger et al. 2023, p.11), crayfish are opportunistic omnivores and the white tubercled crayfish may prey on Black Creek crayfish young. One study found a relatively high rate of animal tissue in the stomachs of white tubercled crayfish (Hightower and Bechler 2013, p. 85) compared to other studied crayfish species (Taylor and Soucek 2010, p.286-289). Few field studies have looked at the direct predation of juvenile crayfish by adults. The available data indicate that adult crayfish do eat newly hatched juveniles; and that frequency of cannibalism is dependent on availability of adequate shelter, food, and the presence of larger crayfish (Olsson and Nyström 2009, p. 36). The presence of large crayfish can also negatively affect feeding behavior, since juveniles would be hiding while the larger crayfish are active, resulting in reduced growth and missed feeding opportunities (Olson and Nyström 2009, p. 36). (USFWS, 2024)

Stressor: Disease (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Another emerging threat associated with potential Black Creek crayfish declines include microsporidian diseases. Black Creek crayfish with an apparent microsporidian disease have been reported by Franz et al. (2008, p. 13), Nelson and Floyd (2011, p. 6), Smith-Hicks (2020, p. 1), and have been extensively studied in more recent years (Reisinger et al. 2023, p. 10-11). Microsporidia are spore-forming, obligate, intracellular parasites whose numerous hosts include crayfish. In crayfish, the disease usually causes the deterioration of muscle tissue, lethargy, and eventually death (Freeman et al. 2020, p. 217-218). Visual signs of the disease are white streaks or white opaque abdominal tissue, lending to the name 'porcelain disease' or cotton tail' that usually becomes more pronounced as the infection progresses (Fig. 4.5). (USFWS, 2024)

Stressor: Water withdrawl (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Water withdrawal for use in public water systems (i.e., residential and nonresidential uses supplied by public and private utilities), agricultural irrigation, recreational irrigation, commercial/industrial use, and thermoelectric power generation has the potential to decrease both surface and groundwater supply, thus potentially affecting Black Creek crayfish habitat. In 2003, the St. Johns River Water Management District (SJRWMD) prepared a water supply assessment to identify future water supply needs (through 2025) and to identify areas where those needs could not be met by the water supply plans without unacceptable impacts to water resources and natural systems within the range of the Black Creek crayfish (SJRWMD 2003, p. 1). The SJRWMD and the neighboring Suwannee River Water Management District (SRWMD) together completed a similar supply plan with future analyses in 2017, which evaluated water use predictions through the year 2035 (SJRWMD and SRWMD 2017, entire). There is a projected increase in total water use based upon assumed average rainfall conditions from 1995 to 2025 (Table 4.2; SJRWMD 2003, p. 34). Similarly, updated projections of water usage from 2015 to 2035 predicted an increase in each occupied county except for Putnam (SJRWMD and SRWMD 2017, p. 23). These predicted percentages increased appreciably in drought years (SJRWMD 2003, p. 34). Additionally, SJRWMD (2003, pp. 89-90) assessed the likelihood of harm to native vegetation related to groundwater withdrawal and found the areas most likely to be impacted by 2025 were outside the range of Black Creek crayfish. (USFWS, 2024)

Stressor: Urbanization (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Urbanization is a significant source of water quality degradation that can reduce the survival of native aquatic organisms, including the Black Creek crayfish (Brody 1990, p. 19; Stranko et al. 2010, p. 603). Urban development can stress aquatic systems in a variety of ways, including by increasing the frequency and magnitude of high flows in streams, increasing sedimentation and nutrient loads, increasing contamination and toxicity, decreasing the aquatic

diversity and changing stream morphology and water chemistry (Coles et al. 2012, entire; CWP 2003, pp. 93- 94). Sources and risks of an acute or catastrophic contamination event, such as a leak from an underground storage tank or a hazardous materials spill on a highway, increase as urbanization increases. Road crossings can be sources of toxic substances from illegal dumping and weed control (Franz et al. 2008, pp. 17-18). Roadwork associated with bridges being newly constructed, repaired, or retrofitted is a potential source of impact to water quality, primarily through siltation and other construction-related pollution. Plans for the construction of Jacksonville's First Coast Outer Beltway, a project that will pass through a portion of the Black Creek crayfish range (U.S. Department of Transportation et. 2013, entire; http://firstcoastexpressway.com/), has the potential to impact stream crossings with Black Creek crayfish habitat. Construction on the southwest portion of the Beltway commenced in 2019. Best management practices (BMPs) are in place to avoid erosion issues (e.g., silt fences, stormwater ponds). As with bridges, construction and maintenance activities on utility corridors and associated infrastructure (e.g., substations, transmission rights of way, and equipment maintenance yards) have the potential to negatively impact streams that they cross, or which occur adjacently. Urbanization and development, including industrial and residential land, also increase pressures on water resources. Most urban land within the Black Creek crayfish range is concentrated in southeast Duval County, northeastern Clay County, and northern St. Johns County around the city of Jacksonville and surrounding areas (Fig. 4.2; Florida Department of Environmental Protection [DEP] 2008, p. 16). (USFWS, 2024)

Stressor: Mining (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Previous research indicates that an increase in metal concentration in surface water, sediment, and detritus from mining can reduce or eliminate crayfish populations (Allert et al. 2012, pp. 568-569). Similarly, improperly controlled effluent from mining sites could degrade water quality, leading to decreased forage, shelter, reproduction and survivorship, and negatively impact Black Creek crayfish populations. The majority of the currently regulated mining operations within the Black Creek crayfish range include heavy mineral extraction which may have impacted Black Creek crayfish in the past. For example, Brody (1990, p. 21) reported the lack of crayfish and other stream fauna from a stream (Boggy Creek) that receives effluent from the mine tailing ponds of a titanium extraction operation. Mining may have legacy impacts; however, efforts to decrease impacts of mining operations to waterways through habitat restoration and best management practices may reduce the impacts of these threats (Service et al. 2017, pp. 8-9). (USFWS, 2024)

Stressor: Climate Change (USFWS, 2024)
Exposure:
Response:
Consequence:
Narrative: Climate change has the potential to increase vulnerability of the Black Creek crayfish to random catastrophic events or to alter habitat suitability within the species' range. The climate in the southeastern United States has warmed approximately 1°C (~ 2 °F) from a cool period in the 1960s and 1970s and is expected to continue to rise (Carter et al. 2014, pp. 398-399; Carter et al. 2018, pp. 749-750). Various emissions scenarios suggest that, by the end of the 21st century, average global temperatures are expected to increase 0.3 °C to 4.8 °C (0.5 °F to 8.6

°F), relative to the period 1986–2005 (Intergovernmental Panel on Climate Change [IPCC 2014], entire). By the end of 2100, it is extremely likely that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales, and it is very likely that heat waves and extreme precipitation events may occur with higher frequency and intensity (IPCC 2014, pp. 15–16; Carter et al. 2018, pp. 750-752). Projections for future precipitation trends in the Southeast are less certain than those for temperature, but suggest that overall annual precipitation may decrease, and that tropical storms may occur less frequently, but with more force (more category 4 and 5 hurricanes) than historical averages (Carter et al. 2014, p. 398). Warmer temperatures and decreased precipitation may increase water temperatures and concurrently decrease dissolved oxygen levels, change runoff regimes, and increase frequency, duration, and intensity of droughts in the southeastern United States (Carter et al. 2018, pp. 746, 773, 775). Droughts cause decreases in water flow and dissolved oxygen levels and increases in temperature in stream systems and can lead to increases in the concentration of pollutants. These issues may be exacerbated by increases in groundwater withdrawals that may likely coincide with human population increases (see Section 4.2). (USFWS, 2024)

Recovery

Conservation Measures and Best Management Practices:

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Additional Threshold Information:

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References

USFWS. 2024. Species status assessment report for Procambarus pictus (Black Creek crayfish), Version 2.0. June 2024. Atlanta, Georgia.

SPECIES ACCOUNT: *Streptocephalus woottoni* (Riverside fairy shrimp)

Species Taxonomic and Listing Information

Commonly-used Acronym: None

Listing Status: Endangered; August 3, 1993 (58 FR 41384).

Physical Description

The Riverside fairy shrimp (Streptocephalus woottoni) is a small (14- to 23-mm [0.56 to 0.92-inch (in.)]) aquatic crustacean belonging to an ancient order of branchiopods, the Anostraca. Like other anostracans, it has stalked compound eyes and eleven pairs of phyllopods (swimming legs that also function as gills) (USFWS 2008). Male Riverside fairy shrimp are distinguished from other fairy shrimp species primarily by the second pair of antennae (USFWS 2008). The male frontal appendage is cylindrical, bibbed at the tip, and extends only partway to the distal end of the basal segment of the antenna (USFWS 1998). The spur of the thumb is a simple blade-like structure. The finger has two teeth; the proximal tooth is shorter than the distal tooth (USFWS 1998). The distal tooth has a lateral shoulder that is equal to about half the tooth's total length measured along the proximal edge (USFWS 1998). The cercopods (which enhance the rudder-like function of the abdomen) are separate, with plumose setae (feathery bristles) along the medial and lateral borders (USFWS 1998).

Taxonomy

The Riverside fairy shrimp was first collected in 1979 by C.H. Erickson. It was identified as a new species in 1985, based on specimens collected between Murrieta Golf Course and California Highway 79 in Riverside County. No changes in taxonomic classification or nomenclature have occurred since listing ((USFWS 1998; USFWS 2008).

Historical Range

The August 3, 1993, listing rule stated that Riverside fairy shrimp were known to inhabit nine vernal pool complexes in Riverside, Orange, and San Diego counties, and Baja Mexico, including four vernal pools in Riverside County, one population in Orange County, two areas in San Diego County, and two locations in Baja California, Mexico. The historical range was unknown at the time of listing (USFWS 2008).

Current Range

Riverside fairy shrimp occur in vernal pools in the inland areas of Riverside County, Orange County, and the vicinity of Ramona, San Diego County; and coastal areas of San Diego County and northwestern Baja California, Mexico (USFWS 2008).

Critical Habitat Designated

Yes; 12/4/2012.

Legal Description

On December 4, 2012, the U.S. Fish and Wildlife Service, revised the critical habitat for the Riverside fairy shrimp under the Endangered Species Act of 1973, as amended. The previous critical habitat consisted of land in four units in Ventura, Orange, and San Diego Counties, California. Land in three units is now designated in Ventura, Orange, and San Diego Counties, California, for a total of approximately 1,724 ac (698 ha), which represents critical habitat for this species. Areas in Riverside County are excluded from critical habitat in the final revised rule.

Critical Habitat Designation

The Service designated 3 units, containing 13 subunits, as critical habitat for Riverside fairy shrimp. The three units are: Unit 1 (Ventura County), Unit 2 (Los Angeles Basin—Orange County Foothills), and Unit 5 (San Diego Southern Coastal Mesas). All of Unit 3 (Riverside County) and Unit 4 (San Diego North and Central Coastal Mesas) are excluded.

Unit 1: Ventura County Unit (Transverse Range). Unit 1 is located in central Ventura County and consists of two occupied subunits totaling approximately 466 ac (189 ha), with 31 ac (13 ha) of local land and 435 ac (176 ha) of private land. Unit 1 is within the geographical area occupied by the species at the time of listing. This unit includes vernal pools near the City of Moorpark in Ventura County at Tierra Rejada Preserve (formerly Carlsberg Ranch) on the west side of State Highway 23, and a basin to the southeast of the Carlsberg Ranch site called South of Tierra Rejada Valley, east of State Highway 23. This unit occurs within the larger Santa ClaraCalleguas/Calleguas-Conejo Tierra Rejada Valley watershed, within the east-west trending Transverse (mountain) Range. The Transverse Range system was formed by the interaction of an east-west oceanic fault zone with the San Andreas Fault. Because the interaction of the two fault systems has been extensive and continues with rapid local uplift, Riverside fairy shrimp habitat within the Transverse Range reflects past activities of tectonic processes and their effects on watershed development. Accelerated erosion, sedimentation, and debris processes, such as mud and rock flows, landslides, wind flows, and debris flows (soil development processes), contribute to a unique set of physiochemical and geomorphic features for pools occupied by Riverside fairy shrimp. Subunit 1a: Tierra Rejada Preserve. Subunit 1a is located near the City of Moorpark in southeastern Ventura County, California. This subunit is located on what was formerly known as the Carlsberg Ranch, at the north end of the Tierra Rejada Valley and just west of State Highway 23. It is near the northeast intersection of Moorpark Road and Tierra Rejada Road in a residential housing development. Subunit 1a consists of 18 ac (7 ha) of privately owned land. The vernal pool (pond), 4.6 acres (1.7 ha) in size, is located in the Tierra Rejada Vernal Pool Preserve, owned and managed by Mountains Recreation and Conservation Authority (MCRA). Subunit 1a contains areas identified in the 1998 Recovery Plan (Appendix F) as necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp. The Service considers this subunit to have been occupied at the time of listing, and it is currently occupied. Subunit 1a is within the geographical area occupied by the species at the time of listing. Resting cysts were detected in recent soil analyses (C. Dellith 2010, pers. comm.) and adult fairy shrimp were observed on April 7, 2011 (J. Tamasi 2011, pers. comm.), the first observation of adults since the 2000–2001 ponding season. This area is essential to the conservation of this species for several reasons. The pool supports endangered Orcuttia californica (Orcutt's grass), which is an indicator of the longer ponding duration necessary to support the life-history needs of Riverside fairy shrimp. This pool is fundamentally different in terms of size, origin, depth, and duration of ponding, contributing areas (watershed), and the thickness of the underlying sediments compared to flat areas of older soils with highly developed claypans and hardpans throughout the State (Hecht et al. 1998, p. 47). This pool was formed primarily by tilting and subsidence along the Santa Rosa fault (Hecht et al. 1998, p. 5). Given its geological and hydrological features and associated wetland vegetation within the subunit, this pool possesses a set of physical and biological factors unique to this occurrence to which the Riverside fairy shrimp has likely become adapted. The present biological resources and value of the pool have been sustained despite ‘‘substantial disturbance and change [in] the general area of the vernal pool'' and given the history of land and water use and analysis of 60 years of aerial photography (Hecht et al. 1998, p. 6 and Appendix A). Although Lahti et al. (2010) did not survey this pool during their completion of a rangewide genetic analysis, this occurrence represents the northernmost extension of the species' occupied range within a notably unique vernal wetland type (Hecht et al. 1998, p. 5, and see discussion below). Subunit 1a contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including appropriate soil series (Azule, Calleguas, Linne; PCE 3) situated on a saturated fault between rocks of different permeability (''tectonogenic''; Hecht et al. 1998, p. 5), and it is ''sediment-tolerant'' given that it possesses a watershed with reasonably steep slopes (10–50 percent) that yield substantial amounts of sediment that provide nutrients and minerals (Hecht et al. 1998, p. 6). The fine clay sediment deposited in the basin settles and allows the pool to fill; this is in contrast to most other vernal pools, where hydrology is maintained through clay soils created by soil forming processes (Hecht et al. 1998, p. 5). Additionally, because of adjacent urban development, altered hydrology, and potential for runoff, the PCEs in this subunit may require special management considerations or protection for the recovery of Riverside fairy shrimp. This subunit has one large ponding feature, and is essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65) at the species' northernmost geographical distribution. Due to its unique geographic location and other features stated above, Subunit 1a is essential to the conservation of Riverside fairy shrimp. Although preliminary genetic studies are not definitive with regard to gene flow and genetic variability across the range of this species, populations at the edge of a species' distribution have been demonstrated to be important sources of genetic variation, may provide an important opportunity for colonization or recolonization of unoccupied vernal pools, and, thus, contribute to long-term conservation (and recovery) of the species (Gilpin and Soule´ 1986, pp. 32– 33; Lande 1999, p. 6). Research on genetic differentiation among fairy shrimp species across their known distributions has demonstrated that geographically distinct populations may or may not be genetically distinct, but that they have unique genetic characteristics that may allow for adaption to environmental changes (Bohonak 2003, p. 3; Lahti et al. 2010, p. 17). These characteristics may not be present in other parts of a species' range (Lesica and Allendorf 1995, p. 756), making preservation of this subunit and the unique genetic diversity it contains essential for the recovery of the species. The Service is lacking specific documentation of Riverside fairy shrimp occupancy in Subunit 1a at the time of listing. However, Subunit 1a contains the physical or biological features necessary to the conservation of the species, and these features support lifehistory characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. However, as discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designates Subunit 1a under section 3(5)(A)(ii) of the Act because the subunit is essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of the rulemaking, the Service determined that Subunit 1a meets the definition of critical habitat in section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act. The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species (nonnative grasses and Schinus molle (Peruvian pepper) groves) and alterations to the hydrological cycle, including type conversion of habitat; activities that remove or destroy the habitat assemblage of the pools, such as creation of fuel breaks, mowing, and grading; and human encroachment that occurs in the area. These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2). For example, inundation from artificial water sources can cause pools to stay inundated longer than normal or even convert vernal pools into perennial pools that are not suitable for Riverside fairy shrimp (Service 2008, p. 16). Please see Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. Subunit 1b: South of Tierra Rejada Valley. Subunit 1b is located near the City of Moorpark in Ventura County, California. This subunit is approximately 1 mi (1.5 km) southeast of Subunit 1a and east of State Highway 23. Subunit 1b consists of 31 ac (13 ha) of locally owned land and 417 ac (169 ha) of private land. The Service assumed that Subunit 1b was not identified in the 1998 Recovery Plan (Appendix F) because at that time the Service was unable to confirm occupancy. To the best of the Service's knowledge, this subunit has never been protocol surveyed to confirm the presence or absence of Riverside fairy shrimp (C. Dellith 2010, pers. comm.). This subunit, however, was proposed and designated as critical habitat in the 2005 final revised critical habitat rule because the Service considered it occupied (see discussion below) and because the necessary PCEs were present. The Service continues to presume that Subunit 1b is occupied, despite the absence of protocol survey results, and have determined that the subunit contains the PCEs. Subunit 1b is located approximately 1 mile to the south of Tierra Rejada Preserve (Subunit 1a) within the Tierra Rejada Valley watershed. Like Subunit 1a, this pool is one of the last representatives of what is believed to be a historical distribution of coastal terrace vernal pools common to the marine terraces and inland area of Ventura County prior to the 1950s (Hecht et al. 1998, p. 6 and Appendix A). This subunit is considered occupied based on several factors that strongly suggest the likelihood of Riverside fairy shrimp occurrence. As discussed in the 2005 proposed rule (70 FR 19154; April 12, 2005), these are: (1) The important biotic and abiotic conditions (soil type, geology, morphology, local climate, topography, and plant associations, for example, Orcuttia californica, which suggests the presence of vernal pool ponding at the appropriate season and for the appropriate duration); (2) topographic features and ponding evidence based on aerial surveys that confirm a ponding pool basin; (3) several large permanent and semipermanent pools observed within the subunit's local watershed; (4) proximity (less than 1 mi (< 1 km)) to a known Riverside fairy shrimp occurrence, and likely within the known dispersal distance expected for an invertebrate species with a resistant cyst stage; and (5) the determination that Subunit 1a and Subunit 1b are adjoined, based on fluvial and geomorphic evidence that suggest the Tierra Rejada Valley river system once likely connected the two pools and would have provided the connectivity to disperse cysts between the two subunits. Subunit 1b is designated as revised critical habitat because the Service has determined it is essential for the conservation of the species. It includes one or more pools capable of maintaining habitat function, genetic diversity, and species viability (Service 1998a, p. 65) for Riverside fairy shrimp at the northern limit of its current distribution, and is near, and likely has connectivity with, a known occupied location of ecological and distributional significance. It is also essential because the best supporting evidence indicates the basin contains the appropriate depth and ponding duration (PCE 1), soils and topography (PCEs 2 and 3), elevation, and water chemistry (pH, temperature, salinity, etc.; PCE 1) to satisfy the lifehistory needs of existing Riverside fairy shrimp populations. Though the life history of Riverside fairy shrimp suggests that Subunit 1b was occupied at the time of listing, specific documentation of occupancy is lacking. Based on the biology and life history of Riverside fairy shrimp, the Service believes that the subunit was indeed occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing and contains all of the PCEs.

