

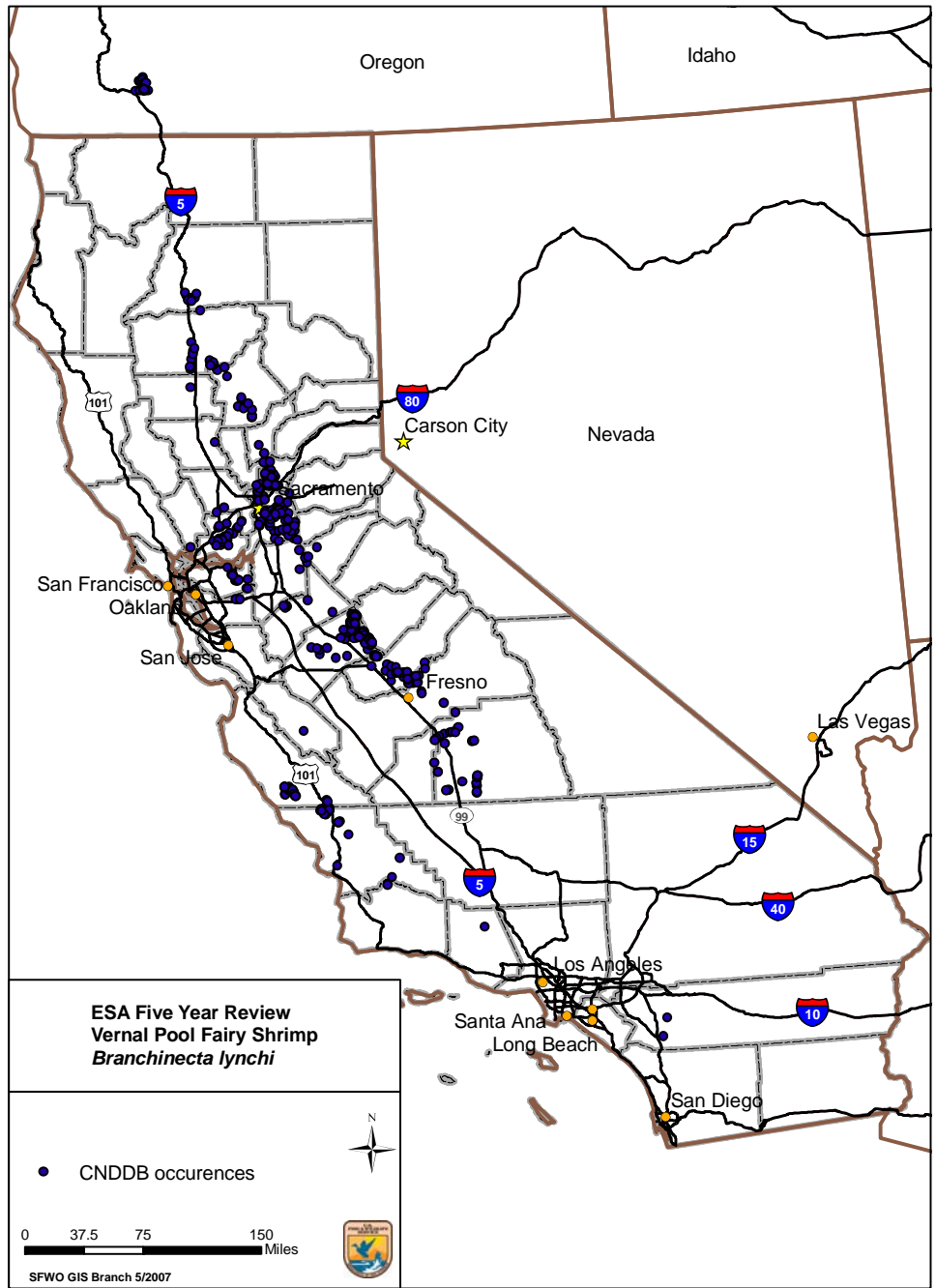
Vernal Pool Fairy Shrimp
(Branchinecta lynchi)

5-Year Review:
Summary and Evaluation



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

September 2007



5-YEAR REVIEW

Vernal Pool Fairy Shrimp (*Branchinecta lynchi*)

I. GENERAL INFORMATION

I.A. Methodology used to complete the review:

This review was an individual effort by Sacramento Fish and Wildlife Office staff using information from the following sources: the December 2005 *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (Recovery Plan) (U.S. Fish and Wildlife Service [Service] 2005); the September 1999 *Vernal Pools of Southern California Recovery Plan* (Service 1998); the June 2006 *Draft Recovery Plan for Species of the Rogue Valley Vernal Pool and Illinois Valley Wet Meadow Ecosystems* (Service 2006a); species survey and monitoring reports; peer-reviewed journal articles; documents generated as part of Endangered Species Act section 7 and section 10 consultations; and species experts including botanists, biologists, and land-managers from the U.S. Forest Service, California Department of Fish and Game (CDFG), and the Service. We also considered information from a Service-contracted report. The Recovery Plan, section 7 consultations, electronic messages from the Service's Carlsbad and Ventura Fish and Wildlife Offices, and communications with species experts and land-managers were the primary sources of information used to update the "species status" and "threats" sections of this review.

I.B. Contacts

Lead Regional or Headquarters Office – Diane Elam, Deputy Division Chief for Listing, Recovery, and Habitat Conservation Planning, and Jenness McBride, Fish and Wildlife Biologist, California/Nevada Operations Office, 916-414-6464

Lead Field Office – **Kirsten Tarp, Recovery Branch**, Sacramento Fish and Wildlife Office, 916-414-6600.

