Longhorn Fairy Shrimp
(Branchinecta longiantenna)

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
Sacramento, California

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5-YEAR REVIEW
Longhorn Fairy Shrimp (*Branchinecta longiantenna*)

I. GENERAL INFORMATION

Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (Service) is required by section 4(c)(2) of the Endangered Species Act (Act) to conduct a status review of each listed species at least once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing of a species as endangered or threatened is based on the existence of threats attributable to one or more of the five threat factors described in section 4(a)(1) of the Act, and we must consider these same five factors in any subsequent consideration of reclassification or delisting of a species. In the 5-year review, we consider the best available scientific and commercial data on the species, and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process defined in the Act that includes public review and comment.

Species Overview:

As summarized in our Recovery Plan (Service 2005a), longhorn fairy shrimp are tiny freshwater crustaceans with delicate elongate bodies, large stalked compound eyes, and 11 pairs of phyllopods (swimming legs that also function as gills). Fairy shrimp do not have a hard shell, a characteristic of the order Anostraca to which they belong. Longhorn fairy shrimp are easily distinguished from other fairy shrimp by the male's extremely long second antennae. Longhorn fairy shrimp are dependent on seasonally inundated wetlands, such as vernal pools, and are endemic to California vernal pool habitat. Longhorn fairy shrimp are restricted to the Central Valley.

Longhorn fairy shrimp are rare, and at the time of listing in 1994, four widely separated populations of this species were known (Service 1994). Prior to the previous five-year review (Service 2007a), extensive surveys for fairy shrimp species throughout the range of longhorn fairy shrimp had not located any additional populations of this species, but had detected additional localities within each of the four populations. Since then, a single new population was discovered in Fresno County, bringing the total to five known populations. Currently, the California Natural Diversity Database (CNDDB) reports 11 occurrences of this species (CNDDB 2012). The CNDDB occurrences are positive-sighting reports submitted to the California Department of Fish and Game (CDFG) by the public. The information is not verified or updated unless a subsequent report for the identical location is submitted. One CNDDB occurrence record may represent a single vernal pool, a single puddle, multiple pools within a vernal pool complex, a substantial portion of a vernal pool complex, or an entire complex.

This 5-year review discusses the longhorn fairy shrimp in terms of populations. For the purpose of this 5-year review, the Service has grouped together "clusters" of individual longhorn fairy shrimp locality records that are in close proximity to each other (i.e., within a few miles), and defined these clusters as "populations." Populations are defined by entire vernal pool complexes, rather than individual pools (Simovich *et al.* 1992). Longhorn fairy shrimp populations are comprised in most cases of multiple localities where the species has been detected. For example, the Carrizo Plain population, in San Luis Obispo County, consists of 38 known localities (A. Kuritsubo, Bureau of Land Management, *in litt.*, 2012), of which only six are reported as occurrences in the CNDDB. As another example, the CNDDB (2012) reports one occurrence of longhorn fairy shrimp at the Vasco Caves Preserve, in Contra Costa County. The number of actual localities at which longhorn fairy shrimp has occurred within the Vasco Caves Preserve has not been quantified. There are numerous rock outcrops within the preserve that have supported longhorn fairy shrimp, and there seems to be substantial inter-annual variation (S. Bobzien, East Bay Regional Park District, pers. comm., 2007; D. Bell, East Bay Regional Park District, pers. comm., 2012). In general, our definition of "locality" does not necessarily coincide with a single vernal pool, nor do we think these groups necessarily represent biological populations. Rather, they are convenient for reference to various parts of the range. Thus, our grouping methodology is consistent with the identification of the four populations known at the time of listing.

The five known populations of longhorn fairy shrimp include: (1) areas within and adjacent to the Carrizo Plain National Monument, San Luis Obispo County; (2) areas within the San Luis National Wildlife Refuge (NWR) Complex, Merced County; (3) areas within the Brushy Peak Preserve, Alameda County; (4) areas within the Vasco Caves Preserve, near the town of Byron in Contra Costa County; and, (5) areas within the proposed Alkali Sink Conservation Bank east of Mendota in Fresno County(Service 2005a; H.T. Harvey and Associates 2009)(Figure 1). The Brushy Peak and Vasco Caves Preserves are within three miles of each other. This species was also detected in a roadside ditch two miles north of Los Banos, in Merced County in 2003. Only one individual was detected in the ditch and this occurrence is considered to be an anomaly and not a sustainable population (CNDDB 2012). Three of the five confirmed populations are found entirely on public lands that are currently protected and managed for vernal pool species. A portion of the Carrizo Plain population is found on public lands, with the remaining portion occurring on private lands. The Alkali Sink area has not yet been finalized as a conservation bank, and is therefore not yet protected.

Methodology Used to Complete This Review:

This review was prepared by the Sacramento Fish and Wildlife Office (SFWO) of the U.S. Fish and Wildlife Service (Service) following the Region 8 guidance issued in March 2008. We used information from the 2005 *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (Recovery Plan) (Service 2005a), information from the previous 5-year review and survey information from experts who have been monitoring various occurrences of this species. We also considered information from a Service-contracted report. The Recovery Plan and personal communications with experts were our primary sources of information used to update the species status and threats sections of this review. We received no information from

the public in response to our Federal Notice initiating this 5-year review. This 5-year review contains updated information on the species' biology and threats, and an assessment of that information compared to that known at the time of listing or since the last 5-year review. We focus on current threats to the species that are attributable to the Act's five listing factors. The review synthesizes all this information to evaluate the listing status of the species and provide an indication of its progress towards recovery. Finally, based on this synthesis and the threats identified in the five-factor analysis, we recommend a prioritized list of conservation actions to be completed or initiated within the next 5 years.

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Federal Register (FR) Notice Citation Announcing Initiation of This Review: A notice announcing initiation of the 5-year review of this taxon and the opening of a 60-day period to receive information from the public was published in the Federal Register on May 25, 2011, (76 FR 30377). We received no responses to this notice.

Listing History:

Original Listing
FR Notice: 59 FR 48136
Date of Final Listing Rule: September 19, 1994
Entity Listed Species (*Branchinecta longiantenna*)
Classification: Endangered

Associated Rulemakings: Critical habitat for this species was proposed on September 24, 2002 (Service 2002). The final rule to designate critical habitat for the longhorn fairy shrimp was published on August 6, 2003 (Service 2003). A re-evaluation of non-economic exclusions from the August 2003 final designation was published on March 8, 2005 (Service 2005b). An evaluation of economic exclusions from the August 2003 final designation was published on August 11, 2005 (Service 2005c). Administrative revisions were published on February 10, 2006 (Service 2006). Clarifications on the economic and non-economic exclusions for the final designation of critical habitat were published on May 31, 2007 (Service 2007b).

Review History:
A 5-year review was conducted for longhorn fairy shrimp, dated September 2007 (Service 2007a), at which time no change in the species' status was recommended.

Species' Recovery Priority Number at Start of 5-Year Review: The recovery priority number for longhorn fairy shrimp is 8 according to the Service's 2011 Recovery Data Call for the Sacramento Fish and Wildlife Office, based on a 1-18 ranking system where 1 is the highest-ranked recovery priority and 18 is the lowest (Service 1983). This number indicates that the taxon is a species that faces a high degree of threat and has a high potential for recovery.

Recovery Plan or Outline

Name of Plan or Outline: Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon
Date Issued: December 15, 2005

II. REVIEW ANALYSIS

Application of the 1996 Distinct Population Segment (DPS) Policy

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

Information on the Species and its Status

Species Biology and Life History

Spatial Distribution

Longhorn fairy shrimp are known from the four widely separated populations identified at the time of listing, as well as a single new population that was discovered in 2009. The original four populations include longhorn fairy shrimp found in pools located within a matrix of alkali sink and alkali scrub plant communities north and northwest of Soda Lake and at the southern end of the Carrizo Plain National Monument in the Carrizo Vernal Pool Region, in a series of sandstone outcrop pools at Vasco Caves Preserve and Brushy Peak Preserve, both within the Livermore Vernal Pool Region, and from alkaline grassland vernal pools in the San Luis NWR (Service 2005a). Since the time of listing in 1994, additional localities of longhorn fairy shrimp have been detected within all four previously known populations (CNDDB 2012). Extensive surveys

for other fairy shrimp species within the range of longhorn fairy shrimp have detected a single additional population since the time of listing, which lies in the proposed Alkali Sink Conservation Bank in Fresno County, and at which fairy shrimp are found in a mix of alkali sink and grassland vernal pools (H.T. Harvey and Associates 2009) We believe that additional surveys in areas between Carrizo Plain and the Livermore Vernal Pool Regions may uncover additional, undiscovered populations of this species (Service 2005a). A summary of the latest information on the five known populations and the single Los Banos observation is provided in the "Abundance" section below.