However, the Service alternatively designated Subunit 1b under section 3(5)(A)(ii) of the Act because the Service considers this subunit essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determined that Subunit 1b meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act.

Unit 2: Los Angeles Basin—Orange County Foothills. Unit 2 is located in central coastal Orange County and consists of 4 subunits totaling approximately 396 ac (160 ha) of privately owned land. Unit 2 falls within the Los Angeles BasinOrange County Management Area as outlined in the 1998 Recovery Plan. The majority of vernal pools in this management area were extirpated prior to 1950, and only a small number of vernal pools remain in Los Angeles and Orange Counties (Service 1998a, p. 40). This unit includes the vernal pools and vernal pool-like ephemeral ponds located along a north-south band in the Orange County Foothills. It includes examples of the historical distribution of coastal terraces at moderate elevations (183 to 414 m (600 to 1,358 ft)), and includes ephemeral ponds formed by landslides and fault activity, and remnant stream (fluvial) terraces along foothill ridgelines (Taylor et al. 2006, pp. 1–2). Occupied Riverside fairy shrimp pools occur on former MCAS El Toro; Southern California Edison (SCE) Viejo Conservation Bank; Saddleback Meadows; O'Neill Regional Park (near Trabuco Canyon east of Tijeras Creek at the intersection of Antonio Parkway and the Foothill Transportation Corridor (FTC-north segment)); O'Neill Regional Park (near Can˜ ada Gobernadora); Chiquita Ridge; Radio Tower Road; and San Onofre State Beach, State Parkleased land (near Christianitos Creek foothills) that falls partially within MCB Camp Pendleton. These vernal pools are the last remaining vernal pools in Orange County known to support this species (58 FR 41384; August 3, 1993) and represent a unique type of vernal pool habitat that differs from the traditional mima mound vernal pool complexes of coastal San Diego County, the coastal pools at MCB Camp Pendleton, and the inland pools of Riverside County (70 FR 19182). Unit 2 is within the geographical area occupied by the species at the time of listing. The areas within Unit 2 are occupied and contain the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and the topography and soils that support ponding during winter and spring months (PCE 3); in almost all cases, slow-moving or still surface water and saturated soils are present at or near vernal pool habitat. Conservation of an array of vernal pools that contain the physical or biological features essential to the conservation of Riverside fairy shrimp in the foothill region of Orange County provides for necessary habitat function, natural genetic diversity and exchange, and species viability in the central portion of the species' range. Subunit 2dA: Saddleback Meadows. Subunit 2dA is located in the community of Silverado in southern Orange County, California. This subunit is near the St. Michael's College Preparatory School, east of El Toro Road and southwest of Live Oak Canyon Road. Subunit 2dA consists of 252 ac (102 ha) of privately owned land. It contains areas identified in the 1998 Recovery Plan (Appendix F) as necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp, as well as other proposed and listed vernal pool species. This subunit is essential to the conservation and recovery of Riverside fairy shrimp because it is currently occupied and includes one or more pools necessary to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp's life-history needs. This vernal pool complex includes a series of natural and impounded cattle troughs that have been breached and degraded by past agricultural activities and urban development. Additionally, Subunit 2dA is an important link to the northern occupied locations, and represents a nearby source for recolonization of pools in the Orange County foothills. Subunit 2dA contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and topography and soils that support ponding during winter and spring months (PCE 3). The Service lacks specific documentation of Riverside fairy shrimp occupancy in Subunit 2dA at the time of listing. However, Subunit 2dA contains the physical or biological features necessary to the conservation of the species and these features support life-history characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. However, as discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designates Subunit 2dA under section 3(5)(A)(ii) of the Act because the Service considers this subunit to be essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determines that Subunit 2dA meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act. The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species, development, or grazing that may occur in the vernal pool basins. These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2). Please see the Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. Subunit 2dB: O’Neill Regional Park (Near Trabuco Canyon). Subunit 2dB is located approximately 1.5 km (1 mi) southeast of Subunit 2dA in southern Orange County, California. This subunit is west of Live Oak Canyon Road and northeast of the O’Neill Regional Park, near Can˜ ada Gobernadora (see Subunit 2e below). In the 2008 5-year review, this area was referred to as ‘‘O’Neill Park/Clay Flats pond property’’ (Service 2008, p. 7). Subunit 2dB consists of 15 ac (6 ha) of privately owned land. Subunit 2dB was not specifically identified in the 1998 Recovery Plan (Appendix F), but is classified as necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp within the ‘‘Orange County Foothills (undescribed)’’ heading in Appendix F (Service 1998a, p. F1). This subunit is essential for the conservation of Riverside fairy shrimp because it is currently occupied and includes one or more pools essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp’s life-history needs. Subunit 2dB contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and topography and soils that support ponding during winter and spring months (PCE 3). A portion of this subunit lies at 1,413 ft (431 m), and is among the highest elevation occurrences of Riverside fairy shrimp. The Service is lacking specific documentation of Riverside fairy shrimp occupancy in Subunit 2dB at the time of listing. However, Subunit 2dB contains the physical or biological features necessary to the conservation of the species and these features support life-history characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. However, as discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designates Subunit 2dB under section 3(5)(A)(ii) of the Act because the Service considers the subunit essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determines that Subunit 2dB meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act. The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species and activities, such as unauthorized recreational use, OHV use, and fire management. These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2) as well as the vegetative coverage and soil substrates surrounding the pool (PCE 2). Please see the Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. Subunit 2e: O'Neill Regional Park (Near Can˜ ada Gobernadora). Subunit 2e is located near the city of Rancho Santa Margarita in southern Orange County, California, and is currently occupied. This subunit is east of Can˜ ada Gobernadora and bounded to the west by State Highway 241. In the 2008 5-year review this area was referred to as ''east of Tijeras Creek complex'' (Service 2008, p. 7). Subunit 2e consists of 22 ac (9 ha) of private land. Subunit 2e was not specifically identified in the 1998 Recovery Plan (Appendix F), but was classified as necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp within the ''Orange County Foothills (undescribed)'' heading in Appendix F (Service 1998a, p. F1). This subunit is essential for the conservation of Riverside fairy shrimp because it includes one or more pools essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp's life-history needs. Areas within this subunit contain clay, clay loam, or sandy loam, and consist primarily of dry-land agriculture and sagebrushbuckwheat scrub habitat. Located in the water drainages of the foothills of the Santa Ana Mountains, this pool rests in a canyon bottomland at approximately 919 ft (280 m) of elevation. Subunit 2e contains the physical or biological features essential to the conservation of Riverside fairy shrimp including clay soils and loamy soils underlain by a clay subsoil (PCE 3); areas with a natural, generally intact surface and subsurface soil structure (PCE 2); and the ephemeral habitat (PCE 1) that supports Riverside fairy shrimp, including slow-moving or still surface water and/or saturated soils. Subunit 2e also supports a stable, persistent occurrence of the species. The Service is lacking specific documentation of Riverside fairy shrimp occupancy in Subunit 2e at the time of listing. However, Subunit 2e contains the physical or biological features necessary to the conservation of the species and these features support lifehistory characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. However, as discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designates Subunit 2e under section 3(5)(A)(ii) of the Act because the Service considers the subunit to be essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determines that Subunit 2e meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section

3(5)(A)(ii) of the Act. The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species and anthropogenic activities (for example, surrounding residential and commercial development, unauthorized recreational use, OHV use, and fire management). These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2) as well as the vegetative coverage and soil substrates surrounding the pool (PCE 2). Please see the Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. Subunit 2h: San Onofre State Beach, State Park-Leased Lands. Subunit 2h is located along the border between Orange and San Diego Counties, southeast of Richard Steed Memorial Park and north of Christianitos Road. Nearly half of this subunit (105 ac (42 ha)) occurs on Department of Defense (DOD) land on MCB Camp Pendleton, and is exempt from critical habitat under section 4(a)(3)(B)(i) of the Act. The other half of Subunit 2h consists of 107 ac (43 ha) of privately owned land. The portion of Subunit 2h that falls within DOD land, the ‘‘Cal State Parks Lease,’’ as described in the 2007 Integrated Natural Resources Management Plan (INRMP) (U.S. Marine Corps 2007, p. 2–30), is part of a lease agreement made between the U.S. Marine Corps and California State Department of Parks on September 1, 1971, for a 50-year term. Portions of Subunit 2h exempt from this final critical habitat rule include military thoroughfares (roads), military training with advanced coordination, utility easements, fire suppression activities, and public recreation. The presence of Riverside fairy shrimp in Subunit 2h was discovered after the 1993 listing rule and 1998 Recovery Plan were written. This subunit is essential for the conservation of Riverside fairy shrimp because it is currently occupied and includes one or more pools essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). It represents an important ecological linkage for genetic exchange between the coastal mesa pools of San Diego and the Orange County Foothills occurrences. Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp’s life-history needs. Subunit 2h consists of two sag ponds (a pool that forms as a result of movement between two plates on an active fault line) at the eastern section of the unit and their associated upland watersheds on land within Orange County near the city of San Clemente. Subunit 2h contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and topography and soils that support ponding during winter and spring months (PCE 3). The Service lacks specific documentation of Riverside fairy shrimp occupancy in Subunit 2h at the time of listing. However, Subunit 2h contains the physical or biological features necessary to the conservation of the species and these features support life-history characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. As discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designates Subunit 2h under section 3(5)(A)(ii) of the Act because the Service considers the subunit essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determines that Subunit 2h meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act. The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species and anthropogenic activities (for example, military activities, unauthorized recreational use, agricultural runoff, OHV use, and fire management). These threats could disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2) as well as the vegetative coverage and soil substrates surrounding the pool (PCE 2). Please see the Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. The 105 ac (42 ha) of lands identified as critical habitat within the boundaries of MCB Camp Pendleton are exempt from critical habitat under section 4(a)(3)(B)(i) of the Act.