Cooperating Field Offices – Ventura and Carlsbad, California, and Roseburg, Oregon

I.C. Background

I.C.1. FR Notice citations announcing initiation of this review: On March 22, 2006, the Service announced initiation of the 5-year review for the vernal pool fairy shrimp and asked for information from the public regarding the species' status (71 FR 14538). On April 3, 2006, a corrected announcement was issued to correct contact information for Service field offices (71 FR 16584). In response to this notice, we received information providing status of known vernal pool fairy shrimp locations at Fort Hunter Liggett Army Reserve Training Site in southern Monterey County and negative survey findings for Camp Parks Reserve Training Site in Contra Costa and Alameda counties (L. Clark, U.S. Army, *in litt.* 2006).

I.C.2. Listing history

Original Listing

FR notice: 59 FR 48136

Date listed: September 19, 1994

Entity listed: Species, vernal pool fairy shrimp (*Branchinecta lynchi*)

Classification: Threatened

I.C.3. Associated rulemakings:

Critical Habitat Listed: Critical habitat for the vernal pool fairy shrimp was originally designated in a final rule published in 68 FR 46683 on August 6, 2003. A revised final rule for critical habitat, with a re-evaluation of non-economic exclusions, was published in 70 FR 11140 on March 8, 2005. Economic exclusions from the 2003 final rule were evaluated in 70 FR 46923; published on August 11, 2005. Administrative revisions with species-by-unit designations were published in 71 FR 7117 on February 10, 2006, providing 35 critical habitat units for the vernal pool fairy shrimp totaling 597,821 acres. On May 31, 2007, the Service published a clarification of the economic and non-economic exclusions for the 2005 final rule designating critical habitat for four vernal pool crustaceans and eleven vernal pool plants in California and southern Oregon (72 FR 30269).

I.C.4. Review History

90-Day finding: A 90-day finding on a petition to delist the vernal pool fairy shrimp and vernal pool tadpole shrimp was published in 65 FR 18026 on April 6, 2000. The finding determined that the petition and additional information did not present substantial scientific or commercial information indicating that delisting the vernal pool fairy shrimp was warranted.

I.C.5. Species' Recovery Priority Number at start of review:

The vernal pool fairy shrimp has a recovery priority number of 2C (based on a 1-18 ranking system where 1 indicates the highest recovery priority and 18 the lowest priority), which signifies that the species is subject to a high degree of threat, but also has a high potential for recovery. The "C" indicates the potential for conflict between species recovery and construction activities, development, or other economic activities (Service 2005 Recovery Datacall).

I.C.6. Recovery Plan or Outline

Name of plan: *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon*

Date issued: December 15, 2005

The *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* is the only recovery plan that provides recovery criteria for the vernal pool fairy shrimp; however, two other recovery plans do provide information pertaining to the shrimp. The *Draft Recovery Plan for Listed Species of the Rogue Valley Vernal Pool and Illinois Valley Wet Meadow Systems* (Service 2006a) provides recovery actions specific to the Oregon range of the vernal pool fairy shrimp. The recovery actions in the draft recovery plan for Oregon occurrences respond to the recovery criteria identified in the broader *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (Service 2005a) by providing site-specific recovery actions for

the shrimp within the Klamath Mountains Recovery Unit; they are not, however, “recovery criteria” required to delist the species. The *Recovery Plan for Vernal Pools of Southern California* (Service 1998) provides recovery guidance for several areas in which vernal pool fairy shrimp are located in Los Angeles and Riverside Counties, to the extent that the species co-occurs with the endangered Riverside fairy shrimp (*Streptocephalus woottoni*).

II. REVIEW ANALYSIS

Species Overview

The vernal pool fairy shrimp (*Branchinecta lynchi*) is a small freshwater crustacean (0.12 to 1.5 inches long) 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) (Belk and Fugate 2000, as cited in Service 2005a). The species was first collected between 1874 and 1941, when it was described incorrectly as *Branchinecta colorodensis* (Linder 1941 in Service 2005a). Its identity as a separate species was resolved only in 1990 (Eng *et al.* 1990). Subsequent genetic analysis has confirmed that the vernal pool fairy shrimp is a distinct species (Fugate 1992).

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 (Eng *et al.* 1990; Eriksen and Belk 1999). The vernal pool fairy shrimp has an ephemeral life cycle and exists only in vernal pools or vernal pool-like habitats; the species does not occur in riverine, marine, or other permanent bodies of water. Roughly 80 percent of observations of the shrimp are from vernal pools (Helm 1998; Helm and Vollmar 2002). Like most other fairy shrimps, the vernal pool fairy shrimp lacks any substantial anti-predator defenses and does not persist in waters with fish (King *et al.* 1996; Eriksen and Belk 1999). When the temporary pools dry, offspring persist in suspended development as desiccation-resistant embryos (commonly called cysts) in the pool substrate until the return of winter rains and appropriate temperatures allow some of the cysts to hatch (Eriksen and Belk 1999). Vernal pool habitats form in depressions above an impervious substrate layer, or claypan/duripan, in alluvial fans and terraces that are known primarily from the eastern side of the Central Valley of California (Vollmar 2002). Due to local topography and geology, the depressions are part of an undulating landscape, where soil mounds are interspersed with basins, swales, and drainages. Both flooding and the movement of wildlife within 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 (King *et al.* 1996; Fugate 1998).

The vernal pool fairy shrimp occurs only in cool-water pools. Individuals hatch from cysts during cold-weather winter storms; they require water temperatures of 50°F or lower to hatch (Helm 1998; Eriksen and Belk 1999). The time to maturity and reproduction is temperature-dependent, varying between 18 days and 147 days, with a mean of 39.7 days (Helm 1998).

Immature and adult shrimp are known to die off when water temperatures rise to approximately 75°F (Helm 1998). The range of the species extends from disjunct locations in Riverside County and the Coast Ranges, north through Central Valley grasslands to Tehama County, and then to a disjunct area of remnant vernal pool habitat in the Agate Desert of Oregon.