Most of what is known about the species is described in Eng *et al.* (1990), Eriksen and Belk (1999), and Helm (1998), and summarized in the Recovery Plan (Service 2005a). 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. There is some evidence that temperatures may not be warm enough for the species to mature in the northern portions of the Central Valley. However, it is likely 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. Despite lack of knowledge on the tolerance of longhorn fairy shrimp to cooler temperatures, its presence in northern Central Valley vernal pool regions cannot be ruled out until further surveys have been conducted (Service 2005a).

Abundance

Status surveys have occurred at five sites: the Carrizo Plain National Monument, the Kestersen Unit of the San Luis NWR, the Brushy Peak Preserve, the Vasco Caves Preserve, and the proposed Alkali Sink Conservation Bank (A. Kuritsubo, pers. comm., 2012; B. Parris, San Luis NWR, pers. comm., 2012; D. Bell, EBRPD, pers. comm., 2012; H.T. Harvey and Associates 2009). There have been no studies of demographic features of longhorn fairy shrimp at any of these locations. Monitoring has not been sufficient to quantify abundance and identify trends but rather just presence of the species in surveyed pools, and is summarized below:

Carrizo Plain, San Luis Obispo County

The previous five-year review reported 12 vernal pools containing longhorn fairy shrimp within the Carrizo Plain National Monument, including six at the south of the monument, and 6 in the north, near Soda Lake An additional 8 vernal pools containing longhorn fairy shrimp were located on private land outside the monument (Service 2007a). Surveys since the previous review have located an additional 7 vernal pools with longhorn fairy shrimp inside the monument, and an additional 12 pools outside the monument (A. Kuritsubo, *in litt*., 2012; Fig. 1). Survey teams also revisited 8 of the pools previously reported to contain longhorn fairy shrimp, all of which still contained longhorn fairy shrimp (A. Kuritsubo, in litt. 2012). The increased number of longhorn fairy shrimp localities is likely due to increased survey effort, not an increase in the population. Further surveys in new locations both within and surrounding the Carrizo Plain National Monument may reveal additional vernal pools that contain fairy shrimp.

All populations within the monument are protected, while those outside the monument are currently not protected.

San Luis National Wildlife Refuge, Merced County

The previous five-year review reported 18 vernal pools within the San Luis NWR Complex at which longhorn fairy shrimp have been detected (Service 2007). Specifically, vernal pools with longhorn fairy shrimp were located within the Sno-bird and Kesterson Units of the Complex. A 2009 survey of 15 vernal pools in the Kesterson Unit found longhorn fairy shrimp in only one pool (Helm Consulting, 2009). There were other large branchiopods found in every pool, primarily vernal pool tadpole shrimp. We are not aware of any recent surveys in the Sno-bird Unit. It is possible that further sampling throughout the San Luis NWR Complex would have detected more pools containing longhorn fairy shrimp. All vernal pools in this region are protected.

Vasco Caves Preserve, Contra Costa County

This location is a 1,400 acre preserve owned and managed by the East Bay Regional Park District (EBRPD). The previous review reported that there were an uncounted number of pools in which longhorn fairy shrimp had been detected (Service 2007a). The site is characterized by large rock outcrops with multiple indentations that seasonally pool water and support fairy shrimp. In one of the largest of these outcrops, longhorn fairy shrimp had been detected in 84 small pools, although not necessarily in the same year. EBRPD began conducting more systematic surveys of pools beginning in 2010. Surveys in 2010 and 2011 detected longhorn fairy shrimp in only a single pool each year (D. Bell, pers. comm., 2012). Many of the pools surveyed contained other fairy shrimp species, including vernal pool fairy shrimp (*Branchinecta lynchi*) and California fairy shrimp (*Linderiella occidentals*), but not longhorn fairy shrimp. Because of the lack of baseline data, it is difficult to say whether the observed decrease in pools supporting longhorn fairy shrimp is due to population declines or natural fluctuations. All pools known to contain longhorn fairy shrimp at this location are protected.

Brushy Peak Preserve, Alameda County

Brushy Peak is a 507-acre preserve owned by the Livermore Area Recreation and Park District and managed by EBRPD. Similar to Vasco Caves, this site contains rock outcrops that pool seasonally and support fairy shrimp. As of the last review, there were several pools known to support longhorn fairy shrimp, although the number had not been quantified (Service 2007a). Systematic surveys by EBRPD have begun at this site as well, and in 2010 no longhorn fairy shrimp were detected. One pool was found to contain longhorn fairy shrimp during surveys in 2011 (D. Bell, pers. comm., 2012). As of March 8, 2012, there had not yet been sufficient rainfall to form pools capable of supporting fairy shrimp. All pools known to contain longhorn fairy shrimp at this location are protected.

Proposed Alkali Sink Conservation Bank, Fresno County

This location is a 945-acre site east of Mendota in Fresno County that has been proposed as a conservation bank. Surveys were conducted by H.T. Harvey and Associates in February and March of 2009. The area was not known to have been surveyed for vernal pool species previously. The site contains alkali sinks and annual grasslands, along with both artificial and natural vernal pools. Longhorn fairy shrimp were found in five pools on March 3, two of which were artificial pools, two of which were natural vernal pools, and one of which was a seasonal wetland. Their abundance was estimated to be in the hundreds in one pool, and in the thousands in the other four pools (H.T. Harvey and Associates 2009). The longhorn fairy shrimp were found co-occurring in pools with both vernal pool fairy shrimp and versatile fairy shrimp. When the pools were resurveyed on March 9, many of the pools had dried up, and no longhorn fairy shrimp were found. The area is privately owned, but CDFG is expected to hold the easement when the property is finalized as a conservation bank. Currently, however, the habitat remains unprotected.

Los Banos, Merced County

In 2003, the California Department of Transportation (Caltrans) reported a single specimen of longhorn fairy shrimp in a roadside ditch adjacent to Miller Road, approximately 2 miles north of Los Banos (CNDDB 2012). The survey was conducted by Caltrans as part of the proposed State Route 152 Los Banos Bypass project. The Service is currently in consultation under ESA section 7 with Caltrans through the Federal Highway Administration for this transportation project. The seasonal wetland in which the longhorn fairy shrimp was detected is not within an area proposed for construction activities. This occurrence is not currently protected. We do not consider this observation an indication of a viable population since only a single specimen was located, although we are not aware of follow-up surveys to determine if this wetland feature commonly supports this species.

Habitat or Ecosystem

The longhorn fairy shrimp is highly adapted to the unpredictable conditions of vernal pool ecosystems. Longhorn fairy shrimp require a minimum of 23 days, but averaged 43 days, to reach maturity in artificial pools (Helm 1998). 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 3.3 feet in diameter, have a pH near neutral, and very low alkalinity and conductivity. Water temperatures in these vernal pools have been measured between 50 and 64 degrees Fahrenheit (Helm 1998). 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 203.4 feet in diameter. Water temperatures in the grassland vernal pools are also warmer, between 50 to 82 degrees Fahrenheit (Helm 1998, Eriksen and Belk 1999). The species has also been observed in a disturbed roadside ditch near Los Banos. Longhorn fairy shrimp have been found at elevations ranging from 75.5 feet in the San Joaquin

Vernal Pool Region to 2,887 feet in the Carrizo Vernal Pool Region (Service 2005a, CNDDB 2012).

Although 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. We do not know the extent of this historical range of variation or at what point the species will no longer be able to adapt to conditions outside of this range. For example, in a Mediterranean climate such as that of California, the annual season of precipitation (November to March) is relatively predictable, although amount of precipitation can vary substantially from year to year (Graham 2003). 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 (Graham 2003). Based on existing data (Helm 1998, Eriksen and Belk 1999), 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 (dormant eggs in the soil from previous years) are depleted. Thus drought is likely to decrease or terminate reproductive output as pools fail to flood, or dry up before reproduction is complete, and prolonged droughts over several successive years could extirpate particular localities or entire populations of longhorn fairy shrimp.