Unit 5: San Diego Southern Coastal Mesas. Unit 5 is located in Southern San Diego County and consists of seven subunits totaling 862 ac (349 ha). This unit contains 250 ac (101 ha) of Stateowned land, 157 ac (64 ha) of locally owned land, and 455 ac (184 ha) of private land. This unit falls within the San Diego Southern Coastal Management Area, as identified in the 1998 Recovery Plan. Land the Service designated as critical habitat includes vernal pool complexes within the jurisdiction of the Service, City of San Diego, County of San Diego, other DOD land, and private interests. This unit contains several mesa-top vernal pool complexes on western Otay Mesa (Bauder vernal pool complexes J2 N, J2 S, J2 W, J4, J5, J11 W, J11 E, J12, J16– 18, J33) and eastern Otay Mesa (Bauder pool complexes J29–31, J33) as in Appendix D of City of San Diego (2004). These vernal pool complexes are associated with coastal mesas from the Sweetwater River south to the U.S.- Mexico International Border, and represent the southernmost occurrences of Riverside fairy shrimp in the United States. This unit is also genetically diverse, including two haplotypes (a unique copy or form of a sequenced gene region) not found outside of the Otay Mesa area (Lahti et al. 2010, Table 5). Additionally, Otay Mesa pools are significantly differentiated from one another (Lahti et al. 2010, p. 19). This area is essential for the conservation of Riverside fairy shrimp for the following reasons: (1) These vernal pool complexes represent the few remaining examples of the much larger and mostly extirpated vernal pool complexes on the highly urbanized Otay Mesa (Bauder 1986a); (2) recent genetic work indicates that complexes within this unit (J26, J29–30) support Riverside fairy shrimp with the unique haplotype B; and (3) this is one of only three locations that supports haplotype C (Lahti et al. 2010). Maintaining this unique genetic structure may be crucial in the conservation of this species. Unit 5 is within the geographical area occupied by the species at the time of listing. Subunit 5a: Sweetwater (J33). Subunit 5a is located in the City of San Diego in southern San Diego County, California. This subunit is at Sweetwater High School (site J33), south of the intersection between Otay Mesa and Airway Roads. Subunit 5a consists of 2 ac (less than 1 ha) of locally owned land and less than 1 ac (< 1 ha) of private land. Subunit 5a contains areas identified in the 1998 Recovery Plan (Appendix F) as necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp, as well as other proposed and listed vernal pool species. This subunit is essential for the conservation of Riverside fairy shrimp because it includes one or more pools essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp's life-history needs. This subunit is under the ownership of the Sweetwater Union High School District. The Service lacks specific documentation of Riverside fairy shrimp occupancy in Subunit 5a at the time of listing. However, Subunit 5a contains the physical or biological features necessary to the conservation of the species and these features support life-history characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. As discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designate Subunit 5a under section 3(5)(A)(ii) of the Act because the Service considers the subunit essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determines that Subunit 5a meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act. Subunit 5a contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and topography and soils (Olivenhain cobbly loam soil series) that support ponding during winter and spring months (PCE 3). The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species, unauthorized recreational use and OHV use, and other human-related activities. These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2) as well as the vegetative coverage surrounding the pool (PCE 2). Please see the Special Management Considerations or Protection section of this rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. Subunit 5c: East Otay Mesa. Subunit 5c is located in the eastern Otay Mesa region of southern San Diego County, California. This subunit is approximately 1.75 mi (2.75 km) southeast of Kuebler Ranch and just north of the U.S.-Mexico Border. Subunit 5c consists of 57 ac (23 ha) of privately owned land. These lands fall within the County of San Diego Subarea Plan under the San Diego MSCP. Subunit 5c was not specifically identified in the 1998 Recovery Plan (Appendix F), but is classified as necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp within the ‘‘J2, J5, J7, J11–21, J23–30 Otay Mesa’’ heading in Appendix F (Service 1998a, p. F1). The pool in Subunit 5c is not included in the list above, but is within the geographical area of those listed pools. Areas within Subunit 5c were also identified as essential in the previous critical habitat rules for Riverside fairy shrimp (66 FR 29384, May 30, 2001; 70 FR 19154, April 12, 2005). Subunit 5c contains one vernal pool; this pool is occupied by Riverside fairy shrimp. It also contains a small stream as well as the downward slope and mima mound topography that make up the watershed associated with the occupied vernal pool. This subunit is currently occupied; dry season surveys in 2011 by Busby Biological Services documented the presence of Riverside fairy shrimp cysts (Busby Biological Services 2011, entire). This subunit was first documented as occupied in 2000 (GIS ID 4). Though the stock pond in Subunit 5c was not surveyed by Lahti et al. (2010), other vernal pools surveyed in Otay Mesa were found to have unique genetic diversity in the range of the species, including two haplotypes not found elsewhere. Otay Mesa pools also show significant genetic differentiation from each other (Lahti et al. 2010, p. 19). Given the subunit’s location as the very easternmost pool in Otay Mesa, the Service determines that Subunit 5c may also host unique genetic diversity. This subunit is essential for the conservation of Riverside fairy shrimp because its occupied pool and surrounding watershed are essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp’s life-history needs. The vernal pool in this subunit has been impacted by OHV use, cattle grazing, development, and nonnative grasses. Subunit 5c contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and topography and soils that support ponding during winter and spring months (PCE 3). This subunit also contains critical habitat for the endangered Quino checkerspot butterfly (Euphydryas editha quino) and is occupied by both the Quino checkerspot butterfly and San Diego fairy shrimp (72 FR 70648, December 12, 2007; 74 FR 28776, June 17, 2009). The Service lacks specific documentation of Riverside fairy shrimp occupancy in Subunit 5c at the time of listing. However, Subunit 5c contains the physical or biological features necessary to the conservation of the species and these features support life-history characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. As discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designate Subunit 5c under section 3(5)(A)(ii) of the Act because the Service considers the subunit to be essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determines that Subunit 5c meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act. The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species and anthropogenic activities (for example, development, OHV use, water runoff, and grazing). These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2) as well as the vegetative coverage and soil substrates surrounding the pool (PCE 2). Please see the Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. Subunit 5d: J29–31. Subunit 5d is located in the Otay Mesa region of southern San Diego County, California. This subunit is to the east and west of State Highway 125, south of the Otay Valley, and north of the U.S.-Mexico Border. Subunit 5d consists of 347 ac (140 ha), including less than 1 ac (< 1 ha) of federally owned land, 205 ac (83 ha) of Stateowned land (Caltrans), and 142 ac (57 ha) of private land. One vernal pool complex within Subunit 5d (J31) was not specifically identified in the 1998 Recovery Plan (Appendix F). However, pool J31 within the same watershed as pool complexes J29 and J30, both of which were listed as necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp within the ‘‘J2, J5, J7, J11–21, J23–30 Otay Mesa’’ heading in Appendix F (Service 1998a, p. F1). This subunit was confirmed occupied at the time of listing by protocol surveys, and is currently occupied. Subunit 5d is within the geographical area occupied by the species at the time of listing. Therefore, the Service designated it under section 3(5)(A)(i) of the Act. This subunit is essential for the conservation of Riverside fairy shrimp because it includes one or more pools essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp’s life-history needs. Subunit 5d is predominantly in the City of San Diego in San Diego County, California, although portions of pools J29–31 are within the County of San Diego’s jurisdiction. This subunit contains a large area of habitat that supports sizable occurrences of Riverside fairy shrimp, and provides potential connectivity between occurrences of Riverside fairy shrimp in Subunits 5e and 5c. This subunit contains several mesa-top vernal pool complexes on eastern Otay Mesa (Bauder vernal pool complexes J22, J29, J30, J31 N, J31 S as in Appendix D of City of San Diego (2004) and Service GIS files). Subunit 5d contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and topography and soils that support ponding during winter and spring months (PCE 3). The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species and anthropogenic activities (for example, OHV use, unauthorized recreational use, impacts from development (including water runoff), and fire management). These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2) as well as the vegetative coverage and soil substrates surrounding the pool (PCE 2). Please see the Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. Subunit 5e: J2 N, J4, J5 (Robinhood Ridge). Subunit 5e is located in the Otay Mesa region of southern San Diego County, California. This subunit is approximately 1 mi (1.5 km) east of Ocean View Hills Parkway, 0.6 mi (1 km) north of State Highway 905, and bounded by Vista Santo Domingo to the east. Subunit 5e consists of 44 ac (18 ha), including 32 ac (13 ha) of locally owned land and 12 ac (5 ha) of private land. Subunit 5e was not specifically identified in the 1998 Recovery Plan (Appendix F), but is classified as necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp within the ‘‘J2, J5, J7, J11–21, J23–30 Otay Mesa’’ heading in Appendix F (Service 1998a, p. F1). This subunit is currently occupied. This subunit is essential for the conservation of Riverside fairy shrimp because it includes one or more pools essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp's life-history needs. Subunit 5e contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and the topography and soils that support ponding during winter and spring months (PCE 3). The Service lacks specific documentation of Riverside fairy shrimp occupancy in Subunit 5e at the time of listing. However, Subunit 5e contains the physical or biological features necessary to the conservation of the species and these features support life-history characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. However, as discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designated Subunit 5e under section 3(5)(A)(ii) of the Act because the Service considers the subunit to be essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determined that Subunit 5e meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act. The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species and anthropogenic activities (for example, OHV use, unauthorized recreational use, impacts from development, and fire management). These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2) as well as the vegetative coverage and soil substrates surrounding the pool (PCE 2). Please see the Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. Subunit 5f: J2 W, J2 S (Hidden Trails, Cal Terraces, Otay Mesa Road). Subunit 5f is located in the Otay Mesa region of southern San Diego County, California, and consists of three pool complexes. All complexes are located north of State Highway 905 and southwest of Subunit 5e, with one complex in the lot southwest of Ocean View Hills Parkway, one bounded to the west by Hidden Trails Road, and one bounded to the west by Corporate Center Drive. Subunit 5f consists of 22 ac (9 ha) of locally owned land and 11 ac (4 ha) of private land. Subunit 5f was not mentioned by name in the 1998 Recovery Plan (Appendix F), but portions of vernal pool complexes within the units (J2 W and J2 S) were listed as necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp within the ''J2, J5, J7, J11–21, J23–30 Otay Mesa'' heading in Appendix F (Service 1998a, p. F1). This subunit is currently occupied. This subunit is essential for the conservation of Riverside fairy shrimp because it includes one or more pools essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp's life-history needs. Subunit 5f contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and topography and soils that support ponding during winter and spring months (PCE 3). The Service lacks specific documentation of Riverside fairy shrimp occupancy in Subunit 5f at the time of listing. However, Subunit 5f contains the physical or biological features necessary to the conservation of the species and these features support life-history characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. However, as discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designated Subunit 5f under section 3(5)(A)(ii) of the Act because the Service considers the subunit to be essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determines that Subunit 5f meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act. The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species and anthropogenic activities (for example, OHV use; unauthorized recreational use; impacts from development, including water runoff; and fire management). These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2) as well as the vegetative coverage and soil substrates surrounding the pool (PCE 2). Please see the Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. Subunit 5g: J14. Subunit 5g is located in the Otay Mesa region of southern San Diego County, California. This subunit is south of State Highway 905, southeast of Caliente Avenue, west of Heritage Road, and northwest of Spring Canyon. Subunit 5g consists of 45 ac (18 ha) of State-owned land (Caltrans), 18 ac (7 ha) of locally owned land, and 72 ac (29 ha) of private land. Subunit 5g was not mentioned by name in the 1998 Recovery Plan (Appendix F), but is included in the list of vernal pool complexes necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp within the ''J2, J5, J7, J11–21, J23–30 Otay Mesa'' heading in Appendix F (Service 1998a, p. F1). This subunit is currently occupied. This subunit is essential for the conservation of Riverside fairy shrimp because it includes one or more pools essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp's life-history needs. Subunit 5g contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and topography and soils that support ponding during winter and spring months (PCE 3). The Service lacks specific documentation of Riverside fairy shrimp occupancy in Subunit 5g at the time of listing. However, Subunit 5g contains the physical or biological features necessary to the conservation of the species and these features support life-history characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. However, as discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designates Subunit 5g under section 3(5)(A)(ii) of the Act because the Service considers the subunit to be essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determines that Subunit 5g meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act. The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species and anthropogenic activities (for example, OHV use; unauthorized recreational use; impacts from development, (including water runoff and fire management). These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2) as well as the vegetative coverage and soil substrates surrounding the pool (PCE 2). Please see the Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations. Subunit 5h: J11 E, J11 W, J12, J16–18 (Goat Mesa). Subunit 5h is located in the Otay Mesa region of southern San Diego County, California. This subunit is north and west of Subunit 5b, bounded by the U.S.-Mexico Border to the south, and bisected by Jeep Trail. Subunit 5h consists of 83 ac (34 ha) of locally owned land (City of San Diego) and 161 ac (65 ha) of privately owned land. Subunit 5h was not mentioned by name in the 1998 Recovery Plan (Appendix F), but is included in the list of vernal pool complexes necessary to stabilize and protect (conserve) existing populations of Riverside fairy shrimp within the ''J2, J5, J7, J11–21, J23–30 Otay Mesa'' heading in Appendix F (Service 1998a, p. F1). This subunit is currently occupied. This subunit is essential for the conservation of Riverside fairy shrimp because it includes one or more pools essential to maintain habitat function, genetic diversity, and species viability (Service 1998a, p. 65). Further, it is essential because the basin contains the appropriate depth and ponding duration, soils, elevation, and water chemistry (pH, temperature, salinity, etc.) to fulfill Riverside fairy shrimp's life-history needs. Subunit 5h contains the physical or biological features essential to the conservation of Riverside fairy shrimp, including ephemeral wetland habitat (PCE 1), intermixed wetland and upland habitats that act as the local watershed (PCE 2), and topography and soils that support ponding during winter and spring months (PCE 3). The Service lacks specific documentation of Riverside fairy shrimp occupancy in Subunit 5h at the time of listing. However, Subunit 5h contains the physical or biological features necessary to the conservation of the species and these features support life-history characteristics of Riverside fairy shrimp (such as the presence of cyst banks that indicate long-term occupancy of a vernal pool). The presence of these traits makes it likely that the subunit was occupied at the time of listing, and that it meets the definition of critical habitat under section 3(5)(A)(i) of the Act because it is within the geographical area occupied by the species at the time of listing. However, as discussed in the Criteria Used To Identify Critical Habitat section above, the Service alternatively designates Subunit 5h under section 3(5)(A)(ii) of the Act because the Service considers the subunit to be essential for the conservation of Riverside fairy shrimp, regardless of occupancy data at the time of listing. Thus, for the purposes of this rulemaking, the Service determined that Subunit 5h meets the definition of critical habitat under section 3(5)(A)(i) or, alternatively, under section 3(5)(A)(ii) of the Act. The physical or biological features essential to the conservation of the species in this subunit may require special management considerations or protection to address threats from nonnative plant species and anthropogenic activities (for example, OHV use; unauthorized recreational use; impacts from development, including water runoff; and fire management). These threats could impact the water chemistry characteristics that support Riverside fairy shrimp (PCE 1) and disrupt the surrounding watershed that provides water to fill the pool in the winter and spring (PCE 2) as well as the vegetative coverage and soil substrates surrounding the pool (PCE 2). Please see the Special Management Considerations or Protection section of this final rule for a discussion of the threats to Riverside fairy shrimp habitat and potential management considerations.

Primary Constituent Elements/Physical or Biological Features

Critical habitat units are designated for Ventura, Orange, and San Diego Counties, California. Within these areas, the primary constituent elements of the physical or biological features essential to the conservation of the Riverside fairy shrimp consist of three components:

(i) Ephemeral wetland habitat consisting of vernal pools and ephemeral habitat that have wet and dry periods appropriate for the incubation, maturation, and reproduction of the Riverside fairy shrimp in all but the driest of years, such that the pools: (A) Are inundated (pond) approximately 2 to 8 months during winter and spring, typically filled by rain, surface, and subsurface flow; (B) Generally dry down in the late spring to summer months; (C) May not pond every year; and (D) Provide the suitable water chemistry characteristics to support the Riverside fairy shrimp. These characteristics include physiochemical factors such as alkalinity, pH, temperature, dissolved solutes, dissolved oxygen, which can vary depending on the amount of recent precipitation, evaporation, or oxygen saturation; time of day; season; and type and depth of soil and subsurface layers. Vernal pool habitat typically exhibits a range of conditions but remains within the physiological tolerance of the species. The general ranges of conditions include, but are not limited to: (1) Dilute, freshwater pools with low levels of total dissolved solids (low ion levels (sodium ion concentrations generally below 70 millimoles per liter)); (2) Low alkalinity levels (lower than 80 to 1,000 milligrams per liter (mg/l)); and (3) A range of pH levels from slightly acidic to neutral (typically in range of 6.4–7.1).

(ii) Intermixed wetland and upland habitats that function as the local watershed, including topographic features characterized by mounds, swales, and low-lying depressions within a matrix of upland habitat that result in intermittently flowing surface and subsurface water in swales, drainages, and pools described in paragraph (h)(2)(i) of this entry. Associated watersheds provide water to fill the vernal or ephemeral pools in the winter and spring months. Associated watersheds vary in size and therefore cannot be generalized, and they are affected by factors including surface and underground hydrology, the topography of the area surrounding the pool or pools, the vegetative coverage, and the soil substrates in the area. The size of associated watersheds likely varies from a few acres to greater than 100 ac (40 ha).

(iii) Soils that support ponding during winter and spring which are found in areas characterized in paragraphs (h)(2)(i) and (h)(2)(ii), respectively, of this entry, that have a clay component or other property that creates an impermeable surface or subsurface layer. Soil series with a clay component or an impermeable surface or subsurface layer typically slow percolation, increase water run-off (at least initially), and contribute to the filling and persistence of ponding of ephemeral wetland habitat where the Riverside fairy shrimp occurs. Soils and soil series known to support vernal pool habitat include, but are not limited to: (A) The Azule, Calleguas, Cropley, and Linne soils series in Ventura County; (B) The Alo, Balcom, Bosanko, Calleguas, Cieneba, and Myford soils series in Orange County; (C) The Cajalco, Claypit, Murrieta, Porterville, Ramona, Traver, and Willows soils series in Riverside County; and (D) The Diablo, Huerhuero, Linne, Placentia, Olivenhain, Redding, Salinas, and Stockpen soils series in San Diego County.

Special Management Considerations or Protections

Critical habitat does not include manmade structures (such as buildings, aqueducts, runways, roads, and other paved areas) and the land on which they are located existing within the legal boundaries on January 3, 2013.

The physical or biological features in areas designated as revised critical habitat all face ongoing threats that require special management considerations or protection. For Riverside fairy shrimp, such threats include vernal pool elimination due to agricultural and urban development, including activities associated with construction of infrastructure (such as highways, utilities, and water storage) (PCEs 1, 2, 3); construction of physical barriers or impervious surfaces around a vernal pool complex (PCEs 1, 2); altered water quality or quantity (PCEs 1, 3) due to channeling water runoff into a vernal pool complex or to the introduction of water, other liquids, or chemicals (including herbicides and pesticides) into the vernal pool basin; physical disturbance to the claypan and hardpan soils within the vernal pool basin (PCEs 1, 3), including discharge of dredged or fill material into vernal pools and erosion of sediments from fill material; disturbance of soil profile by grading, digging, or other earthmoving work within the basin or its upland slopes or by other activities such as OHV use, heavy foot traffic, grazing, vegetation removal, fire management, or road construction within the vernal pool watershed (PCEs 1, 2, 3); invasion of nonnative plant and animal species into the vernal pool basin (PCEs 1, 2), which alters hydrology and soil regimes within the vernal pool; and any activity that permanently alters the function of the underlying claypan or hardpan soil layer (PCE 3), resulting in disturbance or destruction of vernal pool flora or the associated upland watershed (PCEs 2, 3). All of these threats have the potential to permanently reduce or increase the depth of a vernal pool, ponding duration and inundation of the vernal pool, or other vernal pool features beyond the tolerances of Riverside fairy shrimp (PCE 1).

Life History

Feeding Narrative

Adult: Riverside fairy shrimp are opportunistic filter feeders. In general, Anostracans feed on algae, bacteria, protozoa, rotifers, and bits of detritus. No specific studies have been done on the feeding habits of the Riverside fairy shrimp (NatureServe 2015). Riverside fairy shrimp can face competition from other fairy shrimp in their environment. Riverside fairy shrimp swim upside down as they filter-feed on algae and zooplankton with their 11 pairs of leaf-like legs

(Eriksen and Belk 1999; USFWS 2008).