In general, the vernal pool fairy shrimp has a sporadic distribution within the vernal pool complexes, with most pools being uninhabited by the species (59 FR 48136). Helm (1998) found vernal pool fairy shrimp in 16.3 percent of pools sampled across 27 counties, while Sugnet and Associates, in 1993, found the species in 5 percent of 3,092 locations sampled over much of the range (Service 2005a). In several areas, the shrimp has been found more commonly during surveys. For example, in a survey of a Pacific Gas & Electric (PG&E) pipeline right-of-way, the shrimp was found in the majority of pools sampled in 6 of 14 sites along a transect from Shasta to Solano County; all six locales where the shrimp was found were in Tehama County (King *et al.* 1996). In one relatively small locale, the 2000-acre University of California (UC) Merced Planning Area, the species is documented from almost 90 percent of complex pools, although abundance of shrimp within pools is not recorded (Jones and Stokes 2007). The species is typically associated with smaller and shallower vernal pools (typically about 6 inches deep) that have relatively short periods of inundation (Helm 1998) and relatively low to moderate total dissolved solids (TDS) and alkalinity (Eriksen and Belk 1999); however, at the southernmost extremes of the range, the shrimp is present only in large, deep pools.

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. Based on hatching and life history requirements, species may also appear in succession during one season as conditions change within the pool (Simovich and Fugate 1992; 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 (C. Witham, CNPS, pers. comm., 2007). Active vernal pool fairy shrimp die off when water temperatures get too warm (Helm 1998). 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 (Jones and Stokes 2005; Eriksen and Belk 1999). Long-distance dispersal of anostracan cysts is thought to be enabled by waterfowl and other migratory birds that ingest cysts, and by animals that provide for movement of mud and cysts in feathers, fur, and hooves (see authors cited in Fugate 1992; see also Eriksen and Belk 1999; Figuerola and Green 2002). 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.

II.A. Application of the 1996 Distinct Population Segment (DPS) policy

II.A.1. Is the species under review listed as a DPS?

Yes
 No

The Endangered Species Act of 1973, as amended (Act), defines species as including any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate wildlife. This definition limits listings as distinct population segments only to vertebrate species of fish and wildlife. Because the vernal pool fairy shrimp is an invertebrate and the DPS policy is not applicable, the application of the DPS policy to the species listing is not addressed further in this review.

II.B. Recovery Criteria

II.B.1. Does the species have a final, approved recovery plan containing objective, measurable criteria?

Yes.
 No.

II.B.2. Adequacy of recovery criteria.

II.B.2.a. Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?

Yes.
 No.

II.B.2.b. Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

Yes.
 No.

*All relevant listing factors were addressed in the recovery plan; however, there is new information regarding threats.

II.B.3. List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information.

General recovery criteria for the vernal pool fairy shrimp and 19 other listed plants and animals are described in the Recovery Plan (Service 2005a). This Recovery Plan utilizes an ecosystem-level approach because many of the listed species and species of concern co-occur or overlap in distribution within natural vernal pool habitats, and are, therefore, generally threatened by the

same human activities. The overarching recovery strategy for the vernal pool fairy shrimp is habitat protection and management. The five key elements that comprise this ecosystem-level recovery and conservation strategy are: (1) habitat protection; (2) adaptive management, restoration, and monitoring; (3) status surveys; (4) research; and (5) public participation and outreach. The Recovery Plan provides recovery criteria that either directly or implicitly address the four listing factors noted in the final rule to list the species: destruction, modification, or curtailment of habitat or range (factor A), disease or predation (factor C), inadequacy of existing regulatory mechanisms (factor D), and other man-made or natural factors affecting its continued existence (factor E). Factor B, overutilization for commercial recreational, scientific, or education purposes, was not included as a threat in the listing rule and is not addressed in the Recovery Plan.

Delisting criteria for the vernal pool fairy shrimp include:

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 listing factor A.

The Recovery Plan recommends protection of suitable habitat within core areas. Core areas are the specific areas, or contain the specific sites, that are necessary to recover the endangered or threatened species, or the species of concern, addressed in the Recovery Plan. Core areas are not species-specific and may contain multiple listed species and species of concern. For most of the species covered in the Recovery Plan, core areas are ranked as zone 1, 2, or 3 in order of their overall priority for recovery. The Recovery Plan allows the Service to modify core areas in the future based upon the results of status surveys and research. The Recovery Plan is designed to be implemented in a logical, progressive manner. In contrast with the other species, the core recovery areas in which the vernal pool fairy shrimp occurs are not prioritized for recovery (see further description in 1A below).

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

This delisting criterion for the vernal pool fairy shrimp requires that (as of the time the Recovery Plan was published in 2005) 85 percent of the range-wide suitable habitat for the vernal pool fairy shrimp is protected, regardless of whether the core areas in which it is found are zone 1 or zone 2. 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. Protection will occur in such manner as to provide diverse vernal pool habitats in large habitat blocks that encompass local watersheds. Habitat blocks should also include unoccupied pools within vernal pool complexes, and appropriate upland buffers around and between vernal pool complexes. Habitat blocks should be effectively managed to maintain hydrologic function and prevent domination by invasive species.