The longhorn fairy shrimp has been found in the same general area (although often at different localities) as the endangered Conservancy fairy shrimp (*Branchinecta conservatio*) and vernal pool fairy shrimp (*B. lynchi*), and the non-listed California fairy shrimp (*Linderiella occidentalis*), versatile fairy shrimp (*B. lindahli*), and spadefoot toad *(Spea hammondii*) tadpoles. Active adult longhorn fairy shrimp have been observed from the same vernal pool as versatile fairy shrimp and spadefoot toad tadpoles on the Carrizo Plain (Eng *et al.* 1990, Eriksen and Belk 1999)., and from the same pool as vernal pool fairy shrimp and versatile fairy shrimp from the Alkali Sink population (H.T. Harvey and Associates 2009)

Changes in Taxonomic Classification or Nomenclature

There have been no changes in classification or nomenclature since the time of listing.

Genetics

No genetic analysis has been performed for this species.

Species-specific Research and/or Grant-supported Activities

The Service is aware of no research on longhorn fairy shrimp that is ongoing or that has occurred since the previous review. There have also been no Section 6 grants awarded that involve longhorn fairy shrimp.

Five-Factor Analysis

The following five-factor analysis describes and evaluates the threats attributable to one or more of the five listing factors outlined in section 4(a)(1) of the Act.

FACTOR A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Urban development and conversion of native habitats to agriculture were major threats noted for the longhorn fairy shrimp when it was listed as endangered in 1994 (Service 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 within the same populations as those that were previously known, a new population was detected in Fresno County in an area that is currently being proposed as a conservation bank for vernal pool species, and a single individual was detected in Los Banos in a roadside ditch. The Los Banos occurrence is not considered a viable population (CNDDB 2012). Table 2, in section III:1B, provides information on which populations of longhorn fairy shrimp are currently protected from the threat of habitat destruction and modification.

We have little information on the size and configuration of the longhorn fairy shrimp habitat that is protected within the four original populations, or of the Alkali Sink population that is not currently protected. Even habitat that has been protected is often subject to changed hydrological conditions, invasion by nonnative plants and other species, increased vegetation growth, and other conditions that serve to make habitat less suitable for longhorn fairy shrimp. Studies have not been conducted to determine the minimum area (upland and wetland) needed to sustain vernal pool species in the long term, nor have surveys identified the amount of suitable habitat that is present at protected longhorn fairy shrimp localities. Furthermore, lack of monitoring information makes it difficult for land managers to note habitat threats as they appear and to respond with timely control measures.

Although much longhorn fairy shrimp habitat has been protected, the number of unprotected localities has increased considerably since the previous five-year review. At this time, there are twenty unprotected localities of longhorn fairy shrimp within portions of the Carrizo Plain population (A. Kuritsubo, in litt., 2012). These localities occur on privately-owned parcels that are about 20 acres in size. The Service is not aware of any development plans for these parcels at this time. The new localities were discovered by surveys in areas that had not previously been surveyed for fairy shrimp. As such, there is potential for additional longhorn fairy shrimp to occur in unprotected areas that have still not been surveyed outside of the Carrizo Plain National Monument (A. Kuritsubo, pers. comm., 2012). The population at Alkali Sink in Fresno County, discovered in 2009, has yet to be protected, as 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. The Alkali Sink population was found in an area not previously surveyed for longhorn fairy shrimp, suggesting that surveys in the surrounding region might detect more localities. Similarly, further surveys in areas within the Livermore Vernal Pool region, , particularly south of the Brushy Peak and Vasco Caves Preserves, along the west side of the Central Valley may uncover additional

localities or populations.

Within the Livermore area in Alameda County, we believe that 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." Floating means that the locations of the wind power equipment can be moved around on a given percentage of a person's property. Wind leases are fairly common in the grasslands of eastern Alameda County. At this time we do not have specific information about the existence of wind leases on the parcels that support longhorn fairy shrimp; 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, placement of fill), construction of access roads or fencing (altered hydrology, sedimentation, placement of fill), and vegetation management (chemical runoff or drift). In addition, access for monitoring and adaptive management could be limited.

FACTOR B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Overutilization for commercial purposes was not known to be a factor in the 1994 final rule (Service 1994). Overutilization for any purpose does not appear to be a threat at this time.

FACTOR C: Disease or Predation

The 1994 final rule does not state whether disease is a factor for longhorn fairy shrimp (Service 1994). The Service is not aware of any new information regarding disease or predation as threats to this species.

FACTOR D: Inadequacy of Existing Regulatory Mechanisms

The Federal Endangered Species Act: The Endangered Species Act of 1973, as amended (ESA), is the primary Federal law that provides protection for longhorn fairy shrimp. Section 7(a)(2) requires Federal agencies to consult with the Service to ensure any project they fund, authorize, or carry out does not jeopardize a listed species. If a Federal agency is not involved in a proposed project, and federally-listed species may be taken as part of the project, then an incidental take permit pursuant to section 10(a)(1)(B) should be obtained. Section 9 and Federal regulations pursuant to section 4(d) prohibit the "take" of federally endangered wildlife. The protection of Section 9 afforded to endangered species is extended to threatened wildlife and plants by regulation.

Federal Clean Water Act: The Section 404 of the Clean Water Act may afford some protection to longhorn fairy shrimp. The U.S. Army Corps of Engineers (Corps) issues permits for the discharge of dredged or fill material into navigable waters of the U.S. The Corps interprets "the waters of the United States" expansively to include not only traditional navigable waters, but also other defined waters that are adjacent or hydrologically connected to traditional navigable

waters. Before issuing a 404 permit to a project applicant that may affect federally-listed species, the Corps is required under section 7 of the ESA to consult with the Service. If ESA protections were removed, Section 404 of the Clean Water Act would not contribute to the conservation of longhorn fairy shrimp on its own.

Recent Supreme Court rulings have called into question the Corps' definition of Waters of the U.S. On June 19, 2006, the U.S. Supreme Court vacated two district court judgments that upheld this interpretation as it applied to two cases involving "isolated" wetlands. Currently, the Corps regulatory oversight of vernal pools is in doubt because of their "isolated" nature. If the Corps discontinues regulation of vernal pools, unmitigated destruction of suitable habitat for longhorn fairy shrimp may increase over the range of the species. However, the State of California's Regional Water Quality Control Board has the option to regulate projects that result in the dredge and fill of wetland habitat if a Federal 404 permit is not required (see California State Laws, below).

California State Laws: The State's authority to conserve wildlife is comprised of the California Endangered Species Act (CESA) and the California Environmental Quality Act (CEQA). Longhorn fairy shrimp are not listed under CESA. 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. If a project may impact known populations of longhorn fairy shrimp, these impacts would be disclosed to the Service and allow the Service an opportunity to comment on the proposed project's effects to this species. Typically, project proponents proposed conservation measures to offset or minimize adverse effects to listed species. However, CEQA does not guarantee that such conservation measures will be implemented.

The Clean Water Act Section 401 Water Quality Certification and/or Waste Discharge Requirements are regulated by the State of California's Regional Water Quality Control Board. Anyone proposing to conduct a project that requires a Federal permit or involves dredge or fill activities that may result in a discharge to U.S. surface waters and/or "Waters of the State" are required to obtain a Clean Water Act Section 401 Water Quality Certification and/or Waste Discharge Requirements permit. However, if a proposed project does not require a Federal permit, but does involve dredge or fill activities that may result in a discharge to "Waters of the State", the Regional Water Quality Control Board has the option to regulate the project under its state authority (Porter-Cologne) in the form of Waste Discharge Requirements or Waiver of Waste Discharge Requirements.