Reproduction Narrative

Adult: Riverside fairy shrimp are usually observed from January to March. However, the hatching period may be extended in years with early or late rainfall. With the hydration of eggs, time to hatching is usually between 2 and 25 days. Individuals hatch, mature, and reproduce relatively slowly within 7 to 8 weeks of rainfall filling a pool, depending on water temperature. Individuals live an average of 120 days. (USFWS 2008).One hundred to 300 eggs are laid, and cysts from successful reproduction are either dropped to the pool bottom or remain in the brood sac until the female dies and sinks (USFWS 2008). The cysts are capable of withstanding temperature extremes and prolonged drying. Cysts can withstand extreme environmental conditions because of their protective coatings. Unless they are smashed or punctured, cysts are not digested when moved down the intestines of animals. When fairy shrimp cysts dry up, they are even more tolerant of extreme conditions and can be subjected to temperatures of up to 65 degrees Celsius (150 degrees Fahrenheit) or can be frozen for months. Cysts can also withstand near-vacuum conditions for 10 years without damage to the embryo. The cysts do not hatch until they receive proper environmental signals such as rain (Eriksen and Belk 1999).Only a portion (often less than 10 percent) of the cysts may hatch when the pools refill in the same or subsequent rainy seasons; therefore, cyst “banks” develop in pool soils that are composed of the cysts from several years of breeding. This partial hatching of cysts allows the Riverside fairy shrimp to persist in its extremely variable environment, because pools commonly fill and dry before hatched individuals can reproduce, and if all cysts hatched during an insufficient filling, the species could be extirpated from a pool. Riverside fairy shrimp cysts cannot hatch in perennial (i.e., containing water year-round) basins, because the re-wetting of dried cysts is one component of a set of environmental stimuli that trigger hatching. Temperature is another important cue; water chemistry and other factors may also play a role. The ability of Riverside fairy shrimp to develop and maintain cyst banks is vital to the long-term survival of their populations (USFWS 2008).

Geographic or Habitat Restraints or Barriers

Adult: Limited to their home pool. Cysts can be dispersed from dried-up pools, but survival is limited to vernal pools. Development and habitat alteration can isolate populations.

Spatial Arrangements of the Population

Adult: Clumped according to resources.

Environmental Specificity

Adult: Narrow

Tolerance Ranges/Thresholds

Adult: Low

Site Fidelity

Adult: High

Habitat Narrative

Adult: Riverside fairy shrimp are generally restricted to vernal pools and other nonvegetated ephemeral (i.e., containing water a short time) pools greater than 12 in. (30.5 centimeters [cm]) in depth in Riverside, Orange, and San Diego counties in southern California, and northwestern Baja California, Mexico. Riverside fairy shrimp generally occur in vernal pool complexes. There are 45 vernal pool complexes known to be occupied by the Riverside fairy shrimp in Riverside, Orange, and San Diego counties. An analysis of occupied vernal pools indicated that this species is restricted to approximately 24 ha (59 ac.) of remaining habitat. Although the greatest number of individual occupied pools and complexes occur in San Diego County, one pool in Riverside County, Skunk Hollow, is 13 ha (33 ac.) in size; therefore, the greatest extent of occupied habitat occurs in Riverside County (USFWS 2008). Riverside fairy shrimp are generally restricted to vernal pools and other nonvegetated ephemeral (i.e., containing water a short time) pools greater than 30.5 cm (12 in.) in depth. The pools Riverside fairy shrimp are typically found in are quite large, some exceeding 750 square meters (8,072 square feet) (Eriksen and Belk 1999). The thermal and chemical properties of vernal pool waters are two of the primary factors affecting the distributions of specific fairy shrimp species, or their appearance from year to year. Riverside fairy shrimp are restricted to dilute vernal pools, having relatively low sodium (Na+) concentrations (below 60 millimoles per liter), low alkalinity (below 1,000 milligrams per liter), and neutral pH (near 7) (USFWS 2008).Vernal pool complexes tend to average between five and 50 vernal pools, although some contain as few as two vernal pools and others contain several hundred vernal pools. Vegetation communities associated with adjacent upland habitats that surround the vernal pools in southern California are valley needlegrass grassland, annual grasslands, coastal sage scrub, maritime succulent scrub, and chaparral (USFWS 2008).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: Nonmigratory

Dispersal

Adult: Aquatic birds are the most likely agents of dispersal. Large mammals are also known distributors (Eriksen and Belk 1999). How and to what degree dispersal of Riverside fairy shrimp occurs is unknown at this time (USFWS 2008).

Immigration/Emigration

Adult: No

Dispersal/Migration Narrative

Adult: Riverside fairy shrimp are nonmigratory and have relatively little ability to disperse on their own (NatureServe 2015). How and to what degree dispersal of Riverside fairy shrimp occurs is unknown at this time. Genetic mixing that does occur could happen via combination of a number of potential mechanisms, including infrequent large-scale flooding events, dispersal of cysts by animals (e.g., waterfowl), wind dispersal of cysts in desiccated soils, etc. (USFWS 2008). Certain fairy shrimp species are restricted in distribution, and adjacent soils may have different or no fairy shrimp. Pools observed after years seem to have the same species and structural and genetic diversity (Eriksen and Belk 1999).No genetic studies have been done for the Riverside fairy shrimp, but a mitochondrial DNA study was completed for the San Diego fairy shrimp (Branchinecta sandiegonensis), whose range overlaps with the Riverside fairy shrimp in San

Diego and Orange counties. The San Diego fairy shrimp study concluded that individuals of that species have likely been isolated from one another biologically for tens of thousands or perhaps millions of years with little or no dispersal or hybridization. San Diego fairy shrimp in a vernal pool complex or limited geographic area were found to be generally more closely related to each other than to those at more distant locations. Furthermore, the results indicate that gene flow between pool complexes is lower in areas that have fewer disturbances from urbanization and human activities. It is not clear whether a genetic analysis of Riverside fairy shrimp would yield similar results, because fewer pools are occupied by Riverside fairy shrimp, and these pools are generally more spread out (USFWS 2008).

Additional Life History Information

Adult: Certain fairy shrimp species are restricted in distribution, and adjacent soils may have different or no fairy shrimp. Pools observed after years seem to have the same species and structural and genetic diversity (Eriksen and Belk 1999).

Population Information and Trends

Species Trends:

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Number of Populations:

~40 (USFWS< 2021)

Population Size:

Unknown (NatureServe 2015)

Adaptability:

Moderate

Additional Population-level Information:

More than half of all extant complexes known to contain Riverside fairy shrimp are in San Diego County, including eight complexes on Marine Corps Base (MCB) Camp Pendleton. These eight complexes are of particular interest because they support approximately 56 percent of all identified individual vernal pools known to be occupied by the Riverside fairy shrimp. Approximately 24 percent of extant known occupied complexes are in Riverside County, and approximately 17 percent are in Orange County. There is no information on the current status of the two occurrences known in Mexico at the time of listing (USFWS 2008).

Population Narrative:

AIn the 2008 5-year review, we estimated that approximately 45 vernal pool complexes were occupied by RFS (USFWS 2008, Appendix 1, pp. 1–9). We now estimate that RFS occurs in 40 vernal pool locations or complexes, as described in Table 1. The new estimate should not be interpreted as a decrease in the total number of vernal pools or complexes occupied by RFS from 2008 to 2021 because of differences in the way pool complexes and occupied habitat have been mapped and tabulated for this summary. In fact, we estimate that there are up to nine newly occupied locations for RFS in 2021 (known as: Tierra Rejada, Fairview Park, Wickerd Road, Lake Skinner Investor, Lake Skinner Multi-Species Reserve, Santa Rosa Plateau, French Valley Donation, Southwest Village Development, and Dennery West). Information was not available for a status determination to be made for 12 pools, and as such, some of these pools may no longer support RFS (known as: Madrona Marsh, Whiting Ranch/SCE Viejo, El Toro, Live Oak Plaza, O'Neill Park, March Air Force Base, Scott Pool, Rainbow Canyon Pool, Upham, Brownfield Airport, and two locations in Mexico). (USFWS, 2021)

Threats and Stressors

Stressor: Development
Exposure: Human population growth.
Response: Habitat destruction; isolation and fragmentation of habitat; and alteration of hydrology.
Consequence: Mortality and population extirpation.
Narrative: The Riverside fairy shrimp was imperiled because the habitat on which the species is dependent (vernal pools) and the species' overall range had been greatly reduced. By that time the species was listed, vernal pool habitat in San Diego County had declined by an estimated 97 percent. The growth rate of the human population and associated urban and road development in southern California and northwestern Baja California is equal to or exceeds that of any other region in California. San Diego is one of the fastest-growing counties in the nation, and is estimated to have a population of approximately 3.6 million people by the year 2020. This predicted growth rate suggests that urban and road development pressures will continue to rise within the extant range of the Riverside fairy shrimp. Development of border security and associated infrastructure also threatens the Riverside fairy shrimp along the international border. Such development can result in direct impacts to Riverside fairy shrimp habitat, i.e., destruction of vernal pools or their watersheds, and isolation of pools and fragmentation of pool systems; development can also cause alterations in the hydrology of adjacent pools (USFWS 2008).

Stressor: Habitat loss
Exposure: Development
Response: Habitat loss or modification.
Consequence: Reduction in population numbers, and mortality.
Narrative: Habitat loss associated with development is the result of destruction and modification of vernal pools and their watersheds due to filling, grading, discing, leveling, and other activities. Because the species is dependent on this specific habitat type for survival, habitat loss results in the mortality of Riverside fairy shrimp occupying the developed habitat. Despite the prohibition of take of listed species under Section 9 of the Endangered Species Act (ESA) and efforts to minimize take through consultation efforts, unauthorized habitat loss continues to occur in known occupied complexes. Approximately 17 of the 45 known occupied complexes, or about 38 percent, occur on private lands that are not preserved and are thus vulnerable to future development. These privately owned lands total approximately 3 ha (7 ac.) in size and support 12 percent of all known remaining extant habitat (USFWS 2008).

Stressor: Habitat isolation and fragmentation
Exposure: Development
Response: Fragmentation and isolation of populations, change in food source and nutrients, and change in hydrology.
Consequence: Population extirpation and increased susceptibility to stochastic events.
Narrative: Habitat isolation is a significant threat, due to the possibility of stochastic events extirpating populations that then could not be recolonized by dispersal from nearby populations.

Habitat fragmentation in complexes or groups of nearby complexes can isolate pools/complexes from upland habitats, which provide much of the Riverside fairy shrimp's food sources (algae, diatoms, and particulate organic matter brought into pools via overland flow of rainwater). Because of the transportation of water, soil, minerals, and nutrients over the landscape into vernal pools, the upland or upslope areas associated with vernal pools are an important source of these resources for vernal pool organisms. Because vernal pools are mostly rain-fed, they tend to have low nutrient levels. In fact, most of the nutrients that vernal pool crustaceans derive from their vernal pool habitat come from the detritus (decaying organic matter) that washes into pools from the adjacent upslope areas; these nutrients provide the foundation for the food chain in the vernal pool aquatic community, of which the fairy shrimp fauna constitutes an important component. Whenever vernal pools in a complex are impacted by development, some degree of fragmentation occurs in and among complexes. Fragmentation and associated impacts to hydrology continue to threaten the species throughout its range (USFWS 2008).

Stressor: Water management/altered hydrology
Exposure: Changes to uplands, and alterations to topographic watershed.
Response: Alteration of pool hydrology, and habitat becoming unsuitable or degraded.
Consequence: Reduced fitness, and inability to complete life cycle.
Narrative: The complex hydrology of vernal pools is supported by both surface flows in a pool's topographic watershed (e.g., the surface area in which water drains into a vernal pool) and subsurface flows that may extend beyond the surface watershed. Surface and subsurface lateral flows between vernal pools and the surrounding uplands influence the onset and level of inundation, and the seasonal drying of vernal pools. Therefore, modifications to the uplands surrounding a vernal pool (e.g., grading cuts) can negatively affect the pool's hydrology by accelerating the flow of water into or out of the subsoil, even if such modifications occur outside the pool's surface watershed. Alterations of ponding could negatively affect the ability of Riverside fairy shrimp to grow and reproduce, because their phenology is dependent on the onset and duration of ponding. Decreased inundation could result in pools not filling long enough for fairy shrimp to complete their life cycle. Conversely, increased inundation from artificial water sources (e.g., runoff from adjacent development) could cause pools to stay inundated longer than normal or even convert vernal pools into perennial pools that are not suitable for Riverside fairy shrimp (USFWS 2008).

Stressor: Nonnative plants
Exposure: Invasion of nonnative species.
Response: Native plants outcompeted, and change in hydrology.
Consequence: Habitat may no longer be suitable for the species.
Narrative: Vernal pools have been impacted by the introduction of invasive nonnative plants throughout the range of the species, including two nonnative wetland grasses: Pacific bentgrass (Agrostis avenacea) and annual rabbitsfoot grass (Polypogon monspeliensis). Several factors contribute to the decline in habitat conditions, including native plant species being outcompeted by nonnative plant species for nutrients, light, and water. Nonnative invasive plants can overtake pools, and because of their water uptake decrease the number of days of inundation following rain events to the point that the pools may no longer provide suitable habitat for Riverside fairy shrimp (USFWS 2008).

Stressor: Inadequate regulatory mechanisms
Exposure:

Response:
Consequence:
Narrative: The federal ESA provides the most regulatory protection to the Riverside fairy shrimp. The additional potential protection provided by other federal, state, and local laws and ordinances is discretionary, incomplete, subject to funding availability and changing missions, and/or largely dependent on the federally listed status of the Riverside fairy shrimp. Because of this, other federal, state, and local laws and ordinances do not independently or collectively provide adequate regulatory protection to the Riverside fairy shrimp (USFWS 2008).

Stressor: Human access and disturbance
Exposure: Development, foot traffic, and motorized vehicles.
Response: Habitat degradation.
Consequence: Cyst mortality.
Narrative: The potential for human access and disturbance in fairy shrimp habitat increases as greater numbers of people are brought in close proximity to the habitat via encroaching development. Human access and disturbance in Riverside fairy shrimp habitat on foot or on motorized or nonmotorized vehicles affects the species directly by crushing Riverside fairy shrimp cysts. In addition to crushing fairy shrimp cysts, this type of off-road activity (including motorcycles and bicycles) can generally degrade Riverside fairy shrimp habitat by altering pool shape and compacting soil, potentially impacting pool hydrology.Almost all remaining Riverside fairy shrimp habitat is threatened to some degree by increasing human access and disturbance. To lessen these impacts, a 30.5-meter (100-foot) habitat buffer between new development and the watershed boundary of preserved or restored vernal pools has been recommended, although not always implemented. Several preserved and most unpreserved vernal pool complexes are not fenced and are thus subject to illegal activities, although “No Trespassing” signs may be posted in some cases. The City of San Diego’s draft Vernal Pool Management Plan (2006) reports observed or potential effects of human encroachment for almost all complexes listed in the document (USFWS 2008).

Stressor: Pesticides and other pollutants
Exposure: Use of Roundup, pesticides, control agents for mosquitos and blackflies; airborne pollutants; and dumped trash.
Response: Unknown
Consequence: Unknown
Narrative: Pesticides likely pose a threat to the species. Riverside fairy shrimp may be exposed to pesticides used to control weeds and insects. Herbicides are commonly used to control weeds outside (e.g., for roads, farms, and residential landscaping) and even in (i.e., for enhancement/restoration projects) Riverside fairy shrimp habitat. One study showed that the commonly used herbicide Roundup® may pose a risk to San Diego fairy shrimp; this pesticide is therefore likely to pose a threat to Riverside fairy shrimp as well. Pesticide applications for the control of mosquito larvae have become more common to combat West Nile Virus. Although at this time the degree of this threat to Riverside fairy shrimp is unknown, the fact that some pesticides are designed specifically for the purpose of killing certain invertebrates adds strength to the argument that they may be a significant threat to Riverside fairy shrimp in areas where they are used.Other control agents include Bacillus thurgingiensis and Bacillus sphaericus, naturally occurring soil bacteria that act as larvicides and are commonly used to control mosquitoes and blackflies; and methoprene, an insect growth regulator commonly used as a pesticide. Use of these control agents has been proposed in occupied Riverside fairy shrimp

habitat, though the effects of these vector control agents on the Riverside fairy shrimp are unknown.Runoff from adjacent development may also introduce pollutants, including pesticides, that could be toxic to the species; or alter aspects of water chemistry, such as pH, alkalinity, and salinity, to which the species has been shown to be sensitive. Airborne pollutants can be introduced via rainfall and runoff as well. Dumped trash and other litter may decrease water quality as materials dissolve or decompose. Dumped material can also fill pools, leaving little or no space for water to collect; or cover the bottom of pools, preventing cysts from moving from the soil into the water column if they are able to hatch (USFWS 2008).

Stressor: Drought and climate change
Exposure: Weather conditions causing pools to dry up, and rising global temperatures.
Response: Depletion of cyst banks, pools drying up before fairy shrimp can complete their lifecycle, habitat degradation, and decreased inundation periods.
Consequence: Mortality, no reproductive output, reduction in population numbers, and reduced fitness.
Narrative: Drought is likely to decrease or terminate reproductive output as pools fail to flood, or dry up before reproduction is complete. Based on existing data, weather conditions in which vernal pool flooding promotes hatching, but in which pools dry (or become too warm) before embryos are fully developed, are expected to have the greatest negative effect on fairy shrimp resistance and resilience. Long-term or continuing drought conditions may deplete cyst banks in affected pools as new cysts are not deposited, and depletion of the cyst bank could occur. Because current monitoring protocols typically require only one survey for crustaceans each monitoring year, they cannot determine the frequency with which the shrimp die off before completing reproduction (USFWS 2008).Climate change has the potential to adversely affect the fairy shrimp through changes in vernal pool inundation patterns and consistency. Climate scientists are able to predict, with a high level of certainty, that California’s climate will become warmer in the 21st century, although there is still uncertainty about regional effects of warming. Current climate change predictions for terrestrial areas in the northern hemisphere indicate warmer air temperatures, more intense precipitation events, and increased summer continental drying. However, predictions of climatic conditions for smaller sub-regions such as California remain uncertain (USFWS 2008).