By focusing on the protection of large habitat blocks within core recovery areas, this criterion should be adequate to ensure that large clusters of the vernal pool fairy shrimp are conserved. In

2006, of 395 known occurrences in the California Natural Diversity Database (CNDDDB), only 13 percent were preserved and managed for “biodiversity” (Jones and Stokes 2006). Not all vernal pools provide suitable habitat for the vernal pool fairy shrimp; however, pool suitability likely changes to some extent with inter-annual variation in precipitation (Helm 1998; Eriksen and Belk 1999). The Service does not yet have sufficient information to quantify either the acreage of suitable vernal pool fairy shrimp habitat that is present within core recovery areas or the acreage of protected habitat that is suitable for the vernal pool fairy shrimp. Therefore, at this time we are unable to determine the percentage of suitable habitat that is protected within core areas where the vernal pool fairy shrimp is present. In summary, this criterion has not been met. The core recovery areas, including the protected habitat that is suitable for vernal pool fairy shrimp within each core area, are described below in section II.C.2.a. and in the Appendix.

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.

The criterion specifies that 80 percent of the vernal pool fairy shrimp occurrences be protected. Most of the 13 vernal pool regions in which vernal pool fairy shrimp is found contain occurrences of the species that are located on lands receiving some level of protection from loss of habitat. These lands are owned and managed variously by the CDFG (Ecological Reserves), The Nature Conservancy (TNC), and privately-owned conservation banks.

At the extreme northern extent of the species’ range in Oregon, vernal pool habitats where the vernal pool fairy shrimp is located are protected on non-Federal lands in three small Nature Conservancy Preserves totaling 297 acres, and within the 720-acre Oregon Department of Fish and Wildlife’s Denman Wildlife Management Area. Within federally-managed lands in Oregon, the U.S. Bureau of Land Management provides protection on 432 acres and the Bureau of Reclamation on 154 acres. However, other areas in Oregon with extant vernal pools appear to have degraded conditions for the vernal pool fairy shrimp. Conservation planning for private lands has been initiated for these lands (Service 2006a). At the southern extreme of the species’ range in southern California, several private or public ecological preserves have been established to protect remnant pools where the shrimp has been found (CNLM 1997; Service 2005a). Within the Central Coast vernal pool region, which comprises the southwestern extent of the species’ range, the Service is not aware of any lands that are specifically set aside to protect the vernal pool fairy shrimp. Along the western extent of the range, occurrences are protected from loss of habitat in multiple-use County and State parks in Contra Costa County.

A substantial portion of the lands that have been set aside in the past to protect the shrimp are relatively small in size, and likely do not provide full protection to the shrimp under the historic range of climatic conditions (R. Grosberg, UC Davis, *in litt.* 1993). Numerous occurrences have been protected through conservation easements or fee-title within the species range. However, occurrence records frequently contain outdated information and the species may no longer be extant at recorded locations. Because we do not know the status of shrimp occurrences in numerous locations, we cannot yet determine that 80 percent of known occurrences have been protected. We also have insufficient information on the genetics of the species over its range (see Fugate 1992). We do not believe that this criterion has been met at this time, although the

Service and governmental, non-profit, and private partners are making substantial progress in several regions.

This criterion could potentially be adequate if 80 percent of known occurrences within core recovery areas are protected as described. (Also see 1C below.) However, some occurrence records are established based on the observation of only a few active shrimp; such occurrences may be present in one year only, and likely do not represent viable habitat for the shrimp (Eriksen and Belk 1999). CNDDDB occurrences are not synonymous with viable populations. The occurrences known before listing, and those documented since the time of listing, will contribute to recovery to the extent that they are part of functioning vernal pool complexes with demonstrated suitable habitat for stable or increasing populations of vernal pool fairy shrimp, rather than remnant pools or small preserves within a matrix of altered habitat. The Service is not aware of updated status surveys for most occurrences on privately-owned lands so it is difficult to establish which sites are extant, what their quality is, and the proportion of sites that are protected from threats. Within each of the core recovery areas where the species is found, the Service is working with public and private partners to protect vernal pool habitat via fee-title acquisitions and conservation easements.

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

The recovery criterion specifies that the vernal pool fairy shrimp should be reintroduced to vernal pool regions and soil types from which status surveys indicate the species has been extirpated.

The vernal pool fairy shrimp is not known from the Modoc Plateau, Mendocino, or San Diego vernal pool regions, although other fairy shrimp species are found in these regions (Eriksen and Belk 1999). We do not have any information to indicate that the shrimp was historically present in these vernal pool regions. The current status of many occurrences is unknown, so we do not know if the species has disappeared from any of the core recovery areas where it is recorded. The shrimp is known to occur on a variety of soil types, so loss of the shrimp from a specific soil type is not likely to be as important to its recovery as loss of acreages of high terrace landforms (Helm 1998). Because we are not aware of any instances where historical occurrences have been extirpated, this recovery criterion is not relevant to the species at this time.

In several regions, including the Southeastern Sacramento Valley and the Solano-Colusa vernal pool regions, the species has been intentionally introduced into created or restored vernal pools within its existing range as compensation for loss of habitat from development. Monitoring of vernal pool fairy shrimp at some of these sites indicates that the species continues to be present over multiple years, although abundance trends are not generally monitored (May and Associates 2004; CNLM 2004a and b; Live Oak Associates 2006; Helm Biological Consulting 2004). The long-term success of re-introduction and restoration at these sites is not yet known, in part because monitoring does not include measures of shrimp abundance. The few studies comparing created pool biota to natural reference pools provide inconclusive results (Rogers 1998). There are currently no standard success criteria with which to evaluate introductions or re-introductions of this species, and long-term population trends have not been studied (Helm Biological Consulting 2004). Introductions of vernal pool crustaceans that are conducted without

systematic guidelines on such factors as distance between source and receiving sites, and consideration of abiotic factors, or that are not supported by research, may contribute to the genetic degradation of this species by swamping the unique genetic structure of the species in different vernal pool complexes. Such degradation could be caused by exceeding the normal rate of exchange of genetic material between complexes (Fugate 1992; Fugate 1998; C. Witham, pers. comm., 2007). *Branchinecta* species in North America have populations that appear to exchange approximately 3-100 migrants per generation (most species exchange above 20) at 0.62 miles separation, and 0.1-0.2 per generation at 621-1242 miles separation (Fugate 1998). The effect of exceeding this rate on adaptations of the species to local conditions is unknown.