FACTOR E: Other Natural or Manmade Factors Affecting Its Continued Existence

Other natural or manmade threats cited in the 1994 final rule include stochastic extinction due to the high degree of isolation and small numbers of populations of this species (Service 1994). Stochastic extinction as a result of random or unpredictable disturbances is a continued threat to the species, due to its rarity. Additional threats not discussed in the 1994 listing rule include

climate change, nonnative invasive plant species, and inappropriate grazing regimes. The threats of climate change, invasive plant species, inappropriate grazing, and risk of stochastic extirpations remain for localities of longhorn fairy shrimp whether they are on protected lands or not. Threats to longhorn fairy shrimp are not likely being managed at all on private, unprotected lands. The majority of localities of this species do not have systematic monitoring programs to ensure that potential threats posed by invasive weedy species, inappropriate grazing regimes, and climate change are managed and controlled in perpetuity. In addition, funding is not sufficient at any of the protected localities for systematic surveys to be conducted to determine if potential threats are present. The lack of monitoring and funding is not, in itself, a threat to longhorn fairy shrimp; however, without these components, potential threats, as described above, likely will not be identified and eliminated. The ultimate status of the species depends heavily on full implementation of monitoring plans, experimental studies, and adaptive management to identify and address threats. We currently lack adequate information to determine the magnitude and imminence of these various threats at any longhorn fairy shrimp locality.

Small Numbers of Populations/Stochastic Extinction: The combination of highly specialized pool type and soil characteristics makes the longhorn fairy shrimp exceedingly rare. This species is only known to occur in five disjunct populations. The conservation biology literature commonly notes the vulnerability of taxa known from one or very few locations (e.g., Shaffer 1981, 1987; Primack 1998; Groom *et al*. 2006). Localities or entire populations may be highly susceptible to extirpation due to stochastic (random or chance) events, such as a series of prolonged, catastrophic droughts, or additional environmental disturbances (Gilpin and Soule 1988; Goodman 1987), such as adverse effects from adjacent development or agriculture activities, altered hydrology due to climate change, invasive plant species, and 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. We consider the loss of long-term viability in any one of the five extant populations a serious threat the species' recovery.

The number of longhorn fairy shrimp in most localities is unknown, and we do not know whether any population can be characterized as "small" such that stochastic demographic or genetic factors would be important to its long-term viability. Some occurrence data (CNDDB 2012) suggest that longhorn fairy shrimp numbers may be quite low in some sites, but systematic surveys for longhorn fairy shrimp have only begun recently and are focused on presence/absence data rather than true quantitative assessments. Recent surveys in both the Vasco Caves and Brushy Peak Preserves detected only a single pool containing longhorn fairy shrimp at each location, far fewer than had been detected previously (D. Bell, pers. comm., 2012). The San Luis NWR Complex also had only a single pool with longhorn fairy shrimp in the most recent survey, although the survey was restricted to 15 vernal pools (Helm Consulting, 2009), so longhorn fairy shrimp may still exist at other localities in the area that were not surveyed recently. The Alkali Sink population was found in only five pools, although abundance in most of those pools was estimated to be over 1,000 individuals each. These results show a limited number of localities in the majority of longhorn fairy shrimp populations, indicating that concerns related to small population size are a real issue for each of these populations. The

opposite is true in the Carrizo Plain population, on the other hand, where the number of pools with longhorn fairy shrimp has increased since the previous five-year review (A. Kuritsubo, in litt., 2012). This population may therefore be less vulnerable to the problems of low population size, although we reiterate that true quantitative data is lacking.

Population dynamics for longhorn fairy shrimp have not been investigated, and we do not know of any studies that have assessed the status of cyst banks within isolated or connected pools. Fairy shrimp cysts of many species are commonly dispersed by waterfowl, other migratory aquatic birds, and vertebrate animals (Eriksen and Belk 1999). Cysts will hatch into active shrimp under appropriate conditions of water temperature and chemistry. As a result, fairy shrimp individuals may sometimes occur, at least temporarily, in sites that provide the needed hatching conditions, but may not provide the conditions necessary for the long-term persistence of the species in that site (Eriksen and Belk 1999). Therefore, we believe that isolated populations of longhorn fairy shrimp continue to be threatened by stochastic extirpation due to environmental disturbance, while any potential effects of demographic and genetic stochasticity remain unknown.

Nonnative Invasive Plant Species: Nonnative invasive plant species are known to adversely affect vernal pool habitat throughout California (see Service 2005a for a summary). 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 (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). 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 (Sacramento County 2006), which can lead to oxygen depletion in the pools (Dunne and Leopold 1978), and contribute to the shortening of inundation periods through increased evapo-transpiration in the vernal pools (Marty 2005) and the reduction of 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.

Although localities where longhorn fairy shrimp occur have not been intensively surveyed, it is reasonable to expect invasive plants are present at some or many of them. The Alkali Sink location is known to contain non-native grasses, particularly soft chess (*Bromus hordeaceus*) and rattail fescue (*Vulpia myuros*) along with native forbs (H.T. Harvey and Associates 2009). Non-native plants may be less of a concern for the Brushy Peak and Vasco Caves populations, at which the habitat is characterized by rocky outcrops, but surveys are needed to document the extent of nonnative plant cover at all longhorn fairy shrimp localities and determine the level of management response required. This task is explicitly incorporated into the management plan for Carrizo Plain, which gives directives to "assess potential or actual threats" to longhorn fairy shrimp and to "take measures to eliminate non-native species" (BLM 2010). These actions are ongoing, however, so we consider gathering this information Carrizo Plain, as well as all other populations a critical task for evaluating the species' status over the next 5 years.

Grazing: Appropriate grazing practices may be a necessary component to ensure proper function of hydrology in vernal pools (Marty 2005, Pyke and Marty 2005). In particular, grazing may be necessary to ensure that non-native weedy plants such as Italian ryegrass and waxy mannagrass, which increase thatch buildup and decrease ponding durations, do not decrease the aquatic habitat available to longhorn 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 (A. Kuritsubo, in litt., 2012; D. Bell, pers. comm. 2012; B. Parris, pers. comm., 2012; H.T. Harvey and Associates 2009). Each of the four original locations have now incorporated grazing practices into their management plans in an effort to ensure that grazing does not negatively affect vernal pool species (D. Bell, pers. comm. 2012; B. Parris, pers. comm 2012.; BLM 2010). There are now efforts to use adaptive management through appropriate grazing at each of these four populations, which is essential to ensure the sustainability of longhorn fairy shrimp (Marty 2005). We are aware of no management plan for the Alkali Sink location. The area is currently used primarily for cattle ranching, so grazing practices at the site need to be addressed for longhorn fairy shrimp (H.T. Harvey and Associates 2009). There is still very little knowledge about the nature or magnitude of the impacts of grazing on longhorn fairy shrimp, or what levels of grazing might maintain optimal longhorn fairy shrimp habitat. We therefore consider this an important survey task for evaluating the species' status over the next 5 years.

Drought and Climate Change: 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 (Lenihan *et al.* 2003; Pyke 2004). 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 (Pyke and Marty 2005, Pyke 2005). In addition, protected areas could become unusable to the longhorn fairy shrimp if climatic conditions do not allow the necessary hydrological conditions to persist (Pyke and Fisher 2005). 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 (Pyke and Marty 2005).

Current climate change predictions for terrestrial areas in the Northern Hemisphere indicate warmer air temperatures, more intense precipitation events, and increased summer continental drying (Field et al. 1999, Cayan et al. 2005, IPCC 2007, Pyke 2005). However, climatic conditions for smaller sub-regions such as California remain uncertain (Pyke 2005). 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 2005). However, it is possible that either scenario would result in negative effects to vernal pool invertebrate species (Pyke 2004, Pyke and Marty 2005). Cooling and drying trends could adversely affect longhorn fairy shrimp through decreased inundation periods that do not allow the species sufficient time to complete its life cycle.

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 (Field *et al.* 1999), which may exacerbate effects due to drought. Drought-mediated 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.

In contrast, warmer conditions could increase inundation periods. Although longer flooding could increase available habitat for longhorn fairy shrimp, we have no information whether larger pools are in fact occupied by this species, which is often found in small depressions. However, increased inundation periods associated with a warming trend could also 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*) (Erikson and Belk 1999, Balfour and Morey 1999, Pyke 2005).