Stressor:
Exposure:
Response:
Consequence:
Narrative:

Recovery

Reclassification Criteria:
Although the Recovery Plan is outdated in some respects, the general approach is appropriate for Riverside fairy shrimp conservation and recovery. The recovery criteria for stabilization and downlisting the Riverside fairy shrimp are summarized below, and include only those portions relevant to Riverside fairy shrimp (USFWS 2008):

To maintain genetic diversity and population stability of the listed species: a) Existing vernal pools currently occupied by Riverside fairy shrimp and their associated watersheds should be secured from further loss and degradation in a configuration that maintains habitat function and species viability; b) Existing vernal pools and their associated watersheds in the Transverse and Los Angeles Basin-Orange Management Areas should be secured from further loss and degradation in a configuration that maintains habitat function and species viability (USFWS 1998; USFWS 2008).

Existing vernal pools and their associated watersheds contained in the complexes identified in the Recovery Plan must be secured in a configuration that maintains habitat function and species viability (as determined by recommended research) before reclassification of the species to threatened status may be considered (USFWS 1998; USFWS 2008).

Secured vernal pools must be enhanced or restored in such a way that population levels of existing species are stabilized or increased (USFWS 1998; USFWS 2008).

Population trends must be shown to be stable or increasing for a minimum of 10 consecutive years prior to consideration for reclassification (USFWS 1998; USFWS 2008).

Recovery Priority Number: 8C

Delisting Criteria:
Delisting of Riverside fairy shrimp may be considered in the future and is conditioned on the downlisting criteria; improvement (stabilized or increasing population trends) at all currently known sites; restoration, protection, and management of the minimum habitat area and configuration needed to ensure long-term viability; and establishing historic but locally extirpated species populations when needed to ensure viability (USFWS 1998).

USFWS must also determine that the following factors are no longer present, or continue to adversely affect, the Riverside fairy shrimp: (1) the present or threatened destruction, modification, or curtailment of their habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; and (5) other natural or manmade factors affecting their continued existence (50 CFR 424.11).

Recovery Actions:
- Design and establish a vernal pool habitat preserve system in each Management Area that will maximize the ecological distribution of the species, minimize risk of habitat loss, retain genetic differentiation, and provide the opportunity for expansion of populations (USFWS 1998).
- In each Management Area, reestablish vernal pool habitat to historic structure and composition to increase genetic diversity and population stability (USFWS 1998).
- In each Management Area, rehabilitate and enhance secured vernal pool habitats and their constituent species (USFWS 1998).
- Manage protected habitat (USFWS 1998).
- Monitor protected habitat and listed species (USFWS 1998).
- Support continued conservation, enhancement, management, and monitoring of vernal pool habitat, including monitoring of restored/enhanced habitat to determine whether vernal pool restoration projects continue to be viable through time (e.g., artificial clay layer

remains stable and supports adequate ponding) (USFWS 2008).

- Support completion and peer review of Marine Corps' study evaluating the impact of tracked vehicle training on fairy shrimp, and develop conservation measures based on the results (USFWS 2008).
- Conduct a study of the genetic distribution of Riverside fairy shrimp analogous to the San Diego fairy shrimp study (USFWS 2008).
- Determine the extent of all remaining occupied habitat, including status (e.g., conserved, restored, managed, monitored, impacted, illegally impacted) and needs (e.g., conservation, restoration, management, monitoring) categories for all Riverside fairy shrimp habitat complexes (USFWS 2008).
- Develop protocols for quantitative estimates of adult and cyst abundance, as feasible, and define ranges in which – a. cyst banks would be considered adequately populated; and b. adult numbers (given sufficient pooling) reflect a healthy population. The Riverside fairy shrimp survey protocol should be updated to include acquisition of these abundance data. The defined abundance ranges should be used to model population viability analysis (PVA) for Riverside fairy shrimp, and as standards for determining Riverside fairy shrimp habitat restoration success (USFWS 2008).
- Consider revising the Recovery Plan to incorporate new information and address issues discussed in the "Recovery Criteria" section of the 5-Year Review. Recovery criteria should include PVA information available for the Riverside fairy shrimp to help determine which areas should be preserved, and to guide translocation efforts. Recovery criteria should include quantifiable thresholds for downlisting and delisting (USFWS 2008).
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- In the interest of ensuring these criteria are clearly articulated, we are amending the following clarification to the existing recovery plan. This amendment does not represent a revision of the delisting criteria, it simply provides more specific terminology. Delisting for the species covered by the 1998 recovery plan may be considered when the downlisting criteria have been met and: 1. All 74 geographic areas and associated vernal pool complexes as identified in Appendices F and G of the 1998 Recovery Plan under each of the specific management areas are protected and managed to ensure long-term viability. 2. The U.S. Fish and Wildlife Service must determine that the following factors are no longer present, or continue to adversely affect, Eryngium aristulatum var. parishii, Pogogyne abramsii, Pogogyne nudiuscula, Orcuttia californica, and the Riverside and San Diego fairy shrimp: (1) the present or threatened destruction, modification, or curtailment of their habitat range; (2) over utilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; and (5) other natural and manmade factors affecting their continued existence (50 CFR 424.11). 3. Population trends for all seven taxa continue to be stable or increasing for 10 consecutive years after threats have been sufficiently ameliorated or managed (completion of delisting criterion 2) prior to consideration for delisting. (USFWS, 2019)

Conservation Measures and Best Management Practices:

- RECOMMENDATIONS FOR FUTURE ACTIONS The recommended actions listed below are to be completed over the next 5 years. Successful implementation of these actions will reduce threats to RFS and provide information to better understand the biological and physical factors limiting the population growth and distribution. We recognize that conservation of this taxon will require cooperation and coordination with partners (Tribes, Federal, State, and local agencies) to minimize impacts from current threats, aid future restoration, and maximize effectiveness of limited funding. Many of these recommended actions were identified in the 2008 status review and we continue to believe the actions are relevant to the conservation of the species (USFWS 2008, pp. 44–45). 1. Provide funding to conservation partners for ongoing management, monitoring, and stewardship of occupied habitat. 2. Support continued conservation, enhancement, management, and monitoring of vernal pool habitat consistent with the 1998 Recovery Plan (USFWS 1998, Appendix F and G). 3. Determine the extent 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) for all Riverside fairy shrimp occupied vernal pool complexes. Utilize this information to update Appendix 1 of theRECOMMENDATIONS FOR FUTURE ACTIONS The recommended actions listed below are to be completed over the next 5 years. Successful implementation of these actions will reduce threats to RFS and provide information to better understand the biological and physical factors limiting the population growth and distribution. We recognize that conservation of this taxon will require cooperation and coordination with partners (Tribes, Federal, State, and local agencies) to minimize impacts from current threats, aid future restoration, and maximize effectiveness of limited funding. Many of these recommended actions were identified in the 2008 status review and we continue to believe the actions are relevant to the conservation of the species (USFWS 2008, pp. 44–45). 1. Provide funding to conservation partners for ongoing management, monitoring, and stewardship of occupied habitat. 2. Support continued conservation, enhancement, management, and monitoring of vernal pool habitat consistent with the 1998 Recovery Plan (USFWS 1998, Appendix F and G). 3. Determine the extent 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) for all Riverside fairy shrimp occupied vernal pool complexes. Utilize this information to update Appendix 1 of the 2008 review (USFWS 2008, Appendix 1 and 2) and Table 1 of this review. Crossreference these tables with the Recovery Plan (USFWS 1998, Appendix F and G). 4. Develop a population viability analysis (PVA) for the Riverside fairy shrimp, including the following subtasks: a. Develop and implement protocols to determine quantitative estimates of cyst abundance; b. Define ranges within which cyst banks would be considered adequately populated; c. Develop a quantitative estimate for adult abundance to reflect a healthy population (given sufficient pooling); and implement abundance estimates at occupied pools; d. Update the survey protocol to include acquisition of abundance data; e. Apply this knowledge to develop restoration and conservation success targets; and f. Apply this knowledge to assist in determining areas for preservation and translocation. (USFWS, 2021)

- The primary threat to RFS on MCAS Miramar is destruction and degradation of habitat through construction of new facilities, expansion of infrastructure, and unintentional damage by vehicles. However, MCAS Miramar has restored, created, and managed pools to offset impacts to vernal pool habitat. Overall, the Marine Corps' management of vernal pools at MCAS Miramar has provided a net benefit to the vernal pool resources through implementation of management objectives defined in Chapter 4 of their Integrated Natural Resource Management Plan (U.S. Marine Corps 2018, p. 4-1) and by offsetting project-related impacts through habitat restoration and enhancement efforts. City of Carlsbad Poinsettia Station (also known as complex JJ2) in the City of Carlsbad continues to be occupied, as reported in the 2008 review (USFWS 2008, p. 8). Lack of management over the last several decades resulted in significant degradation of the complex; however, the management and conservation status at this location has recently improved. In 2018, a project to expand the existing railroad station platform adjacent to the vernal pool complex resulted in minor temporary impacts to the pools. Funding was provided to enhance the pools as offsetting mitigation for the platform project. The City of Carlsbad took over management of the complex in 2019 to fulfill commitments under their Habitat Management Plan, a Subarea Plan within the North County Multiple Habitat Conservation Plan. The City of Carlsbad is working with the regulatory agencies and local jurisdictions to record an expanded conservation easement to protect the entire complex. The Poinsettia Station vernal pool complex continues to face challenges with the surrounding hydrology due to nearby residential runoff and the train station platform, but it will receive more management moving forward and is likely to continue to support RFS. (USFWS, 2021)

- The Sunroad Centrum/Otay 250 vernal pool complex (also known as J22) was not known to support RFS when the Recovery Plan (USFWS 1998, p. E2) was published, but the we subsequently assumed presence of this species onsite (USFWS 2008, p. 8). RFS was recently confirmed at this location with the discovery of RFS cysts onsite in 2020 (USFWS 2021, p. 10). The proposed construction of a residential housing development will avoid direct impacts to basins occupied by RFS; however, these occupied basins will be surrounded by development which will reduce the size of the surrounding watershed. Hence, construction is anticipated to degrade the ability of the pools to support RFS in the long-term and will not provide long-term conservation value to the species (USFWS 2021, p. 11). Offsetting measures associated with the project will result in vernal pool restoration and enhancement of additional pools (i.e., in addition to the existing RFS occupied pools that will be surrounded by development) on the property aimed at benefitting the species over the long-term, including preservation and management in perpetuity (USFWS 2021, pp. 11–14). The Brownfield airport vernal pool complex (also known as J35++, EO 64) was considered extant at the time of the last status review (USFWS 2008, p. 8; CDFW 2021, p. 72). The J35++ complex is adjacent to the airport runway and consists of former concrete basins for drying sea kelp. It is unknown if the species continues to be extant, and if the habitat conditions are suitable to support RFS. The Dennery West vernal pool complex (also known as J31) was not identified in the Recovery Plan (USFWS 1998, p. 20) nor the recent 5-year review (USFWS 2008, Appendix 1) as a site occupied by RFS. The site consists of a complex of pools enhanced and/or restored by the California Department of Transportation (Caltrans) to offset project impacts associated with State Route 905. The site was slated to receive soil inoculum with the goal of translocating RFS onsite, but after Caltrans completed restoring vernal pool habitat onsite, the species was detected naturally in 10 pools and the inoculum was not needed (Scatolini 2021, in litt; AECOM 2010, pp. 4–7). The site is unlikely to be developed and will support the conservation of RFS into the future. (USFWS, 2021)

Additional Threshold Information:

- Riverside fairy shrimp cannot tolerate 800 to 1,000 parts per million of alkalinity for 24 hours (Eriksen and Belk 1999).
- Riverside fairy shrimp cannot tolerate 800 to 1,000 parts per million of alkalinity for 24 hours (Eriksen and Belk 1999).

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SPECIES ACCOUNT: *Stygobromus (=Stygonectes) pecki* (Peck's cave amphipod)

Species Taxonomic and Listing Information

Listing Status: Endangered; 12/18/1997; Southwest Region (Region 2) (USFWS, 2016)

Physical Description

An eyeless, unpigmented cave amphipod. (NatureServe, 2015)

Taxonomy

The amphipod family Crangonyctidae (Insecta: Amphipoda) is a group with freshwater origins (Holsinger and Longley 1980, p. 5). This Holarctic and Laurasian family includes 12 genera found in North America, Africa, and Asia (Lowry and Myers 2013, p. 47-48; Horton et al. 2022, entire). Stygobromus (Cope 1872, entire) is a large genus with 140 described species and four subspecies (Horton et al. 2022, entire). Species in this genus are all aquatic subterranean crustaceans, and Stygobromus is the most speciose genus of subterranean amphipods known from Texas, with 13 recognized species (USFWS, 2024b)

Current Range

Peck's cave amphipods are groundwater obligate invertebrates that inhabit subterranean areas and gravel near springs, have restricted ranges, and can potentially occupy deep groundwater niches (Holsinger 1967, p. 119; Arsuffi 1993, p. 14; Krejca and Sprouse 2003, p. 9). Mature and immature life stages have been collected only near spring outlets, from seeps along the spring runs, and from a shallow groundwater well (Gibson et al. 2008, p. 76). This species is known from the headwaters of the Comal Springs complex at spring runs 1 through 4 and 7, the western shoreline (the impounded portion of the Comal Springs system) and Spring Island of Landa Lake, and Panther Canyon well (a shallow well located 110 m (360 ft) upslope of Comal Springs) in Comal County, Texas (Holsinger 1967, p. 119; Fries et al. 2004, pp. 5, 14; Gibson et al. 2008, pp.76-81). It also occurs in Hueco Springs at all four primary spring runs in Hays County, Texas (7 km [4 mi] north of Comal Springs) (USFWS, 2024b)

Critical Habitat Designated

Yes; 7/17/2007.

Legal Description

On October 23, 2013, the U.S. Fish and Wildlife Service (Service), revised the critical habitat for Peck's cave amphipod (Stygobromus pecki) in comal County, Texas, under the Endangered Species Act of 1973, as amended. Critical habitat was previously designated on July 17, 2007 (72 FR 39248).

Critical Habitat Designation

The critical habitat designation for Stygobromus (=Stygonectes) pecki includes 38.4 ac (15.16 ha) of surface and 138 ac (56 ha) of subsurface habitat in two units in Comal County, Texas. The units are 1. Comal Springs and 2. Hueco Springs.

Unit 1: Comal Springs Unit: The purpose of this unit is to independently support a population of Comal Springs dryopid beetle, Comal Springs riffle beetle, and Peck's cave amphipod in a functioning spring system with associated streams and underground spaces immediately inside of or adjacent to springs, seeps, and upwellings that provide suitable water quality, supply, and detritus (decomposed plant material). Unit 1 contains Comal Springs and consists of 124 ac (50 ha) of subsurface critical habitat for the Comal Springs dryopid beetle and the Peck's cave amphipod (Tables 2 and 4). Unit 1 also contains 38 ac (15 ha) of surface habitat for these two species and the Comal Springs riffle beetle (Table 3). This unit was occupied at the time of listing and is still occupied by the Comal Springs dryopid beetle, Comal Springs riffle beetle, and Peck's cave amphipod (Table 1). Portions of the Comal Springs Unit are owned by the State of Texas, City of New Braunfels, and private landowners in southern Comal County, Texas. A large portion of the unit is operated as a city park (Landa Park) with private residences and landscaped yards along the edge of the lower part of the unit. The surface water and bottom of Landa Lake are State-owned. The City of New Braunfels owns approximately 40 percent of the land surface adjacent to the lake, and private landowners own approximately 60 percent. This nearly L-shaped lake is surrounded by the City of New Braunfels. The spring system primarily occurs as a series of spring outlets that lie along the west shore of Landa Lake and within the lake itself. Practically all of the spring outlets and spring runs associated with Comal Springs occur within the upper part of the lake above the confluence of Spring Run No. 1 to the lake. This unit contains all of the essential physical and biological features for these species. The physical or biological features in this unit require special management or protection because of the potential for depletion of spring flow from water withdrawals, hazardous materials spills from a variety of sources in the watershed, pesticide use throughout the watershed, excavation and construction surrounding the springs and in the watershed, stormwater pollutants in the watershed, and invasive species impacts on the surface habitat.

Unit 2: Hueco Springs: The purpose of this unit is to independently support a population of Peck's cave amphipod in a functioning spring system with associated streams and underground spaces immediately inside of or adjacent to springs, seeps, and upwellings that provide suitable water quality, supply, and detritus (decomposed plant material). Unit 2 contains Hueco Springs and consists of 14 ac (6 ha) of subsurface and 0.4 ac (0.16 ha) of surface critical habitat for the Peck's cave amphipod (Table 4). This unit was occupied at the time of listing and is still occupied by the Peck's cave amphipod (Table 1). The Hueco Springs Unit is on private land in Comal County, Texas. The property is primarily undeveloped. The spring system has a main outlet that is located approximately 0.1 mi (0.2 km) south of the junction of Elm Creek with the Guadalupe River in Comal County. The main outlet itself lies approximately 500 ft (152 m) from the west bank of the Guadalupe River. Several satellite springs lie farther south between the main outlet and the river. The main outlet of Hueco Springs is located on undeveloped land, but the associated satellite springs occur within a privately owned campground for recreational vehicles. There is an access road to a field for parking, but no facilities or utilities. This unit contains all of the essential physical and biological features for this species. The physical or biological features in this unit require special management because of the potential for depletion of spring flow from water withdrawals, pesticide use throughout the watershed, and excavation and construction surrounding the springs and in the watershed.