1D. Additional occurrences identified through future site assessments, GIS and other analyses, and status surveys that are determined essential to recovery are protected. Any newly found occurrences may count towards recovery goals if the occurrences are permanently protected as described in the Recovery Plan.

This criterion is adequate, but it has not been met. In 1993, R. Grosberg (UC Davis, *in litt.*) indicated that scientists did not have enough population-level information to complete viability analyses for vernal pool species. The Service is not aware of any other type of additional research that has been conducted since then that would provide the means to determine which occurrences are essential to recovery, although Tehama County, eastern Sacramento County, and eastern Merced County are thought to be important to recovery based on the density of extant vernal pool habitat (Helm and Vollmar 2002). The Service has been notified of additional vernal pool fairy shrimp occurrences that have been discovered since the species was listed in 1994 (see discussion on current abundance in section II.C.1.a. below). Although the shrimp have been discovered in Jackson County, Oregon, in several locations on the coastal plains of the Central Coast Vernal Pool Region of California, and in additional sites within the general vicinity of previously known occurrences, most new occurrences have not been protected in the manner described in the Recovery Plan. Nor have they been monitored sufficiently to confirm viability. The Service has not yet evaluated the additional occurrences to determine if any are essential to the species' recovery.

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.

Hydrological studies would be needed for most sites to determine the extent to which vernal pool ecosystem function has been protected. On large protected areas that encompass one or more complete watersheds, hydrology could be unimpaired; however, in protected areas within or adjacent to altered watersheds, either surface or subsurface changes to water flow could have deleterious effects on vernal pool ecosystem function (see discussion in Williamson *et al.* 2005). To our knowledge, on most protected habitat, assessment and monitoring of hydrology has not occurred in a manner needed to determine whether the hydrology has been protected sufficiently to allow vernal pool function. Moreover, the Service has not identified parameters that need to be monitored to determine whether this criterion has been met.

2. Adaptive Habitat Management and Monitoring

This criterion implicitly addresses listing 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 in Sections 1 A-E, above.

The criterion has been partially met. Occurrences such as those at the Wilcox Ranch and the Elsie Gridley Conservation Bank, in Solano County, are protected in perpetuity, and have management and monitoring plans in place. However, some management plans do not require monitoring of species and instead monitor vernal pool condition and grazing status. In some cases, a larger percentage of pools should be monitored to establish trends within the preserve. For example, at the Fitzgerald Ranch Preserve, San Joaquin County, monitoring is only required for 7 pools each year out of approximately 527 pools present on the preserve (C. Feldheim, CNLM, *in litt.* 2007). In some cases, conservation easements on large parcels do not include habitat management and monitoring plans (Jones and Stokes 2007). In most cases, plans are too new to determine whether they adequately facilitate maintenance of vernal pool ecosystem function. A variety of preserves areas do not have adequate funding mechanisms in place for long-term site protection.

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

This criterion has been partially met, in part because criteria 1A and 1B have not yet been met. While a portion of the sites that have been protected to support occurrences of vernal pool fairy shrimp have endowment funds to ensure management and monitoring of habitat in perpetuity, some protected sites have older and inadequate funding mechanisms that may hinder long-term management and monitoring (S. Egan, ECORP, pers. comm., 2007, C. Feldheim, CNLM, *in litt.* 2007). Further, some non-bank preserves lack endowments and are managed through normal operating budgets and fundraising by the organization (e.g., Vina Plains Preserve, Tehama County; R. Reiner, TNC, pers. comm., 2006). Several sites with known occurrences of vernal pool fairy shrimp do not have funding mechanisms to provide for management and long-term monitoring in perpetuity (e.g., Borden Ranch [C. Feldheim, CLNM, pers. comm., 2007] and some parcels within the Sacramento Prairie Vernal Pool Complex [A. Rutledge, Sacramento Valley Conservancy, pers. comm., 2007]). Management and monitoring of occurrences on Federal and State lands, including National Wildlife Refuges (NWR), Department of Defense holdings, National Forests, CDFG Ecological Preserves, and California State Parks are dependant on annual allocations of Federal and State monies to the respective agencies.

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

To our knowledge, monitoring of ecosystem function has not occurred at any protected location. This criterion has not been met.

3. Status Surveys:

This criterion implicitly addresses listing 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.

Status surveys. To our knowledge, updated status surveys of known occurrences have not been conducted. Many of the occurrences were recorded before listing and those on unprotected lands have generally not been updated. Where more recent surveys have been conducted for vernal pool fairy shrimp, they were designed for the purpose of determining presence of species within proposed development or infrastructure projects, or for the purposes of establishing a conservation bank or preserve, so have generally been limited in scope, focusing on a single parcel or occurrence.

Population monitoring. Monitoring has been initiated on a variety of vernal pool fairy shrimp preserves and conservation banks. At this time, however, we are not aware of any monitoring that has occurred during a time period that meets the requirements specified in the Recovery Plan at any of the sites with known occurrences. Moreover, specific monitoring parameters have not been identified. Monitoring at some older sites indicates that vernal pool fairy shrimp are present in varying numbers of pools from year to year; however, the proportion of pools in which monitoring is required varies by bank and can be lower than five percent (May and Associates 2004; CNLM 2004a; Live Oak Associates 2006; Helm Biological Consulting 2004 and 2005a; C. Feldheim, CNLM, *in litt.* 2007).