III. RECOVERY CRITERIA

Recovery plans provide guidance to the Service, States, and other partners and interested parties on ways to minimize threats to listed species, and on criteria that may be used to determine when recovery goals are achieved. There are many paths to accomplishing the recovery of a species and recovery may be achieved without fully meeting all recovery plan criteria. For example, one or more criteria may have been exceeded while other criteria may not have been accomplished. In that instance, we may determine that, over all, the threats have been minimized sufficiently, and the species is robust enough, to downlist or delist the species. In other cases, new recovery approaches and/or opportunities unknown at the time the recovery plan was finalized may be more appropriate ways to achieve recovery. Likewise, new information may change the extent that criteria need to be met for recognizing recovery of the species. Overall, recovery is a dynamic process requiring adaptive management, and assessing a species' degree of recovery is likewise an adaptive process that may, or may not, fully follow the guidance provided in a recovery plan. We focus our evaluation of species status in this 5-year review on progress that has been made toward recovery since the species was listed (or since the most recent 5-year review) by eliminating or reducing the threats discussed in the five-factor analysis. In that context, progress towards fulfilling recovery criteria serves to indicate the extent to which threat factors have been reduced or eliminated.

1. Habitat protection: Accomplish habitat protection that promotes vernal pool ecosystem function sufficient to contribute to population viability of the covered species.

This criterion addresses Factor A.

1A. Suitable vernal pool habitat within each prioritized core area for the species is protected.

Vernal pool regions used in the Recovery Plan are based largely on the presence of endemic species, with soils and geomorphology as secondary elements, and each region contains one or more of the vernal pool species covered in the plan. Core areas are distinct areas in each vernal pool regions that support high concentrations of federally-listed vernal pool species, are representative of a given species range, and are generally where recovery actions are focused. Core areas represent viable populations (possibly even source populations of vernal pool species for larger metapopulations) that will contribute to the connectivity of habitat and thus increase dispersal opportunities between populations. The Recovery Plan identifies specific percentages of suitable habitat to be protected in each of the four longhorn fairy shrimp core areas, which include: (1) North Carrizo Plain; (2) South Carrizo Plain; (3) Altamont Hills; and (4) the Grasslands Ecological Area. In the Recovery Plan, core areas are ranked as zone 1, 2, or 3 in order of their overall priority for recovery (zone 3 represents currently unoccupied, historical habitat, which has not been identified for this species). Core areas containing longhorn fairy shrimp are included as both zones 1 and 2 in the Recovery Plan, with no core areas ranked as zone 3. These core areas are multi-species habitats that may also contain other federally-listed vernal pool species, and are much larger than the areas that are actually occupied by longhorn fairy shrimp.

Table 1 provides a summary of the four core recovery areas, by vernal pool region, and the corresponding zone designation for each core area.

Table 1: Longhorn fairy shrimp core recovery areas.

Carrizo Vernal Pool Region Core areas: North Carrizo Plain (zone 2) South Carrizo Plain (zone 2)
Livermore Vernal Pool Region Core area: Altamont Hills (zone 1)
San Joaquin Vernal Pool Region Core area: Grasslands Ecological Area (zone 1)

Recovery goals include both population and habitat criteria. To downlist the longhorn fairy shrimp, the Recovery Plan recommends that 100 percent of known localities where the species has been detected (i.e., "occurrences", not necessarily as defined by CNDDB) be protected rangewide. In addition, the Recovery Plan specifies criteria for protection of suitable longhorn fairy shrimp habitat within the four core recovery areas; suitable habitat includes both occupied and unoccupied habitat. For longhorn fairy shrimp, the Recovery Plan recommends that 95 percent of the suitable habitat in each of the zone 1 and zone 2 core recovery areas be protected. To delist the longhorn fairy shrimp, the Recovery Plan recommends that 100 percent of any newly discovered and reintroduced populations be protected. There is now one new population since the time of listing, located at Alkali Sink in Fresno County. This population lies outside of any core areas, but within the San Joaquin Vernal Pool Region. Alkali Sink is currently not protected, although it is in the process of being designated as a conservation bank, which could lead to its protection in the near future. In addition, the Recovery Plan recommends that species be reintroduced to vernal pool regions and soil types from which status surveys indicate the

species has been extirpated. The Service is not aware of any populations of longhorn fairy shrimp that have been extirpated; therefore, this criterion is not applicable.

The Service does not yet have sufficient information to quantify either the acreage of suitable habitat within each core area or the acreage of protected habitat that is suitable for longhorn fairy shrimp. The amount of suitable habitat that exists range wide has not yet been estimated; therefore, the percent that has been protected range wide is still unknown.

1B. Species occurrences distributed across the species geographic range and genetic range are protected. Protection of extreme edges of populations protects the genetic differences that occur there.

Within the four known populations, species localities are distributed across the species' geographic range and the genetic range is protected. Extreme edges of the longhorn fairy shrimp's range are protected. Therefore, this criterion is close to fulfillment in the sense that the majority of localities are protected from land-use conversion, although other threats may be present (see section II above). The northern-most population occurs within the Altamont Hills core area, where all known localities are protected within the Brushy Peak Preserve and the Vasco Caves Preserve. The Carrizo Plain National Monument partially protects the southern-most population of this species, where 19 of 39 known localities are protected. The San Luis NWR contains 18 known localities that have contained longhorn fairy shrimp at some point, all of which are protected for vernal pool species. Table 2 provides information on the protection status of each population. The Alkali Sink population, currently unprotected, lies in between the San Luis NWR population and the Carrizo Plain population, so it does not represent a significant range expansion. Due to the lack of genetic studies, however, the level to which this population, or any population, is divergent and represents an expansion of the genetic range is not known.

Table 2: Known populations (from North to South) of longhorn fairy shrimp and protection status.

Population	Land owner(s)	Status of Protection of Population
Vasco Caves Preserve	East Bay Regional Park District	Protected – Public lands
Brushy Peak Preserve	Livermore Area Recreation and Park District	Protected – Public lands
San Luis NWR	Service	Protected – Public lands
Alkali Sink	private	Not protected – proposed as a conservation bank
Carrizo Plain	Bureau of Land Management and private	19 localities protected on the Carrizo Plain National Monument and 20 localities on private land are not protected.

1C. Reintroduction and introductions must be carried out and meet success criteria.

The Recovery Plan recommends introduction to vernal pool regions and soil types from which status surveys indicate longhorn fairy shrimp has been extirpated. As of this review, the Service is not aware of any instances where the species has been extirpated. Therefore, this recovery criterion is not relevant to the species at this time.

1D. Additional occurrences (i.e., localities) are permanently protected, if determined essential to recovery goals.

At this time, the Service is aware of additional localities that have been discovered since the species was listed in 1994 (CNDDB 2012). Many of the additional localities have been detected within protected areas (i.e., Vasco Caves Preserve, Brushy Peak Preserve, San Luis NWR, and Carrizo Plains National Monument). There are exceptions, which include nineteen localities outside of the Carrizo Plain National Monument, San Luis Obispo County, which lie on private, unprotected land. Additionally, a new population, consisting of five localities, was recently detected at Alkali Sink in Fresno County. While this population lies within a proposed conservation bank, it is currently unprotected. As a new population located a significant distance from the four original populations, this occurrence should be considered essential to recovery goals, and therefore its protection is a priority. Lastly, there was a single individual detected in a roadside ditch two miles north of Los Banos, in Merced County. This occurrence is considered to be an anomaly and not a sustainable population (CNDDB 2012) due to the presence of only one individual. The Service has determined that this locality is not essential to the recovery of this species.

1E. 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.

Monitoring of hydrology has not occurred at any of the known extant populations; therefore the Service is unable to determine whether the hydrology at extant localities has supported viable populations through a variety of hydrologic conditions. It is probable that many of the protected sites have functional hydrology that would meet the requirements specified in this recovery criterion. However, the Service has not identified the parameters that need to be monitored to determine if this criterion has been met.

2. Adaptive Habitat Management and Monitoring

This criterion implicitly addresses Factors A, D, and E.

2A. 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 in sections 1A-E.