Primary Constituent Elements/Physical or Biological Features

Within these areas, the primary constituent elements of the physical or biological features essential to the conservation of Peck's cave amphipod consist of these components:

(i) Springs, associated streams, and underground spaces immediately inside of or adjacent to springs, seeps, and upwellings that include: (A) High-quality water with no or minimal pollutant levels of soaps, detergents, heavy metals, pesticides, fertilizer nutrients, petroleum hydrocarbons, and semivolatile compounds such as industrial cleaning agents; and (B) Hydrologic regimes similar to the historical pattern of the specific sites, with continuous surface flow from the spring sites and in the subterranean aquifer;

(ii) Spring system water temperatures that range from approximately 68 to 75 °F (20 to 24 °C); and

(iii) Food supply that includes, but is not limited to, detritus (decomposed materials), leaf litter, living plant material, algae, fungi, bacteria, other microorganisms, and decaying roots.

Special Management Considerations or Protections

Critical habitat does not include manmade structures (such as buildings, aqueducts, runways, roads, and other paved areas) and the land on which they are located existing on the surface within the legal boundaries on November 22, 2013.

Examples of special management actions that would ameliorate threats to adequate water quantity and quality (PCEs 1 and 2) include: (1) Maintenance of sustainable groundwater use and subsurface flows; (2) use of adequate buffers for water quality protection; (3) selection of appropriate pesticides and herbicides; and (4) implementation of integrated pest management plans to manage existing invasive species as well as prevent the introduction of additional invasive species.

Life History

Feeding Narrative

Adult: This cave amphipod is likely an omnivore and upon reaching the surface, consumes terrestrial-derived organic matter from riparian vegetation sources (78 FR 63100; Nair et al. 2021, p. 3). In the Comal ecosystem, this cave amphipod occupies a higher trophic level as a predator consuming other surface aquatic crustaceans (Nowlin et al. 2017, pp. 15-16). Therefore, riparian areas adjacent to the spring ecosystem provide a necessary role in the nutrient cycle for the food web of this invertebrate and influence its habitat distribution (USFWS, 2024).

Reproduction Narrative

Adult: The Peck's cave amphipod in a laboratory study exhibited lower basal metabolic rates, greater bulk carbohydrate reserves, and slower declines in lipid reserve uptake when starved compared to a surface amphipod species, Sicifera (Synurella) sp. (Nair et al. 2020, p. 11). These lowered energetic requirements match metabolic strategies of deep phreatic organisms of low or infrequent food accessible systems, despite the species' association with shallower groundwater habitat. This suggests that earlier in the evolutionary history of this amphipod, the species may have occurred at deeper depths (Nair et al. 2020, p. 11). Brooding females are capable of cannibalizing their young or dropping eggs with agitation or motility, with those eggs unable to survive outside of the marsupium (i.e., a type of brooding pouch of a female crustacean) (Nowlin et al. 2016, p. 31; Kosnicki and Julius 2019a, p. 12; USFWS 2019b, p. 57).

Live prey crustacean species (Daphnia sp., Lirceolus sp., and Hyalella sp.) have been fed as supplemental feed in the refugia but are not actively sought out for consumption; this hunting behavior has not been observed in the wild (USFWS 2020b, p. 20). Subterranean amphipods can live for four to 10 years (Wellborn et al. 2015, p. 788). Wild-caught Peck's cave amphipods have survived in captivity for three years, and F2 generations have been accomplished (BIO-WEST, Inc. 2007b, p. 40). No mating behavior or cues have been identified for this amphipod, but larger females have been observed cannibalizing smaller males (Nowlin et al. 2016, p. 31). Wild adult females kept in captive environments were able to produce eggs, with an average of 10 eggs per female, 24 percent hatching success and average brooding incubation times of 49.7 ± 12.4 days (Fries et al. 2004, p. 9; Kosnicki and Julius 2019a, p. 11). It was observed that eggs need more than 32 days to survive their first molting event to the next life stage as neonates (i.e., newborns), having an average of 50 days between several molts (up to eight instars in captivity) to final adult life stage under stressful captive conditions (Kosnicki and Julius 2019a, pp. 11-12, 20). The number of instars to reach maturity likely depends on food resources available and water temperature (USFWS, 2024b)

Geographic or Habitat Restraints or Barriers

Adult: Subterranean obligate that is restricted to springs (NatureServe, 2015)

Habitat Narrative

Adult: Subterranean obligate that is restricted to springs. (NatureServe, 2015)

Dispersal/Migration

Dispersal/Migration Narrative

Adult: Not available.

Population Information and Trends

Population Trends:

Unknown (NatureServe, 2015)

Number of Populations:

2 (USFWS, 2024)

Population Size:

250 - 1000 individuals (NatureServe, 2015)

Population Narrative:

Over three hundred specimens have been collected (USFWS, 1995). This species is known from two springs; one specimen only from one of the springs. Various researchers have examined amphipod assemblages from springs, caves, and wells from neighboring counties, without finding the Peck's cave amphipod elsewhere, beyond the known occurrences at Comal and Hueco spring ecosystems (Holsinger 1967, entire; Holsinger and Longley, 1980 entire; Barr 1993, entire; Gibson et al. 2008, entire). This suggests that individuals of the species may be confined to small areas surrounding the spring openings and are not distributed throughout the aquifer. The collection of Peck's cave amphipods at Panther Canyon well lends support to early characterizations of the flagellatus group suggesting they inhabit deeper groundwater niches compared to other amphipod groups found above the water table and in hyporheic (i.e., saturated sediments near a streambed gravel or river) habitats (Holsinger 1967, pp. 143, 159).This distinction in partitioned niche habitat zones were also exhibited at Hueco Springs, with Peck's cave amphipods found more prevalent at deeper sites than others in the genus, Stygobromus russelli (Gibson et al. 2008, p. 80). To what extent the subterranean connections between Hueco and Comal Springs are inhabited by this amphipod are unknown (72 FR 39255). Presumably an interconnected area, the subterranean portion of this habitat provides for feeding, growth, survival, and reproduction of the Peck's cave amphipod. Both springs have local and regional groundwater contributions, with Comal Springs having a more phreatic, older origin than Hueco Springs (Ogden et al. 1986, pp. 80, 124; Rothermel and Ogden 1987, p. 76). These groundwater sources can intermix when aquifer levels are high and separate during severe droughts. This regional flowpath connection could explain the distribution of Peck's cave amphipods over these two spring systems (USFWS, 2024).

Threats and Stressors

Stressor: Human water use and removal from aquifer (USFWS, 1997)
Exposure:
Response:
Consequence:
Narrative: The main threat to the habitat of this species is a reduction or loss of water of adequate quantity and quality, due primarily to human withdrawal of water from the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer and other activities. Total withdrawal from the San Antonio region of the Edwards Aquifer has been increasing since at least 1934. There is an integral connection between the water in the aquifer west of the springs and the water serving as habitat for this species. Water in the Edwards Aquifer flows from west to east or northeast and withdrawal or contamination of water in the western part of the aquifer can have a direct effect on the quantity and quality of water flowing toward the springs and at the spring openings (USFWS, 1997).

Stressor: Pollution (USFWS, 1997)
Exposure:
Response:
Consequence:
Narrative: Other possible effects of reduced spring flow include changes in the chemical composition of the water in the aquifer and at the springs, a decrease in current velocity and corresponding increase in siltation, and an increase in temperature and temperature fluctuations in the aquatic habitat (McKinney and Watkins 1993). Another threat to the habitat of this species is the potential for groundwater contamination. Pollutants of concern include, but are not limited to, those associated with human sewage (particularly septic tanks), leaking underground storage tanks, animal/feedlot waste, agricultural chemicals (especially insecticides, herbicides, and fertilizers) and urban runoff (including pesticides, fertilizers, and detergents). Pipeline, highway, and railway transportation of hydrocarbons and other potentially harmful materials in the Edwards Aquifer recharge zone and its watershed, with the attendant possibility of accidents, present a particular risk to water quality in Comal and San Marcos Springs. Comal and San Marcos Springs are both located in urbanized areas. Hueco Springs is located alongside River Road, which is heavily traveled for recreation on the Guadalupe River, and may be susceptible to road runoff and spills related to traffic. Of the counties containing portions of the San Antonio

segment of the Edwards Aquifer, the potential for acute, catastrophic contamination of the aquifer is greatest in Bexar, Hays, and Comal counties because of the greater level of urbanization compared to the western counties. Although spill or contamination events that could affect water quality do happen to the west of Bexar County, dilution and the time required for the water to reach the springs may lessen the threat from that area. As aquifer levels decrease, however, dilution of contaminants moving through the aquifer may also decrease. The TWC reported that in 1988 within the San Antonio segment of the Edwards Aquifer, Bexar, Hays, and Comal counties had the greatest number of land-based oil and chemical spills in central Texas that affected surface and/or groundwater with 28, 6, and 4 spills, respectively (TWC 1989). As of July, 1988, Bexar County had between 26 and 50 confirmed leaking underground storage tanks, Hays County had between 6 and 10, and Comal County had between 2 and 5 (TWC 1989) putting them among the top 5 counties in central Texas for confirmed underground storage tank leaks. The TWC estimates that, on average, every leaking underground storage tank will leak about 500 gallons per year of contaminants before the leak is detected. These tanks are considered one of the most significant sources of groundwater contamination in the state (TWC 1989). The TWC (1989), using the assessment tool DRASTIC (Aller, et al. 1987), classified aquifers statewide according to their pollution potential. The Edwards Aquifer (Balcones Fault Zone—Austin and San Antonio Regions) was ranked among the highest in pollution potential of all major Texas aquifers. ’ (USFWS, 1997)

Recovery

Reclassification Criteria:
Not available.

Recovery Priority Number: 2C

Delisting Criteria:
Not available.

Recovery Actions:

- 1. Recovery Action 1: Ensure Adequate Water Quantity and Quality within the Southern Edwards Aquifer and Management Units. Priority 1. • Recovery Activity 1-1: Gather information necessary to determine water quantity needed at each Management Unit. Information needs to be gathered and evaluated to ensure adequate water quantity to the Management Units at levels that protect the species and their habitat. This will involve monitoring of aquifer levels and spring flow under normal and drought conditions, modeling the impact of drought, groundwater pumping, and climate change on aquifer levels and spring flows, and incorporating any new information into water quantity requirements for each species at each Management Unit. Implement measures to provide adequate water quantity. Continuous flow monitoring should be implemented at Fern Bank Springs as part of this activity. • Recovery Activity 1-2: Implement measures to provide adequate water quantity. To protect habitat, a comprehensive water management plan or equivalent would protect water quantity. This should include a regional aquifer management plan and the protection of aquifer recharge features. Long-term commitments need to be in place to ensure that these protections will continue in perpetuity. The plan must also identify how regional water needs will be met while considering these water limitations during severe droughts that could occur as a result of climate change. Considering comprehensive water planning should help ensure that the aquifer is not depleted due to lack of alternative water sources. • Recovery Activity 1-3: Evaluate the effectiveness of measures to provide adequate water quantity. Long-term water quantity monitoring should evaluate how well the implemented measures are protecting water quantity, especially during droughts. This monitoring campaign will include using the aquifer level, springflow, and groundwater pumping data collected by local groundwater conservation districts, Texas Water Development Board, U.S. Geological Service, and other entities. These data will be placed into a management framework that identifies critical aquifer levels and associated on-the-ground habitat conditions. This information should also be used to update the Contingency Plan for springflow triggers to salvage species for the refugia if needed. Projected frequency of droughts and groundwater levels used in models should be validated with data collected during future drought conditions. • Recovery Activity 1-4: Model effects of projected future land use changes on water quality and aquifer recharge, and whether additional land protection is needed. Increasing development and associated impervious cover in the contributing, recharge, and artesian zones of the Edwards Aquifer threatens water quality, may affect recharge, and increases the risk of catastrophic spills. Modeling these effects is necessary to consider for preventing water quality degradation and whether land preservation in the contributing and recharge zones is needed. • Recovery Activity 1-5: Develop and implement effective measures to avoid chronic water quality degradation and maintain aquifer recharge. Measures to avoid or limit chronic water quality degradation should be developed, implemented, and when needed, modified to ensure their effectiveness. These measures could involve land acquisition, conservation easements, best management practices, impervious cover regulations, buffer zones, outreach programs, and numerous other tools. Evaluate the effectiveness of these measures. • Recovery Activity 1-6: Develop and implement effective measures to avoid chronic water quality degradation, contaminant spills, and maintain aquifer recharge. Measures to avoid or limit spills and chronic water quality degradation should be developed, implemented, and when needed, modified to ensure their effectiveness. These measures could involve land acquisition, conservation easements, best management practices, impervious cover regulations, buffer zones, outreach programs, and numerous other tools. Plans should also be developed to reduce the risk of spill and reduce the impacts of spills through containment to avoid contaminants entering groundwater. These measures should also evaluate the effectiveness of these measures. • Recovery Activity 1.7: Monitor the physical and chemical constituents (sediment, nutrients, ions, and contaminants) present during baseflow and stormflow conditions at the springs. Information should be collected on the physical and chemical constituents of greatest concern during baseflow and stormflow conditions. This research should also be designed to evaluate the effectiveness and modify, if necessary, the measures that avoid or minimize water quality degradation. • Recovery Activity 1-8: Consult with environmental agencies on effects of wastewater discharges. Use interagency consultation to evaluate the combined effects of permitted wastewater discharges and future permitted discharges in the recharge and contributing zone on water quality in the Management Units. Implement conservation measures as part of the consultations to protect water quality (USFWS, 2024a)

- 2. Recovery Action 2. Protect and Restore Habitat in Waters and on Lands Within and Adjacent to the Management Units. Priority 1. • Recovery Activity 2-1: Control non-native species. Control or eliminate non-native species spread that outcompete native flora and fauna, contribute to scouring flood severity, and reduce the adaptive capacity and resiliency of listed species' populations within the Management Units. Additionally, proactive measures to reduce conditions preferred by non-native species should be a long-term priority. Regulations to prevent the spread or introduction of non-native species should be enforced through TPWD and the Service. Private landowners should be educated on illegal activity reporting and prevention of introducing non-native species that may adversely affect the habitats within the Management Units. • Recovery Activity 2-2: Reduce human disturbance in habitat. Reduce unintentional disturbance from recreation using measures such as designated access points and prohibiting access in sensitive areas. Intentional disturbance (e.g., from vegetation removal and littering) could be reduced from education, availability of alternatives that would prevent the disturbance, and from legal enforcement. • Recovery Activity 2-3: Develop and implement habitat management plans. Management plans should include descriptions of on-the-ground projects and activities necessary to improve or maintain adequate high-quality habitat in which the species' populations can be resilient. This may include erosion control strategies and reducing mechanical disturbances in coordination with local jurisdictions, resource management agencies, and private landowners. Land development effects should be minimized using best management practices. Sediment removal projects, in coordination of resource management agencies and industries, should minimize disturbance to the habitat where possible, to enhance areas of diminished habitat value. The habitat can be evaluated to determine if it has degraded to the point where specific habitat restoration projects would be beneficial to improve habitat. Adjacent riparian zones should be included in the habitat management plans to protect aquatic habitat. Additionally, the habitat management plans should include abatement strategies for existing threats and measures to identify undetected threats as new information becomes available. • Recovery Activity 2-4: Protect and restore habitat at Fern Bank and Hueco springs. Access to these springs is needed to evaluate habitat restoration needs. Easements or other conservation agreements could be used to protect these springs from human disturbance. • Recovery Activity 2-5: Evaluate the efficacy of recovery activities in protecting and restoring species habitat. Plans and activities should be reviewed and revised as needed based on outcomes from activities and new information. (USFWS, 2024a)

- 3. Recovery Action 3: Establish and Implement a Captive Population Management Plan and Reintroduction Plan. Priority 1 for San Marcos salamander, Texas blind salamander, Texas wild-rice; Priority 2 for Comal Springs riffle beetle, Comal Springs dryopid beetle, Peck's cave amphipod, fountain darter. • Recovery Activity 3-1: Determine optimal conditions for captive breeding of each listed species. Ensure that each species has captive conditions that maximize life expectancy and reflect or exceed life expectancy of wild individuals. Ensure that under captive conditions, most individuals successfully reproduce and offspring from most broods survive until maturity and also reproduce. Until the optimal conditions have been determined for a species, large numbers of a species should not be kept in captivity because they will not be useful for the activities outlined in 3.3 or provide a safeguard against extinction. • Recovery Activity 3-2: Maintain captive breeding programs of each of the listed species. Captive breeding programs for each species will be maintained until threats to the species are ameliorated and delisting is achieved. The program is intended to achieve the goals of the plan described in 3.3. However, captive breeding programs should be established even if the plan has not yet been created to safeguard against extinction.+ • Recovery Activity 3-3: Develop and implement a comprehensive strategy for the six endangered species. This includes developing and updating Captive Propagation, Contingency, and Reintroduction Plans to ensure their long-term survival. Regular reassessment and adjustments (e.g., annually) are essential. The Captive Propagation plans should be consistent with the USFWS "Policy Regarding Controlled Propagation of Species