A variety of the species in the Recovery Plan may sometimes be found in the same vernal pool complex; however, their habitat requirements are not often identical. The population trends of vernal pool fairy shrimp (and their cyst banks) should be monitored to determine viability. For example, vernal pool habitat is often preserved for both the vernal pool fairy shrimp and the endangered vernal pool tadpole shrimp (*Lepidurus packardi*); however, the two species require different vernal pool conditions, so the extent to which one species might be favored over the other by the created or preserved pool types at a protected site is not known. Without species-specific monitoring, rather than just habitat monitoring, at least in representative areas, the Service does not know whether populations of vernal pool fairy shrimp are declining. To our knowledge, no preserves are monitoring abundance or the status of the cyst bank over time. The Service is not aware of any monitoring that addresses population dynamics of the vernal pool fairy shrimp.

Vernal pool region working groups will be important for tracking the progress of recovery efforts, including monitoring the status of occurrences of this species, particularly on private lands that are not currently monitored.

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.

This criterion has not been met. The primary threats identified in the listing rule were loss of habitat due to urban development, water supply/flood control activities and conversion to agricultural use. Although some occurrences have been protected throughout the species' range, proposed urban development and related projects such as road widening and agricultural conversion continue to threaten a portion of the occurrences. Surveys conducted for vernal pool fairy shrimp since the listing have been designed for the purpose of determining presence of the species within proposed development or road projects and have generally been limited in scope, focusing on a single parcel or occurrence rather than on threats to the occurrences.

Although substantial progress has been made in protecting known occurrences from threats, in the past preservation sites have often been small and subject to threats such as either increased or decreased inundation due to adjacent land use practices (Clark *et al.* 1998). At this time, there are no standardized site assessments to identify existing site-specific threats. All of the threats to this species described in the 1994 listing rule are still present throughout the species' range.

4. Research:

Research implicitly addresses all 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 needs that would help to 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 2005a).

Although progress has been made, the criterion has not been met. The majority of information needs discussed in the 2005 Recovery Plan are still outstanding for this species. A 1996 Conference on Ecology, Conservation, and Management of Vernal Pool Ecosystems generated several papers relevant to vernal pool fairy shrimp (Witham *et al.* 1998). Recent research by Dr. Jaymee Marty on the effects of grazing on vernal pool species and inundation periods (Marty 2005; Pyke and Marty 2005) has been used to address grazing recommendations for preserves and private vernal pool habitat, although it may not yet be formally incorporated into many

management plans. A study of vernal pool classification and hydrology has recently been completed (Williamson *et al.* 2005; Rains *et al.* 2006) that describes hydrologic connectivity between perched aquifers, surface water, and vernal pools, and provides information on how various vernal pool types function. Virginia Meyer, a Ph.D. student with Dr. Michael Barbour of UC Davis, is currently comparing hydrology and vegetation of created and natural vernal pools at three vernal pool conservation sites within northern California (V. Meyer, UC Davis, pers. comm., 2007). Research-based expected effects of climate change in California are reviewed in Field *et al.* (1999). Additional studies have modeled potential effects of climate change and habitat loss on vernal pool crustaceans in the Central Valley (Pyke 2004; Pyke 2005a and 2005b).

A statewide floristic classification of vernal pools is underway, and includes a functional model of vernal pool hydrology and water quality (Williamson *et al.* 2005; see also Rains *et al.* 2006). To our knowledge, no additional research on the genetics of the species has been published since the species was listed, although Fugate (1998) has published conservation recommendations based on his dissertation research on *Branchinecta* genetics (Fugate 1992).

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 (the Recovery Plan), described previously in Sections 1 A-E.

This criterion has not been met. Research on the genetic structure of the vernal pool fairy shrimp between core recovery areas has not been completed, although the genetics of a subset of locations has been studied (Fugate 1992). To our knowledge, information on vernal pool fairy shrimp genetics has not been specifically incorporated into habitat protection plans to date.

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

The Service is not aware of research to establish appropriate population viability parameters for this species.

5. Participation and Outreach:

Public participation and outreach implicitly address all listing factors.

5A. Recovery Implementation Team is established and functioning to oversee range-wide 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 Service is currently in the preliminary stages of organizing both a recovery implementation team and multiple working

groups. Service employees have met with various stakeholders to determine interest of stakeholders to be involved in working groups and/or the recovery implementation team. This criterion has not yet been met.

5B. Vernal pool regional working groups are established and functioning to oversee regional recovery efforts.

See 5A, above.

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.

II.C. Updated Information and Current Species Status

II.C.1. Biology and Habitat

II.C.1.a. Abundance, population trends (e.g., increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

The Service does not have information to indicate population or abundance trends for the vernal pool fairy shrimp, although the number of recorded observations has increased due to project-related surveys for federally-listed species. Surveys (and monitoring) of vernal pool fairy shrimp generally only record presence/absence in pools and do not provide information on shrimp abundance within pools (for example see Rincon Consultants, Inc. 2005; abundance information is provided by Borgias *et al.* 1999). The surveyor will sometimes note the number of individuals seen or captured, and some monitoring provides information on coarse relative abundance in pools over one or several years (Jones and Stokes 2005). The Service is not aware of any studies that have quantified population trends for vernal pool fairy shrimp. Nor does the Service know of any studies of cyst-bank dynamics to see if natural, artificial, or created pools are maintaining cyst-banks over time. At protected sites such as conservation and mitigation lands, monitoring is not designed to track population trends (C. Feldheim, CNLM, *in litt.* 2007). However, monitoring can detect changes in vernal pool habitat that can affect the species presence in specific pools. For example, at Camp Roberts, in Monterey and San Luis Obispo Counties, monitoring has suggested that hydrologic changes to several pools may negatively affect abundance or presence of the shrimp in those pools (Jones and Stokes 2005).