This criterion has been largely met. The San Luis NWR Complex is comprised of the San Joaquin, San Luis, and Merced NWRs. All of these NWRs have vernal pools that have contained longhorn fairy shrimp. Of these three NWRs, only the San Joaquin NWR has completed a Comprehensive Conservation Plan (CCP). This CCP implements management for vernal pool species, including longhorn fairy shrimp. Refuge biologists are currently preparing a CCP for the entire San Luis NWR Complex which addresses vernal pool species management, and is expected to be completed in 2012 (M. Pelz, Service, in litt., 2012). The Bureau of Land Management (BLM) completed the Carrizo Resource Management Plan in 2010, which specifically addresses management for vernal pool species within the Carrizo Plain National Monument. This plan includes directives to "increase or maintain viable populations" of fairy shrimp, "monitor populations and assess habitat quality," along with addressing the needs to study the effects of grazing and the impacts of invasive plants (BLM 2010). Regular monitoring is now occurring at the Carrizo location in accordance with this management plan. There are also management plans now in place at Brushy Peak and Vasco Caves Preserves. Systematic surveys of rock outcrops containing pools began at Vasco Caves and Brushy Peak in 2010, and are being carried out annually (D. Bell, pers. comm., 2012), and include measures of water quality as well as presence/absence of fairy shrimp (Kneitel, 2010; Kneitel, 2011). The plans specifically address management for vernal pool species, and ensure that practices such as grazing are consistent with sustaining longhorn fairy shrimp (D. Bell, in litt., 2012).

Although the efficacy of these management plans for facilitating ecosystem function and population viability has not yet been proven, they cover (or will soon cover) all protected populations of longhorn fairy shrimp. Each of them has provisions specifically designed to maintain vernal pool habitat that is suitable for longhorn fairy shrimp. Fully meeting this criterion requires the completion of the San Luis NWR CCP, and the accumulation of data that shows these management plans are effectively preserving ecosystem function and maintaining population viability. This criterion is not currently relevant to the Alkali Sink population, since it is not yet considered protected. Development of a management plan for that population, however, will be necessary assuming the population is protected in the near future as a conservation bank.

2B. Mechanisms are in place to provide for management in perpetuity and long-term monitoring of 1A-E, as previously discussed (funding, personnel, etc).

The San Luis NWR is managed by the Service, the Carrizo Plain National Monument is managed by the Bureau of Land Management, the Vasco Caves and Brushy Peak Preserves are managed by East Bay Regional Park District. Therefore, funding for management and protection of vernal pool species depends on funding to these agencies. This criterion has been partially met for these sites through budget practices of the involved agencies. The Alkali Sink population lies on privately owned land. The area is nearing completion as a conservation bank, in which case CDFG would hold an easement for the property. Funding for management and monitoring, however, is not currently in place, so this criterion has yet to be fulfilled for this population.

2C. Monitoring indicates that ecosystem function has been maintained in the areas

protected under 1A-D 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.

Monitoring of ecosystem function has not occurred for any of the known populations of this species; therefore, the Service is unable to determine if the ecosystem function has been maintained at extant localities that has supported viable populations through a variety of hydrologic conditions. Given the increased number of localities at Carrizo that support longhorn fairy shrimp, it is likely that the ecosystem there meets the specified criterion. The occurrence of longhorn fairy shrimp in numbers greater than 1,000 in several pools at the Alkali Sink site indicate that ecosystem function there, too, is adequate to meet this criterion. The other three sites, namely Vasco Caves, Brushy Peak and the San Luis NWR, each had smaller numbers of localities supporting fairy shrimp in recent surveys compared with previous years. For Brushy Peak and Vasco Caves, this reduction was found despite the start of more systematic surveys in 2010. These results raise doubts about the functionality of the ecosystems at these three locations to support longhorn fairy shrimp. Further monitoring data is therefore required to determine if this criterion has been met.

3. Status Surveys:

This criterion implicitly addresses Factors A, D, and E.

3A. Status surveys, 5-year status reviews, and population monitoring show populations within 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.

Monitoring has not occurred during a time period that meets the requirements specified in the Recovery Plan at any of the sites with known occurrences; therefore, the Service is unable to determine if this criterion has been met. The Recovery Plan states that standardized status surveys should establish parameters that evaluate population sizes to determine overall trends in species status rangewide (e.g., evidence of reproduction and recruitment). Specific monitoring parameters have not yet been identified. The Carrizo Plain population has been monitored for evidence of reproduction on a non-annual basis and females with brood pouches have been detected when the species is present (A. Kuritsubo, pers. comm., 2012).

Vernal pool region working groups (see section 5A and 5B for a description of vernal pool working groups) will be important for tracking the progress of recovery efforts, including monitoring the status of populations of this species, particularly on private lands that are not currently monitored. This will be particularly important for the Brushy Peak, Vasco Caves and San Luis NWR, for which population viability is in doubt due to recent apparent reductions in number of longhorn fairy shrimp.

3B. 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.

Informal monitoring of known populations of longhorn fairy shrimp has occurred within the Carrizo Plain, the San Luis NWR, the Brushy Peak Preserve, and the Vasco Caves Preserve, and 3 surveys were performed in spring of 2009 at the Alkali Sink population. For all known localities, biologists have noted observations of longhorn fairy shrimp when out in the field, but survey methods have not been standardized between locations (A. Kuritsubo, pers. comm., 2012; D. Bell, pers. comm., 2012; Helm Biological Consulting 2009). There are now, however, consistent surveys for presence of fairy shrimp being performed at Carrizo Plain, Brushy Peak and Vasco Caves, though these surveys have not shown the threats to have been eliminated. The primary threat to this species described in the 1994 final listing rule is habitat loss due to agriculture conversion and urbanization. While this continues to be a threat to vernal pool species in general, the majority of known populations of longhorn fairy shrimp are protected from land-use conversion on public lands. Therefore, this threat has been removed from protected populations. Other threats exist, however, such as the increased risk of local extirpations from stochastic events because of the small number of isolated populations for this species, and risks from environmental disturbances, including severe drought, degradation of habitat from invasive weedy plant species, inappropriate grazing regimes, and other unforeseen events. Further information regarding current threats to the species is provided in Section II, above.

4. Research:

Research implicitly addresses all five listing factors.

4A. 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.

The Recovery Plan discusses a variety of research that would be beneficial to help refine recovery actions and criteria, and guide overall recovery and long-term conservation efforts. The Recovery Plan recommends research on genetics, taxonomy, biology of vernal pool species, the effects of habitat management practices on vernal pool species and their habitat, and threats to vernal pool species and ecosystems (Service 2005). The majority of information needs discussed in the Recovery Plan are still outstanding. The Service has not processed any scientific/recovery permits in support of research on this species. The Service has contacted species experts and there is no ongoing or proposed research pertaining to longhorn fairy shrimp; therefore, this criterion has not been met.

4B. 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 within and among population genetic variation is fully representative by populations protected in the Habitat Protection section of this document, described previously in sections 1A-E.

See 4A, above.

4C. Research necessary to determine appropriate parameters to measure population viability for each species have been completed.

See 4A, above.

5. Participation and outreach:

Public participation and outreach implicitly address all five listing factors.

5A. Recovery Implementation Team is established and functioning to oversee rangewide recovery efforts.

The Recovery Plan discusses a variety of participation programs to achieve the goal of recovery of the listed species in the plan. An essential component of this collaborative approach is the formation of a single recovery implementation team overseeing the formation and function of multiple working groups formed at the vernal pool region level. The Recovery Implementation Team has been established, and is now functioning to direct recovery actions for vernal pool species. However, their efforts to date have not focused on regions in which the longhorn fairy shrimp are found. Therefore this criterion has not yet been met.

5B. Vernal pool regional working groups are established and functioning to oversee regional recovery efforts.
No regional working groups have been established in the areas of concern for longhorn fairy shrimp.

5C. Participation plans for each vernal pool region have been completed and implemented.

This action has not been initiated.

5D. Vernal pool region working groups have developed and implemented outreach and incentive programs that develop partnerships contributing to achieving recovery criteria 1-4.

This action has not been initiated.