Listed Under the Endangered Species Act" (USFWS and NOAA 2000, entire). The plan should address four captive rearing situations: 1) captive rearing during non-crisis times in the event of a rapidly developing crisis when there is no time to collect wild animals, 2) collection and captive rearing of animals as a response to a rapidly developing crisis in which there is time to collect additional wild animals, 3) collection and captive rearing of animals in response to a slowly developing crisis, and 4) captive rearing of animals during non-crisis times without a developing crisis (i.e., standard operating procedures). The plans should balance the needs of the captive refugia with those of the wild populations through employing strategies that minimize the need for collecting wild individuals, while still fulfilling plan objectives. The Contingency Plans should establish the protocols needed to respond to crisis situations, including the emergency threat of water quantity (springs drying or limited flow), water quality (contaminant events such as oil spills), habitat fragmentation or isolation, or habitat loss. Contingency planning should be regularly updated, independent of the completion of genetic, breeding, and reintroduction studies. To mitigate the risk of extirpation before further collections can be made, the plans must address: maintaining and reproducing the species in captivity for multiple generations, maintain a sufficient captive population with genetic diversity representative of the wild for an extended period without the possibility of additional collections in case of extirpation from the wild, managing diseases and parasites in captivity, and incorporating strategies to avoid artificial selection that could reduce successful reintroductions. The Reintroduction Plans should adhere to standard guidelines for reintroduction plans (e.g., Association of Zoos & Aquariums). They should outline the process and circumstances under which the captive population(s) would be reintroduced into the wild, address research needed to improve reintroduction success (White et al. 2015, entire), consider the possibility of multiple reintroduction attempts, address contingency plans if reintroduction is unsuccessful, and include a post-release monitoring plan. The plan should be developed in coordination with agencies, permittees, and academic experts to ensure collection efforts maintain genetic diversity and population viability. An existing contingency plan exists (USFWS 1996) for managing salvage collections from the wild, though it requires substantial updates to align with current knowledge of the species. Additionally, a Participation Plan should be developed in coordination with the USFWS that outlines the level of commitment that partner facilities will implement this plan (i.e., long-term versus short-term holding facilities), personnel willing to collect and transport animals, research to be conducted, and level of information to be collected. The CPCP and Participation Plans. should regularly updated. (USFWS, 2024a)

- 4. Recovery Action 4: Promote Edwards Aquifer Species Conservation and Recovery through outreach, education, and cooperation. Priority 3. • Recovery Activity 4-1: Provide outreach and education to local communities. Partners and management agencies will conduct outreach through events and engaging social media posts. Additionally, events and workshops hosted to the local community (e.g., tribes, local governments, citizens, and associations within the taxon's range) should use strategies to seek out broad participation, including those that may not pursue conservation-focused events. Development and installation of interpretive signage should be considered to improve public awareness and appreciation for the ecosystems the seven species depend on and conservation of aquifer and aquatic habitats in general. • Recovery Activity 4-2: Promote cooperation and provide incentives and education for private landowners, land managers, and businesses. All habitat within management units in which land managers, landowners, and businesses are the primary caretaker should be incentivized and provided with education on the significance of their cooperation for the recovery of these species. Incentives are encouraged to engage landowners in activities that would improve or restore habitat. This can be achieved through obtaining conservation agreements (e.g., Safe Harbors or easements) whenever possible to protect natural attributes of the property from disturbance, participation or permission for the monitoring of populations, and adaptive management and timeline transparencies for agreements (e.g., Habitat Conservation Plans) with businesses. (USFWS, 2024a)

- 5. Recovery Action 5: Establish and Implement Effective Disease and Parasite Protocols. Priority 2. • Recovery Activity 5-1: Investigate largemouth bass virus in fountain darters. Evaluate whether the virus affecting fountain darters is largemouth bass virus or a novel virus using genetic sequencing. Develop captive techniques to treat this virus and reduce mortality of infected individuals. • Recovery Activity 5-2: Control parasites in fountain darters and salamanders in captivity. Develop captive techniques to treat parasites, reduce mortality, and increase reproduction from infected individuals. • Recovery Activity 5-3: Monitor parasite prevalence at Management Units and assess whether it affects resiliency of wild populations. This action should also investigate the relationship between population trends and parasite prevalence and assess health of infected individuals to assess the extent that parasites are affecting individual fitness. • Recovery Activity 5-4: Control parasites at Management Units if needed. Based on monitoring results, techniques to reduce parasites in the wild may need to be implemented such that the parasites are not decreasing the resiliency of the population (USFWS, 2024a)
- 6. Recovery Action 6. Monitor Progress Toward Criteria within the Management Units: Priority 3. • Recovery Activity 6-1: Create and implement monitoring plan to evaluate habitat quality and population resiliency of each species at each Management Unit. This should include mark/recapture or other population level analyses to provide population estimates when feasible, as well as the use of other techniques, such as abundance estimates and eDNA. Data should be statistically analyzed for trends in population and habitat quality over time. Population viability analysis should be performed at each Management Unit. Monitoring data should also be analyzed to evaluate the extent that climate change affects groundwater recharge, water temperature and water quality in species habitat. • Recovery Activity 6-2: Determine data needs for monitoring. Due to the subterranean nature of some of the listed species, it may not be possible to obtain adequate data to assess population size. Other estimates may be needed as surrogates in these cases. For subterranean species populations, presence/absence detection through eDNA sampling may provide suitable information in place of formal monitoring due to the inaccessibility of this habitat, access to private properties where species could occupy, and survey difficulties that result in repeatable detection accuracies. New monitoring techniques that provide better population estimates for subsurface species, and how springflows and groundwater levels affect subsurface habitat should be used if they become available. (USFWS, 2024a)

Conservation Measures and Best Management Practices:

- Groundwater Quality There are several laws and regulations to protect water quality that apply to the Edwards Aquifer. The Federal Safe Drinking Water Act of 1974, as amended, regulates pollution and sedimentation of public drinking water sources, including the Edwards Aquifer. This legislation mandates enforcement of drinking water standards established by the Environmental Protection Agency. The Texas Commission on Environmental Quality (TCEQ) is responsible for enforcement of these standards in Texas. Under the authority of the Texas Administrative Code (30 TAC § 213), the TCEQ regulates activities having the potential for polluting the Edwards Aquifer and hydrologically connected surface streams through the Edwards Aquifer Protection Program or “Edwards Rules.” The Edwards Rules require a number of water-quality protection measures for new development occurring in the recharge zone and portions of the contributing zone of the Edwards Aquifer. The TCEQ also prohibits facilities such as municipal solid waste landfills and waste disposal wells from being built in the recharge or transition zones (USFWS, 2024).

- Habitat Conservation Plan The EARIP HCP was finalized in 2013, amended in 2020, and covers incidental take of these species for groundwater withdrawal, recreation, and other activities through 2028 (EARIP HCP 2020, entire). Permittees to the plan include the EAA, City of San Antonio acting through the San Antonio Water System, City of New Braunfels, City of San Marcos, and Texas State University (National Research Council 2015, pp. 25–26). The EARIP HCP includes activities to minimize and mitigate impacts and contribute to the recovery of the eleven Covered Species and addresses a variety of aquifer management issues, including ensuring springflow during a repeat of the drought of record (Payne et al. 2019, p. 200; EARIP HCP 2020, pp. 4-57–4-59, 4-62–4-66). Long-term commitments to protect listed species in the Edwards Aquifer beyond the HCP and the term of its associated section 10(a)(1)(b) permit are not currently in place. However, a new habitat conservation plan is expected in 2028 (USFWS, 2024).
- RECOMMENDATIONS FOR FUTURE ACTIONS • If possible given workload and priorities, a Species Status Assessment could be conducted to guide the development of a revised recovery plan. • Continue to plan and implement regular surveys that monitor Peck's cave amphipod occurrence, habitat condition, groundwater and surface water quality, as well as any potential threat to the Peck's cave amphipod from disease and parasitism (Section 2.2.2.3). • Status survey at the Hueco Springs ecosystem in Comal County to assess species persistence, abundance, and habitat health of this sub-population, in addition to improving habitat conditions and landowner cooperation. Currently, the status of this sub-population is unknown. • Continue to investigate the extent of groundwater watersheds between the Comal and Hueco ecosystems, including eDNA or physical sampling in between the sites when available, in order to get a more accurate representation of drainage areas and habitat connectivity and gene flow. • Incorporate habitat-centered biological goals and objectives during EARIP HCP renewal process to promote protection of suitable habitat quality and quantity and species resiliency. • Establish conservation easements or fund land purchases within the contributing and recharge zones of the Edwards Aquifer for the benefit of the Peck's cave amphipod and to ensure adequate springflow is sustained through droughts. Additionally, a siteprioritization tool could be developed to support decision making about strategic land acquisitions. • Research to reduce sources of nitrate into the Comal ecosystem through coordination with agencies, public education, and other non-governmental organizations. • To the extent possible, prevent or reduce increases in impervious surfaces or clearing of forest within the recharge areas supporting the species. • Continuation of the captive propagation research: o Conduct ongoing research to enhance captive propagation techniques. o Develop the capacity to produce offspring on-demand, anticipating standard operating procedures to inform action for potential catastrophic events or extirpation in the wild. o Formulate a comprehensive reintroduction plan based on research findings, ensuring the ability to replenish populations as needed. • Continue water quantity and quality monitoring at accessible spring and well sites within and areas that recharge the Comal ecosystem. • Continue to measure genetic variability among sub-populations of the Peck's cave amphipod in order to evaluate gene flow, population structure, and estimate population sizes. These data can inform captive husbandry practices to preserve genetic diversity in the refugia population and future recovery plan implementation. (USFWS, 2024)

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SPECIES ACCOUNT: *Stygobromus hayi* (Hay's Spring amphipod)

Species Taxonomic and Listing Information

Listing Status: Endangered; 02/05/1982; Northeast Region (R5) (USFWS, 2015)

Physical Description

A small aquatic amphipod. Albinistic; eyes lacking, body laterally compressed. Antennal flagellum 2-segmented; uropod 3 uninamous. Rostrum absent. Antenna 1-1.5 times body length; 1.25 times longer than antenna 2. Apex of male telson with 18-20 unequal spines (NatureServe, 2015).

Taxonomy

Previously thought to be a synonym of S. tenuis (NatureServe, 2015). Formerly considered a member of the family Gammaridae, Hay’s spring amphipod is now placed in the Crangonyctidae (Holsinger, 1977). It is one of a number of species in this genus (USFWS, 1980).

Historical Range

The original site was a spring on National Zoo property adjacent to Rock Creek in the District of Columbia (USFWS, 2013).

Current Range

The other six sites (confirmed and probable) in addition to the original site consist of five springs and one interstitial sample from the sediments of Rock Creek, all within Rock Creek Park in the District of Columbia (USFWS, 2013).

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: It presumably feeds as do other amphipods (detritivore) (NatureServe, 2015).

Reproduction Narrative

Adult: Not available

Habitat Narrative

Adult: It occupies mud or leaf litter in cave streams and small springs (Holsinger 1978) (USFWS, 1980).

Dispersal/Migration

Dispersal/Migration Narrative

Adult: Not available

Population Information and Trends

Population Trends:

Not available

Number of Populations:

7 sites (USFWS, 2020)

Population Size:

Unknown (USFWS, 2020)

Population Narrative:

Collectively, all seven known and probable sites are within a 3-mile reach of the Rock Creek floodplain and all are subject to similar environmental conditions (USFWS, 2013). The population size is unknown (NatureServe, 2015). The population size of the Hay's spring amphipod is unknown. Its entire range is limited to 2.5 miles (4 km) of the Lower Rock Creek watershed in the District of Columbia with seven extant populations (redundancy), and two populations that are probable but unconfirmed. The species has been collected from three different habitat types (representation). (USFWS, 2020)

Threats and Stressors

Stressor: Habitat degradation (USFWS, 2013)
Exposure:
Response:
Consequence:
Narrative: The 1982 listing rule cites two main threats to the Hay's Spring amphipod habitat: (1) The increasing frequency of flooding of Rock Creek, which may remove individual amphipods and adversely affect habitat by removing leaves and sediment that form the species' spring habitat; and (2) construction activities affecting spring habitats. These threats remain. In addition, increased recreational use of Rock Creek Park and changes in hydrology and water quality in the spring recharge areas are threats to the species' habitat (Feller 1997, Culver and Sereg 2004) (USFWS, 2013).

Recovery

Reclassification Criteria:

Not available - this species does not have a recovery plan.

Recovery Priority Number: 5

Delisting Criteria:

Criterion 1: The species is documented to persist in a stable or increasing trend in the current metapopulations over a 20-year period. Persistence data are collected via implementation of a monitoring program designed to provide confidence in presence/absence detection of the species. Due to the difficulty of surveying for the species, we are not able to monitor abundance or population trends. For each 5-year sampling period, the persistence of at least one population in each metapopulation must be documented; the population documented to persist may differ between sampling periods (USFWS, 2022).

Criterion 2: Water quality parameters (physical and chemical) associated with urban storm runoff in the drainage areas of occupied and unoccupied springs within each metapopulation are reduced to levels shown to be unharmful to the species' long-term persistence. Monitoring of these parameters shows these levels are maintained for 20 years, and water quality regulations are in place to ensure long-term protection of water quality (USFWS, 2022).

Criterion 3: Long-term agreements are in place and being implemented to provide protection from habitat degradation from recreation, construction, or management activities within the spring recharge areas and buffer zones (USFWS, 2022).

Recovery Actions:

- Not available - this species does not have a recovery plan.
- Take additional amphipod samples at the three sites where probable Hay's Spring amphipods have been found in order to allow confirmation of the species' occurrence (USFWS, 2013).
- Carry out a study to delineate recharge areas for the springs supporting Hay's Spring amphipod. Once this delineation is complete, designate areas within the parks to protect these recharge zones (USFWS, 2013).
- Redirect existing artificial surface flows away from springs and spring runs supporting this species (USFWS, 2013).
- To the extent possible, prevent any increase in impervious surfaces or clearing of forest lands within the drainages and recharge areas supporting this species (USFWS, 2013).
- Maintain a buffer area around each of the springs/seeps and associated spring runs where recreational activities, construction activities (including new trails), and activities adversely affecting water quality are prohibited or discouraged (USFWS, 2013).
- Develop a recovery outline and (if deemed appropriate as a consequence of the analysis in the recovery outline) a recovery plan for the amphipod (USFWS, 2013).
- 1. Assess water quality and quantity adjacent to delineated recharge areas and determine necessary remediation measures. 2. Protect recharge areas from recreational and construction activities (e.g., new trails, increases in impervious surface, forest clearing, stream restoration), as well as activities adversely affecting water quality and quantity (i.e., application of harmful pesticides, changes in surface or subsurface flows). 3. Implement a formal monitoring plan that involves both eDNA sampling and traditional sampling for the species at an interval that provides useful information about the status and trends of the species. 4. Investigate connectivity of the populations within each metapopulation to evaluate representation and contribution to species viability (genetics, geology, etc.). 5. Implement research studies to learn more about species habitat requirements (water chemistry, water temperature, etc.) (USFWS, 2022)

Conservation Measures and Best Management Practices:

- RECOMMENDATIONS FOR FUTURE ACTIONS • Conduct surveys at all the sites with repeated visits at the two sites with "unknown" status and the two sites with "probable" status in FY21. • Continue to collect eDNA samples at sites to better understand how well it supports presence. • Evaluate additional conservation actions or projects that might be implemented adjacent to recharge areas recently delineated by the Service to further improve water quality and quantity. • Continue to investigate the extent of groundwater watersheds at each spring in order to get a more accurate representation of drainage areas. • To the extent possible, prevent any increase in impervious surfaces or clearing of forest within the recharge areas supporting the species. • Work with the National Park Service and Smithsonian Institution to ensure that recreational activities and construction activities (including new trails), and activities adversely affecting water quality and quantity in recharge areas are discouraged (i.e. application of pesticides, changes in surface or subsurface flows). Continue to support deer management at Rock Creek Park. • Develop a recovery outline for the species by the end of FY20 and if deemed appropriate as a consequence of the analysis in the recovery outline, develop a recovery plan in FY21. (USFWS, 2020)

- The key elements of this recovery plan include: 1. Protect, restore, maintain, and manage habitat to increase or maintain resiliency across all populations. This includes addressing threats to water quality and water quantity and providing long-term protection from the impacts of human activities. 2. Monitor existing sites and new areas to better evaluate persistence (resiliency) and potentially discover additional populations. 3. Continue to improve understanding of the needs of the species and its habitat through research and monitoring (USFWS, 2022)

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SPECIES ACCOUNT: *Syncaris pacifica* (California freshwater shrimp)

Species Taxonomic and Listing Information

Listing Status: Endangered, October 31, 1998 (53 FR 43884).