Within the range of the vernal pool fairy shrimp, required surveys for federally-listed crustaceans have increased the recorded observations of the shrimp. There are currently 400 “occurrences”

posted on the California Natural Diversity Database (CNDDDB 2007). However, the number of occurrence records overstates the number of separate localities that have been recorded for the shrimp. A CNDDDB “occurrence” represents any documented collection, observation, or museum specimen of a species that is submitted to the CDFG by the public. Each collection or observance may be recorded and mapped separately, but if there are multiple observations/collections within 1/4 mile of each other they may be combined into a single occurrence record. However, if the multiple individual observation records that are within 1/4 mile of each other have different levels of resolution, or different purposes, there may be multiple records for the same parcel of land. One such case would be where one occurrence record denotes just the boundary of a project area in which the species was found and another record establishes a precise location (e.g., a specific vernal pool) within that project area where the species was found. Individual occurrences represent locations where a species has been documented to occur; they do not represent distinct populations as they are observation records of individuals, not population-level records (D. McGriff, CDFG, *in litt.* 2007).

CNDDDB staff do not list occurrence records as extirpated unless they receive a credible report that extirpation has occurred (D. McGriff, CDFG, *in litt.* 2007). Although occurrence reports are frequently submitted by consultants for development projects, there is no follow-up to document whether the project was built and if habitat was destroyed, avoided, or protected (CNDDDB 2007). Therefore, the CNDDDB lists all vernal pool fairy shrimp occurrences as “presumed extant” (CNDDDB 2007) when in fact some occurrences may be extirpated. CNDDDB also does not generally provide an indication of the amount of suitable habitat. Potential threats may or may not be included in the occurrence records. One CNDDDB occurrence record may represent a single vernal pool, a single puddle, multiple pools within a vernal pool complex, or a substantial portion of a vernal pool complex. Separate occurrence reports may be submitted for each separate legal parcel within a small geographic area, or for each day that a survey is conducted, resulting in multiple occurrence records for the pools within a small geographic area. For example, 36 records have been established for the vernal pool habitat located within the UC Merced planning area (CNDDDB 2007). In contrast, one CNDDDB record represents most of the remaining vernal pool complex at Beale Air Force Base (AFB) (CNDDDB 2007). Of these two examples, the one Beale AFB record would likely be much more reflective of a vernal pool fairy shrimp population on the ground. Some CNDDDB records have been established based on an observation of less than 10 shrimp in one small pool (CNDDDB 2007).

Surveys have indicated that vernal pool fairy shrimp often occur in only a small percentage of the pools within a survey area. In some core recovery areas, pools with active shrimp (shrimp that have hatched and are living in the aquatic environment) occur only rarely in a landscape (59 FR 48136; J. Silveira, Service, *in litt.* 2007; K. Griggs, Service, *in litt.* 2007). However, in locales such as the Madera core recovery area in Merced County, the shrimp can be present in a substantial portion of the pools. The Madera core recovery area is exceptional within the range of the vernal pool fairy shrimp in that it retains the full complement of intact alluvial fan substrates, providing a largely undegraded range of vernal pool types over an extensive area. In one portion of the UC Merced planning area (within the Madera core recovery area), vernal pool fairy shrimp are found in almost 90 percent of over 700 vernal pools surveyed within the 2000-acre planning area (Jones and Stokes 2007). Within the greater east Merced County area

(portions of which are in the Madera core recovery area), the shrimp are present in almost 40 percent of surveyed sites.

At the southern extent of the species' range, informal surveys of the Skunk Hollow and Field pools in western Riverside County have detected the vernal pool fairy shrimp only in the cyst stage (Eriksen and Belk 1999; S. Brown, Service, *in litt.* 2007), suggesting one of several possibilities: that surveys were not conducted early enough in the season to coincide with the vernal pool fairy shrimp's active period; that the species is very rare in comparison to the very high densities of the versatile fairy shrimp (*Branchinecta lindahli*) present at the site (Eriksen and Belk 1999); or that the species did not have the required conditions needed to stimulate hatching previous to the time of surveys.

II.C.1.b. Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

Populations: 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 (59 FR 48136). 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) (unpublished Service files). 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 only known from single pools occupied by the species (59 FR 48136).

We are not aware of any research that has been completed that provides information on the structure (or extent) of vernal pool fairy shrimp populations; however, the Service 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. Several of these described populations, including the El Dorado (Folsom vicinity, El Dorado and Sacramento Counties), Skunk Hollow (Riverside County), and Santa Rosa Plateau (Riverside County) populations are within urban and suburban landscapes where extant vernal pool fairy shrimp habitat remains in isolated patches, even where protected. No new records have been established for the single known occurrence in

the Pinnacles area of San Benito County or single occurrence from the Cachuma Canyon area of Santa Barbara County, and the current status of these two occurrences is unknown. However, many new occurrence records have been established for the known populations located in some areas where substantial urban and suburban growth is occurring, including the Redding/Shasta County, Butte County, Lincoln complex/Placer County, east Sacramento Complex/County, south Sacramento Complex/County, Solano County, and Haystack Mountain/Merced County populations (CNDDDB 2007; Service undated).

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. These occurrences now comprise a disjunct population center in the Klamath Mountains Vernal Pool Region, approximately 130 miles north of the species' previously known range (Service 2006a). The vernal pool fairy shrimp is known only from this area of Oregon, although other fairy shrimp species occur within various portions of the state (Borgias *et al.* 1999).

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. Although additional pools were sampled at the site, no other pools were found to contain branchiopods (CNDDDB 2007). Climate (e.g., average temperature) is known to be important in determining distributions for fairy shrimp species (Hathaway and Simovich 1996). The Lake-Napa region may not generally provide the needed climatic conditions for the vernal pool fairy shrimp; although the animal has not been found elsewhere in the region, more widespread species of fairy shrimp are often found (Rogers, Ecoanalysts, *in litt.* 2007). The Service is not aware of any other locations where the shrimp is extant within this region, so this single pool is unlikely to represent a meaningful range extension for the species.