IV. SYNTHESIS

When the longhorn fairy shrimp was listed as endangered in 1994, the primary threats to its survival and recovery were stochastic (random) extinction by virtue of the small isolated nature of the remaining populations, and loss of habitat due to urban development and conversion to agriculture. The Service has determined that this species is still in danger of extinction throughout its range. Longhorn fairy shrimp are extremely rare and were only known to occur in four disjunct populations as of the last review. The species has since been detected at a new location at Alkali Sink in Fresno County, thereby increasing the known distribution, although not appreciably expanding the range. Additional localities have also been detected at the Carrizo Plain population since the last review. Despite these positive indications, the populations at Brushy Peak, Vasco Caves and the San Luis NWR seem to have declined in recent surveys, with only a single pool supporting longhorn fairy shrimp in each population, despite more systematic annual surveys beginning in 2010 at both Brushy Peak and Vasco Caves. While these apparent reductions may be due to the timing of surveys, or to natural fluctuations in longhorn fairy shrimp dynamics, they are noteworthy. In most cases, we have no information to indicate that observed localities represent demographically independent units that contribute to species viability, and the long-term viability of the species at most sites is unknown regardless of the number of localities. The potential reduction to a single locality in three sites, however, raises serious concerns about the continued persistence of those populations. This species is highly susceptible to extirpation at any locality due to chance events or additional environmental disturbance as described above. 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. We consider the loss of long-term viability in any one of the five extant populations a serious threat the species' recovery.

The majority of the five known populations of longhorn fairy shrimp are found on public lands, so many of the known localities are protected from land-use conversion; however the localities near Livermore, in Alameda County, are potentially threatened by wind energy leases. The Alkali Sink population is currently unprotected, although its designation as a conservation bank is pending, which will likely lead to its protection under a conservation easement. Additionally, roughly half of the localities in the Carrizo Plain population remain unprotected on private lands. Given the overall rarity of the longhorn fairy shrimp, we believe protection of all localities would best ensure the long-term viability of the Carrizo Plain population and its contribution to the overall survival and recovery of the species.

Beyond habitat preservation, other conservation measures, such as habitat and species monitoring, are necessary to ensure the long-term sustainability of this species. Potential threats such as habitat degradation due to inappropriate grazing regimes, altered hydrology due to drought and climate change, and nonnative invasive weedy species remain for longhorn fairy shrimp whether they are on protected lands or not. We have no information on the magnitude and imminence of these threats at any known locality of longhorn fairy shrimp. Habitat management and monitoring are essential so that potential threats to the species can be identified and eliminated. Although there are now management and surveying plans in place at most of the known populations of longhorn fairy shrimp, there is not yet sufficient information available to

determine habitat quality or species status trends. These management plans direct efforts to identify and manage the threats listed above, but this task will still be challenging in some cases, particularly in relation to habitat alteration brought about by climate change. In section VI below we recommend actions that should be implemented over the next 5 years to obtain the information needed to further assess the status and threats to the species.

We conclude that the longhorn fairy shrimp still meets the ESA definition of endangered for the following reasons: (1) the rare nature of this species increases the risk of local extirpations from stochastic events that could reduce the long-term viability of localities or entire populations; (2) all localities of longhorn fairy shrimp are still threatened by additional environmental disturbances, including drought and climate change, degradation of habitat from invasive weedy plant species, inappropriate grazing regimes, and other unforeseen events; and (3) the lack of standardized monitoring data for the majority of known localities of this species makes it difficult to characterize the size and connectivity of occupied habitats, identify the magnitude and imminence of remaining threats, and ensure that threats at particular localities will be identified and ameliorated. Therefore, we recommend no status change at this time.

V. RESULTS

Recommended Listing Action:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (indicate reason for delisting according to 50 CFR 424.11):
    ____ *Extinction*
    ____ *Recovery*
    ____ *Original data for classification in error*
_X_ No Change

New Recovery Priority Number and Brief Rationale: We recommend that the recovery priority number remain 8. The threats remain imminent, but moderate in magnitude, given the habitat protection afforded most localities by being on public land. There has been no change to longhorn fairy shrimp's species status.

VI. RECOMMENDATIONS FOR ACTIONS OVER THE NEXT 5 YEARS

The following recommendations for future actions are from the 2005 Recovery Plan and the results of discussions on the status of the species and the species' needs with several recognized longhorn fairy shrimp experts. Implementation of these recommendations over the next 5 years, particularly items 1 and 2, is needed to provide information that would allow us to consider the potential downlisting of this species:

1. 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.

2. Develop a standardized monitoring method to identify threats and management needs, and to monitor species status and population trends at all known populations.

3. Management and monitoring plans should be completed 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 in item 2, above, should be included in the management plans for all five populations.

4. In addition, the following research should be prioritized over the next five 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 west 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 Banos, 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.

5. Regional vernal pool working groups should be created in regions where longhorn fairy shrimp are known to occur.

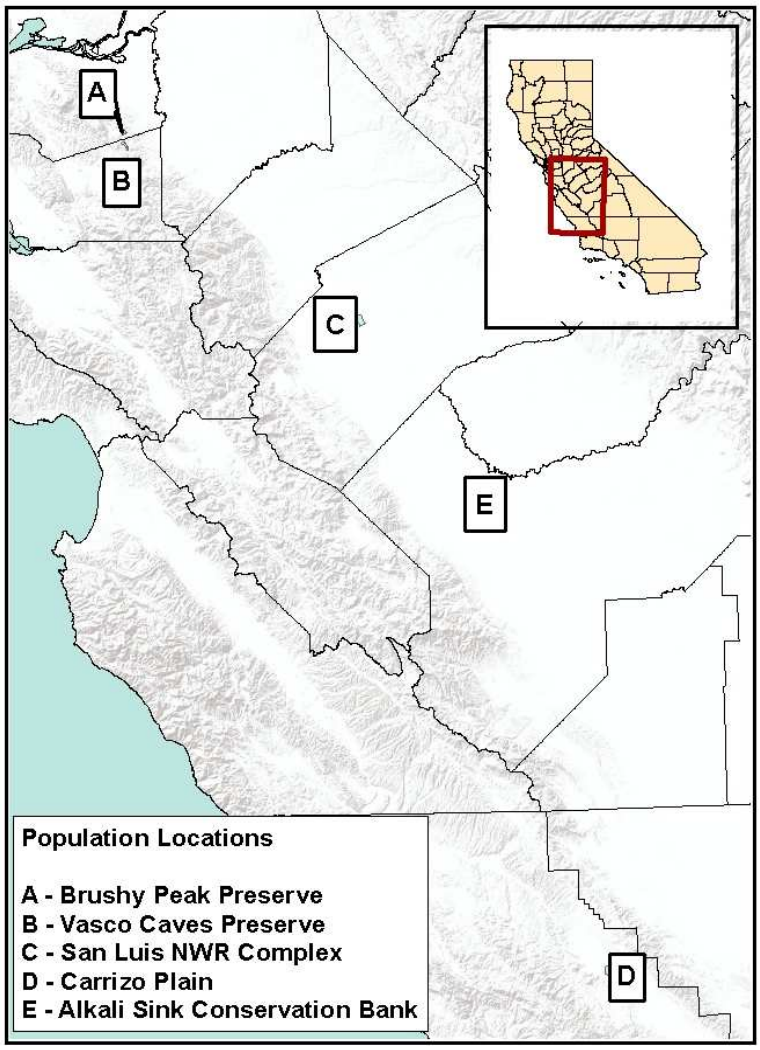

Figure 1. Labels represent locations of the five known populations of longhorn fairy shrimp. Black lines represent California county boundaries.

VII. REFERENCES CITED

Balfour, P. and S. Morey. 1999. Prey selection by juvenile bullfrogs in a constructed vernal pool complex. Transactions of the Western Section of the Wildlife Society 35:34-40.

Bureau of Land Management. 2010. Carrizo plain national monument approved resource management plan and record of decision. 75 FR 18547.

California Natural Diversity Database (CNDDB). 2012. RAREFIND, Natural Heritage Division. California Department of Fish and Game, State of California.

Cayan, D., M. Dettinger, I. Stewart, and N. Knowles. 2005. Recent changes towards earlier springs: early signs of climate warming in western North America? U.S. Geological Survey, Scripps Institution of Oceanography, La Jolla, California.

Dunne T. and L. B. Leopold. 1978. Water in Environmental Planning. W. H. Freeman and Company. New York. Page 740.

Eng, L., D. Belk, and C.H. Eriksen. 1990. Californian Anostraca: distribution, habitat, and status. Journal of Crustacean Biology 10:247-277.

Eriksen, C.H. and D. Belk. 1999. Fairy shrimps of California's puddles, pools, and playas. Mad River Press, Eureka, California.