Physical Description

The California freshwater shrimp grows to about 5 centimeters (cm) (2.5 inches [in.]). Males are translucent to nearly transparent. They have small surface and internal color-producing cells (chromatophores) clustered in a pattern to disrupt perception of their body outline and maximize the illusory disguise of submerged, decaying vegetation. Undisturbed shrimp move slowly; they are virtually invisible on submerged leaf and twig substrates, and among the fine, exposed, live roots of vegetation along undercut stream banks. The coloration of females ranges from a dark brown to a purple color. In some, a broad tan dorsal band may also be present. Females may change rapidly from this very dark cryptic color to nearly transparent, with diffuse chromatophores. Females are generally larger and deeper-bodied than males (USFWS 1998).

Taxonomy

California freshwater shrimp were first described as Miersia pacifica in 1895. In 1900, a new genus, Syncaris, was created for the California atyids based on notable differences in the chelae (pinchers) and rostrum (the horn-shaped structure between the eyes). The description of the freshwater atyid shrimp group in California to which Syncaris pacifica belongs was revised following a review of the genus Syncaris. The revised description primarily focused on the lack of detailed descriptions for both S. pacifica and S. pasadenae. However, the review did not result in a change in the taxonomy of either species, but recommended the retention of their current taxonomy based on morphological differences. S. pacifica is the only surviving species in the genus Syncaris. California freshwater shrimp can distinguished from other shrimp found in the same habitat by the length of their pincer-like claws (chelae), the presence of terminal bristles (setae) at the tips of the first and second chelae, the presence of a short spine above the eye, and the angled articulation of the second chelae with the carpus ("wrist") (53 FR 43884; USFWS 2011).

Historical Range

Prior to human disturbances, the shrimp is assumed to have been common in low elevation, perennial freshwater streams in Marin, Sonoma, and Napa counties in California (NatureServe 2015; USFWS 1998; USFWS 2015).

Current Range

The California freshwater shrimp is currently restricted to 23 stream segments in a few coastal streams in Marin, Sonoma, and Napa counties in California. The distribution can be separated into four general geographic regions: tributary streams in the lower Russian River drainage, which flows westward into the Pacific Ocean; coastal streams flowing westward directly into the Pacific Ocean; streams draining into Tomales Bay; and streams flowing southward into northern San Pablo Bay (NatureServe 2015; USFWS 2007; USFWS 2015).

Distinct Population Segments Defined

No

Critical Habitat Designated

No;

Life History

Feeding Narrative

Adult: California freshwater shrimp eat mostly small decaying particles found widely distributed throughout their habitat, but will also eat algae (USFWS 2015). California freshwater shrimp may use visual, tactile, or chemical cues in foraging activities. To eat, they brush up the food with tufts at the ends of their claws and lift it to their mouths (USFWS 1998; USFWS 2015). Activities, including foraging activities, are reduced in the winter. Growth is also reduced in the winter (USFWS 1998).

Reproduction Narrative

Adult: The California freshwater shrimp has R-selective spawning. Adults reach sexual maturity by their second summer of growth, and breeding begins in fall. To breed, the male transfers and fixes the sperm sac to the female shrimp immediately after her last molt, and the female lays 50 to 120 eggs (USFWS 2007). Females then carry the eggs with them for 8 months throughout the winter to allow for slow, overwintering development. Eggs hatch in June (NatureServe 2015; USFWS 2015). During the incubation period in which the mother carries the eggs with, her many larvae die due to either adult female death or genetic/embryonic developmental problems. As a result, the number of embryos emerging from the eggs during May and June are reduced typically by 50 percent (53 FR 43884). California freshwater shrimp live up to 3 years (USFWS 1998).

Geographic or Habitat Restraints or Barriers

Adult: Limited habitat due to habitat destruction and polluted waters.

Spatial Arrangements of the Population

Adult: Clumped

Environmental Specificity

Adult: Narrow

Tolerance Ranges/Thresholds

Adult: Low; no data are available for defining the optimum temperature and stream flow regime for the shrimp, or the minimum and maximum limits it can tolerate (USFWS 2007).

Site Fidelity

Adult: High

Habitat Narrative

Adult: The California freshwater shrimp is found in low-elevation (less than 116 m [380 ft.]), low-gradient (generally less than 1 percent) perennial freshwater streams or intermittent streams with perennial pools, where banks are structurally diverse with undercut banks, exposed roots, overhanging woody debris, or overhanging vegetation (USFWS 1998). Excellent habitat conditions for the shrimp include streams 30 to 90 cm (12 to 36 in.) in depth, with exposed live roots along completely submerged undercut banks (horizontal depth greater than 15 cm [6 in.]), with overhanging stream vegetation and vines (USFWS 2007). California freshwater shrimp are most likely found in areas with bottom substrates dominated by sand (USFWS 1998). They require high water quality, low pollution, and good oxygen levels, and have a low tolerance for other conditions; but no data are available for defining the optimum temperature and stream-flow regime for the shrimp, or the minimum and maximum limits it can tolerate (USFWS 2007).

Dispersal/Migration

Motility/Mobility

Adult: Moderate

Migratory vs Non-migratory vs Seasonal Movements

Adult: Nonmigratory

Dispersal

Adult: Unknown (USFWS 1998)

Immigration/Emigration

Adult: Unlikely

Dispersal/Migration Narrative

Adult: Basic information regarding the mobility of the species (e.g., dispersal conditions, age and sex composition of drift, passive vs. active dispersal) is not known (USFWS 1998). Although many experts in the field of shrimp biology would agree that upstream migration of shrimp occurs, no data to date have been collected to show how this is done, or to confirm that it does happen. California fresh water shrimp are moderately strong swimmers; in addition to being able to swim forwards and backwards, shrimp can “skip” over the water surface when disturbed (USFWS 1998; USFWS 2007).

Additional Life History Information

Adult: In addition to being able to swim forwards and backwards, shrimp can “skip” over the water surface when disturbed. Although many experts in the field of shrimp biology would agree that upstream migration of shrimp occurs, no data to date have been collected to show how this is done, or to confirm that it does happen (USFWS 2007).

Population Information and Trends

Population Trends:

Unknown (USFWS 2011)

Species Trends:

Most likely increasing.

Number of Populations:

present in 25 creeks across these four drainages (USFWS, 2022).

Population Size:

The number of individual California freshwater shrimp collected at six sites in Lagunitas Creek increased from approximately 1,878 in 1991 to approximately 4,407 in 2000 (USFWS 2011). Golden Gate National Recreational Area (2020, p. 8) used a habitat modeling approach to estimate an abundance of 3,383 shrimp (95% confidence interval: 643 to 7846) within the Olema Creek basin at the time of sampling (USFWS, 2022).

Adaptability:

Low

Population Narrative:

It is known that the range and (most likely) population of the California freshwater shrimp has grown since the shrimp was first listed. When first listed, the California freshwater shrimp was found in 13 locations; it is now known from 23 locations. Population data for the California freshwater shrimp are limited, because few long-term studies of populations have been recorded. The number of individual California freshwater shrimp collected at six sites in Lagunitas creek increased from approximately 1,878 in 1991 to approximately 4,407 in 2000 (USFWS 2011). Distribution At listing, the species was present in 12 streams across four drainages in coastal Northern California (Point Reyes, Salmon Creek, San Francisco Bay, and Russian River; Service 1988; p. 43884). At the time of the species' first 5-year review in 2007, the species was present in 23 streams across these four drainages (Service 2007, p. 3). At the time of the most recent 5-year review in 2011, the species remained present in these same 23 streams (Service 2011, p. 6). Currently, the species is present in 25 creeks across these four drainages. Following the Service's 2011 5-year review for the species, the Sonoma County Water Agency identified California freshwater shrimp along Hudspeth Creek near its confluence with Jonive Creek in the Russian River drainage unit (Sonoma County Water Agency 2016, p. 1) and Prunuske Chatham, Inc. identified California freshwater shrimp along an unnamed tributary to Redwood Creek where the species was not previously known to occur also in the Russian River drainage unit (Prunuske Chatham, Inc. 2017, p. 3). These new localities are tributaries to creeks where the species was previously known to occur (Jonive and Redwood Creeks, respectively) and are nearby previous observations of the species. Therefore, these observations do not alter the overall status of the species from the Service's 2011 5-year review. Abundance The listing rule for the species did not provide abundance estimates for populations, however the species' Recovery Plan provided information on abundance and length of distribution (Service 1998; Table 2) from all 17 streams known to be occupied at the time of the Recovery Plan. The Service's 2007 5-year review noted a lack of data from streams other than Lagunitas Creek in the Point Reyes drainage but reported an increase in abundance from 1,878 in 1991 to 4,407 in 2000 across six sampling sites in Lagunitas Creek following an increase in available habitat within the stream after 1997 (Service 2007, p. 6). The Service's 2011 5-year review noted that long term in the number of known occupied streams following listing may not reflect an increase in abundance of the species (Service 2011, p. 6). Currently, there are no range-wide abundance surveys for the California freshwater shrimp. The Point Reyes drainage is surveyed for California freshwater shrimp much more frequently than the other three drainages that the species occupies. Serpa (2015, p. 20) in 2015 re-surveyed the six sites in Lagunitas Creek he had previously surveyed in 2000 and found only 644 shrimp, a decrease he attributes to a reduction in available habitat and limited survey effort in 2015. The Marin Municipal Water District conducts annual electrofishing and snorkeling surveys of 13.4 km of Lagunitas Creek, 7.2 km of San Geronimo Creek, and 3.3 km of Devil's Gulch in the Point Reyes drainage unit. The purpose of these surveys is to observe juvenile salmonid abundance however the surveyors note observations and bycatch of California freshwater shrimp. Following the species' previous 5-year review in 2011, Marin Municipal Water District has observed the following counts of the species during these surveys (Table 6; Marin Municipal Water District 2020). Golden Gate National Recreational Area (2020, p. 8) surveyed Olema Creek in the Point Reyes drainage in 2018 and 2019 and found that the distribution of the species in Olema Creek had increased following previous survey efforts in Olema Creek over 20 years ago. Additionally, Golden Gate National Recreational Area (2020, p. 8) used a habitat modeling approach to estimate an abundance of 3,383 shrimp (95% confidence interval: 643 to 7846) within the Olema Creek basin at the time of sampling. (USFWS, 2022).

Threats and Stressors

Stressor: Drought
Exposure: Reduced water flow.
Response: Reduced available habitat.
Consequence: Reduction in population numbers.
Narrative: Reduced precipitation and increased temperatures could have two compounding effects on the California freshwater shrimp. First, reduced rainfall and increased temperatures would result in lower stream flows through reduced runoff and increased evaporation, thereby increasing the likelihood that stream segments dry out during the summer months; this could result in local extirpations and further isolate populations of the shrimp. Drought could also devastate populations of the California freshwater shrimp because the loss of habitat makes it difficult for this species to repopulate affected areas. A second, compounding factor would be an increase in water demand for household and agricultural purposes, which could further reduce stream flows and increase the likelihood that stream segments harboring the species dry out (USFWS 2011).

Stressor: Nonnative species/predation
Exposure: Introduction of nonnative fish.
Response: Limited habitat, mortality.
Consequence: Reduction in population numbers.
Narrative: Various introduced fish and minnows, such as green sunfish (Lepomis cyanellus), bluegill (Lepomis macrochirus), smallmouth bass (Micropterus dolomieui), largemouth bass (Micropterus salmoides), mosquitofish (Gambusia affinis), prey on the California freshwater shrimp, thereby limiting the species' distribution. Additionally, several native fish species may also prey on the shrimp (USFWS 2011).

Stressor: Pollution
Exposure: Runoff from urban use.
Response: Response unknown, but thought to be mortality.
Consequence: Reduction in population numbers.
Narrative: Urban development creates impervious surfaces that increase the amount of runoff from non-point-source pollutants, as well as increased sedimentation. The sources of pollutants vary, and include runoff from housing developments and golf courses, and the disposal of paints, petroleum products (i.e., automotive fluids), and household cleaning agents into storm drains. In addition, chemical spills, although relatively rare events, represent a significant threat to the recovery of the California freshwater shrimp (USFWS 2011).

Stressor: Livestock grazing
Exposure: Livestock grazing in California freshwater shrimp habitat.
Response: Habitat destruction, mortality.
Consequence: Reduction in population numbers.
Narrative: Grazing activities may destroy California freshwater shrimp habitat through the removal of riparian vegetation, adverse bank and channel changes, decreased water quality due to runoff from manure lots, increased sediment loads, change in runoff characteristics, and increased water temperatures due to a reduced riparian canopy. When livestock are not excluded from riparian areas, grazing animals typically concentrate along watercourses, particularly during the summer when the creek and adjacent riparian areas offer the livestock water and palatable forage In addition, runoff from manure lots following storms and direct inputs increase nutrient levels and result in high production of algae. Algal blooms cause oxygen supersaturation during the day and result in oxygen depletion at night because of respiration and decomposition (USFWS 2011).

Stressor: Dams
Exposure: Construction of dams and diversion of water.
Response: Limited habitat, mortality.
Consequence: Reduction in population numbers.
Narrative: The construction of dams adversely affects California freshwater shrimp in several ways, including: (1) crushing individuals due to construction; (2) inundating habitat; (3) serving as a barrier to movement; (4) altering flow patterns; and (5) increasing sedimentation and siltation downstream when dams are washed out during high winter flows. Impoundments raise the elevation of the inundation zone, drowning the roots of riparian vegetation not adapted to periods of prolonged inundation, and likely reduce riparian vegetation in the area. Lack of riparian vegetation harms shrimp by reducing habitat complexity, increasing the potential for bank scour, reducing detritus production, and eliminating high flow refugia. During drought years, natural reductions in flow combined with water exports could result in losses to shrimp populations (USFWS 2011).

Recovery

Reclassification Criteria:
Downlisting from endangered to threatened will be considered when:

A watershed plan has been prepared and implemented for Lagunitas Creek (including Olema Creek), Walker Creek (including Keys Creek), Stemple Creek, Salmon Creek, Austin Creek (including East Austin Creek), Green Valley Creek (including Atascadero, Jonive, and Redwood creeks), Laguna de Santa Rosa (including Santa Rosa and Blucher creeks), Sonoma Creek (including Yulupa Creek), Napa River (including Gamett Creek), and Huichica Creek.

Long-term protection is assured for at least one shrimp stream in each of the four drainage units.

The abundance of California freshwater shrimp approaches carrying capacity in each of 17 streams.

Recovery Priority Number: 7C

Delisting Criteria:
Delisting of the California freshwater shrimp will be considered when:

A watershed plan has been prepared and implemented for Lagunitas Creek (including Olema Creek), Walker Creek (including Keys Creek), Stemple Creek, Salmon Creek, Austin Creek (including East Austin Creek), Green Valley Creek (including Atascadero, Jonive, and Redwood creeks), Laguna de Santa Rosa (including Santa Rosa and Blucher creeks), Sonoma Creek (including Yulupa Creek), Napa River (including Gamett Creek), and Huichica Creek.

Long-term protection is assured for at least eight shrimp streams, with at least one in each of the four drainage units.

Shrimp-bearing streams having fewer than 8 kilometers (km) (5 miles) of potential shrimp habitat have shrimp distributed in all potential habitat; those with more than 8 km (5 mi.) of potential shrimp habitat have shrimp distributed over 8 km (5 mi.) or more.

Populations of shrimp maintain stable populations approaching carrying capacity for at least 10 years in each of 17 streams.

Recovery Actions:
- Remove existing threats to known populations of shrimp (USFWS 1998).
- Restore habitat conditions favorable to shrimp and other native aquatic species at extant localities (USFWS 1998).
- Protect and manage shrimp populations and habitat once the threats have been removed and restoration has been completed (USFWS 1998).
- Monitor and evaluate shrimp habitat conditions and populations (USFWS 1998).
- Assess effectiveness of various conservation efforts on shrimp (USFWS 1998).
- Conduct research on the biology of the species (USFWS 1998).
- Restore and maintain viable shrimp populations at extirpated localities (USFWS 1998).
- Increase public awareness and involvement in the protection of shrimp and native, cohabiting species through various outreach programs (USFWS 1998).
- Assess effects of various conservation efforts on cohabiting, native species (USFWS 1998).
- Assemble a California freshwater shrimp recovery team (USFWS 1998).
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Conservation Measures and Best Management Practices:
- RECOMMENDATIONS FOR FUTURE ACTIONS: Here we propose several habitat conservation and ecological research recommendations which will aid in the recovery and conservation of the California freshwater shrimp. Some of these recommendations have already been discussed in previous recovery documents (Service 2007, pp. 15–16; Service 2011, pp. 19–20) and remain valid. 1. Conduct a habitat assessment of Santa Rosa Creek to determine if there is suitable habitat for reintroduction. 2. Develop a range wide monitoring and survey program to determine the current distribution of the species, assess habitat conditions, and assess population trends. This range-wide monitoring and survey program has not yet been developed or implemented. 3. Identify areas where restoration actions could improve habitat quality and quantity. To the Service’s knowledge, there has been no concerted effort to identify such areas, though successful restoration has

occurred in a few areas (e.g., Stemple Creek; Martin et al. 2009, p. 603). 4. Revise downlisting criterion 3 and delisting criteria 3 and 4 (Service 1998, pp. 54 and 55; Service 2011, pp. 19–20) (USFWS, 2022).

Additional Threshold Information:

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