Field, C.B., G.C. Daily, F.W. Davis, S. Gaines, P.A. Matson, J. Melack, and N.L. Miller. 1999. Confronting Climate Change in California. Ecological Impacts on the Golden State. A Report of the Union of Concerned Scientists and the Ecological Society of America. 62 pp.

Gilpin, M. E. and M. E. Soulé. 1988. "Minimum viable populations: processes of species extinction." Pages 18-34. *In* M. E. Soulé (editor). Conservation Biology: The Science of Scarcity and Diversity. Sinauer Associates, Inc.; Sunderland, Massachusetts.

Goodman, D. 1987. "The demography of chance extinction." Pages 11-19. *In* M. E. Soulé (editor). Conservation Biology: The Science of Scarcity and Diversity. Sinauer Associates, Inc.; Sunderland, Massachusetts.

Graham, T.B. 2003. Climate change and ephemeral pool ecosystems: potholes and vernal pools as potential indicator systems. U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division. Available on the internet at http://geochange.er.usgs.gov/sw/impacts/biology/vernal. Accessed September 2007.

Groom, M. J., G. K. Meffe, and C.R. Carroll. 2006. Principles of conservation biology, third edition. Sinauer Associates, Inc., Sunderland, Massachusetts.

Helm, B. 1998. Biogeography of eight large branchiopods endemic to California. Pages 124-139 *in* C. Witham, E.T. Bauder, D. Belk, W.R. Ferren Jr., and R. Ornduff, editors. Ecology, conservation, and management of vernal pool ecosystems-Proceedings from a 1996 Conference. California Native Plant Society, Sacramento, California

Helm Biological Consulting, LLC. 2009. Large branchiopod wet-season sampling at the Kesterson Unit of the San Luis National Wildlife Refuge. Report to U.S. Fish and Wildlife Service.

H.T. Harvey and Associates. 2009. Proposed alkali sink conservation bank wet season vernal pool branchiopod survey report. Report to U.S. Fish and Wildlife Service.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate change 2007: the physical science basis. Summary for policymakers. IPCC Secretariat, World Meteorological Organization and United Nations Environmental Programme, Paris, France.

Kneitel, J. M. 2010. Summary report for rock pool aquatic communities at Vasco Caves and Brushy Peak sites (East Bay Regional Park District).

Kneitel, J. M. 2011. Summary report for rock pool aquatic communities at Vasco Caves and Brushy Peak sites (East Bay Regional Park District).

Lenihan, J. M., R. Drapek, D. Bachelet, and R.P. Neilson. 2003. Climate change effects on vegetation distribution, carbon, and fire in California. Ecological Applications 13(6): 1667-1681.

Marty, J. T. 2005. Effects of cattle grazing on diversity in ephemeral wetlands. Conservation Biology 19(5): 1626 – 1632.

Primack, R. B. 1998. Essentials of conservation biology. Sinauer Associates, Sunderland, Massachusetts.

Pyke, C. R. 2004. Habitat loss confounds climate change impacts. Frontiers in Ecology and the Environment 2: 178-182.

Pyke, C. R. 2005. Assessing climate change impacts on vernal pool ecosystems and endemic branchiopods. Ecosystems 8: 95-105.

Pyke C. R. and D. T. Fisher. 2005. Selection of bioclimatically representative biological reserve systems under climate change. Biological Conservation 121: 429-441.

Pyke, C. R. and J. T. Marty. 2005. Cattle grazing mediates climate change impacts on ephemeral wetlands. Conservation Biology 19(5): 1619-1625.

Sacramento County. 2006. Draft South Sacramento Habitat Conservation Plan, Appendix B: Habitat Analysis: Vernal Pools, Prepared for Sacramento County by Dittes and Guardino

Consulting, Third Draft, March 2006. Pages A1 – A132. http://www.saccounty.net//PLANNING/habitat-conservation/docs/habitat/Vernal-Pool-Habitat.pdf. Accesssed September 2007.

Shaffer, M. L. 1981. Minimum population sizes for species conservation. Bioscience 31:131-134.

Shaffer, M. L. 1987. Minimum viable populations: coping with uncertainty. Pages 69-86 *in* M.E. Soulé (editor), Viable populations for conservation. Cambridge University Press, New York, New York.

Simovich, M. A., R. C. Brusca and J. L. King. 1992. Invertebrate survey, PGT-PG&E/Bechtel Pipeline Expansion Project. University of San Diego, San Diego California.

U.S. Fish and Wildlife Service (Service). 1983. Endangered and Threatened Species Listing and Recovery Priority Guidelines. 48 FR 43098.

U.S. Fish and Wildlife Service (Service). 1994. Endangered and threatened wildlife and plants; Final rule: Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Conservancy Fairy Shrimp, Longhorn Fairy Shrimp, and the Vernal Pool Tadpole Shrimp; and Threatened Status for the Vernal Pool Fairy Shrimp. 59 FR 48136.

U.S. Fish and Wildlife Service (Service). 2002. Endangered and threatened wildlife and plants; Critical Habitat Designation for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon; Proposed Rule (Part 4 of 4). 67 FR 60033.

U.S. Fish and Wildlife Service (Service). 2003. Endangered and threatened wildlife and plants; Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon; (Part 1 of 4). 68 FR 46684.

U.S. Fish and Wildlife Service (Service). 2005a. Recovery plan for vernal pools ecosystems of California and Southern Oregon. Portland, Oregon. xxvi + 606 pages.

U.S. Fish and Wildlife Service (Service). 2005b. Endangered and threatened wildlife and plants; Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon; Re-evaluation of Non-Economic Exclusions From August 2003 Final Designation. 70 FR 11140.

U.S. Fish and Wildlife Service (Service). 2005c. Endangered and threatened wildlife and plants; Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon; Evaluation of Economic Exclusions From August 2003 Final Designation. 70 FR 46924.

U.S. Fish and Wildlife Service (Service). 2006a. Endangered and threatened wildlife and plants; Final rule; administrative revisions - Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants. 71 FR 7118 7316.

U.S. Fish and Wildlife Service (Service). 2006b. Endangered and threatened wildlife and plants; Clarification of the Economic and Non-Economic Exclusions for the Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon. 72 FR 30279.

U.S. Fish and Wildlife Service (Service). 2007. Longhorn fairy shrimp 5-year review. Dated September 28, 2007.

Wells, M.I., S.A. Hathaway, and M.A. Simovich. 1997. Resilience of anostracan cysts to fire. Hydrobiologia **359**: 199-202.

Personal Communications

Bell, Doug. 2012. Telephone conversation between Peter Bjorn Erickson, Sacramento FWO, and Doug Bell, East Bay Regional Park District, on March 8, 2012.

Bobzien, Steve. 2007. Telephone conversation between Steve Bobzien, East Bay Regional Park District, and Rick Kuyper, Sacramento FWO.

Kuritsubo, Amy. 2012. Telephone call between Peter Bjorn Erickson, Sacramento FWO, and Amy Kuritsubo, Bureau of Land Management, on February 29, 2012.

Parris, Bob. 2012. Telephone conversation between Peter Bjorn Erickson, Sacramento FWO, and Bob Parris, San Luis NWR, on March 21, 2012.

In Litteris References

Kuritsubo, Amy. 2012. Electronic mail correspondence from Amy Kuritsubo, Bureau of Land Management, to Peter Bjorn Erickson, Sacramento FWO, regarding longhorn fairy shrimp occurrences and management plans at Carrizo Plain National Monument.

Bell, Doug. 2012. Electronic mail correspondence from Doug Bell, East Bay Regional Park District, to Peter Bjorn Erickson, Sacramento FWO, regarding longhorn fairy shrimp occurrences and management plans at Brushy Peak and Vasco Caves Preserves.

Pelz, Mark. 2012. Electronic mail correspondence from Mark Pelz, U.S. Fish and Wildlife Service, Refuge Planning, to Peter Bjorn Erickson, Sacramento FWO, regarding the San Luis NWR management plan.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW

Longhorn Fairy Shrimp (*Branchinecta longiantenna*)

Current Classification: Endangered

Recommendation Resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change needed

Review Conducted By: _____ Peter Bjorn Erickson, Sacramento Fish and Wildlife Office

FIELD OFFICE APPROVAL:

for **Lead Field Supervisor, U.S. Fish and Wildlife Service**

Approve _____ Date 20 June 2012