Since the species' listing, surveys for the vernal pool fairy shrimp occurrences have documented the shrimp in several locations along the edge of the species' range in the Santa Barbara Vernal Pool Region: at several Department of Defense bases (Fort Hunter-Liggett, Camp Roberts, and Vandenburg Air Force Base), near the City of San Luis Obispo, at the Santa Maria Airport, and in an isolated pool on the Los Padres National Forest (Rincon Consultants 2005; Ecoanalysts 2006; Julie Vanderwier, Service, *in litt.* 2006; Wolff, David Wolff Environmental, *in litt.* 2006; CNDDDB 2007). In Western Riverside County, the shrimp has also been discovered at a limited number of additional pools (S. Brown, Service, *in litt.* 2007). It has also been collected from several pools at Cruzan Mesa in Los Angeles County (T. Bomkamp, Glenn Lukos Associates, *in litt.* 2007). These discoveries have indicated that occurrences at the southern extent of the species' range may be less disjunct than previously thought, although several sites are threatened by development. The Service does not have information on the long-term viability of any of these occurrences.

Most additional occurrences recorded since listing are in areas where the shrimp were already known to exist. Additional occurrences of vernal pool fairy shrimp in such areas have been recorded in Alameda, Butte, Contra Costa, Fresno, Glenn, Madera, Merced, Placer, Riverside, Sacramento, San Joaquin, San Luis Obispo, Shasta, Solano, Stanislaus, Sutter, Tehama, Tulare,

and Yuba counties. New county occurrence records (number of new occurrences in parentheses) have been established for Calaveras (4), Colusa (1), Kings (2), Monterey (34: all at Fort Hunter-Liggett and Camp Roberts), Napa (1), and Yolo (4) counties (CNDDDB 2007).

Vernal Pool Regions: The Recovery Plan delineates a total of 85 core recovery areas that are based on mapped areas of extant vernal pool habitat and that are deemed necessary to recover one or more listed vernal pool species. Currently, the vernal pool fairy shrimp is presumed to occur in at least one pool in 45 of the core recovery areas (CNDDDB 2007; Service 2005a). The occurrences are few, small, and/or fragmented in the White City, Llano Seco, Sacramento NWR, Southeastern Sacramento Valley, Stone Lakes, San Joaquin, Merced, Napa River, Dolan, Pixley, Cross Creek, San Benito, North Carrizo and South Carrizo Plains, Paso Robles, Ventura County, Skunk Hollow, Santa Rosa Plateau, and San Jacinto-Hemet core recovery areas. In some of these core recovery areas the shrimp is recorded from only one or just a few pools (CNDDDB 2007), or is isolated within an urban landscape. The following 10 core recovery areas still have relatively large areas of extant vernal pool habitat where known records of the shrimp are located within or near to the core area: Vina Plains, Beale, Western Placer County, Mather, Cosumnes/Rancho Seco, Grasslands Ecological Area, Madera, Fresno, Central Coast Ranges, and Fort Hunter Liggett. Details of the status of the vernal pool fairy shrimp in the vernal pool regions where it is found are summarized below and described more fully in the Appendix. In addition, 12 recorded occurrences for the vernal pool fairy shrimp are located in pools that are outside of the defined vernal pool regions.

Klamath Mountains Vernal Pool Region: Within this region, there are three core recovery areas, Agate Desert, White City, and Table Rocks, all clustered within 12.4 miles of each other near Medford, Jackson County, Oregon (Borgias and Patterson 1999; Service 2005a). Estimates by the Oregon Natural Heritage Program (ONHP) suggest that the range of the vernal pool fairy shrimp in Oregon has most likely declined by 75 percent (ONHP [1997] in Service 2006a).

In the Agate Desert core recovery area, the shrimp has been found in 26 pools located on TNC's 53-acre Agate Desert Preserve. The shrimp also has been found in 31 pools of varying quality at TNC's 144-acre Whetstone Savannah Preserve and in several pools within TNC's 100-acre Rogue River Plains preserve. The shrimp have also been found in four pools occurring within the Bureau of Reclamation's 154-acre Agate Reservoir area. Lands in and around the White City core area contain few pools that support active shrimp (Borgias *et al.* 1999). The 720-acre Denman Wildlife Management Area contains the largest known area of vernal pools in the Rogue Valley, but vernal pool fairy were present only in a few pools unaffected by timber harvest wood waste, which comprised 8 percent of the pools on the area. Vernal pool fairy shrimp also occur in vernal pool habitat underlain by lava bedrock on 320 acres managed by the Bureau of Land Management at Table Rocks, in the Table Rocks core recovery area (Service 2006a).

Northwestern Sacramento Valley Vernal Pool Region: Within the Northwestern Sacramento Valley region, there are a total of 13 CNDDDB occurrence records, including occurrences in the Orland, Red Bluff, Black Butte, Millville Plains, and Redding core recovery areas. The only known record from the Orland core area is located on a PG&E pipeline right-of-way, and is subject to altered hydrology. The Red Bluff core area includes one record from the Truckee

Creek Restoration Site for the PG&E pipeline. One record is for vernal pool habitat at the Thomes Creek Ecological Reserve, managed by the CDFG, while a third record notes presence of the shrimp in two pools at the proposed Hancock Vernal Pool Ecological Preserve (CNDDDB 2007).

Northeastern Sacramento Valley Vernal Pool Region: There are 24 CNDDDB occurrence records established within this region. Most CNDDDB occurrences are located outside the region's core recovery areas; however, there are occurrences present in the Chico, Dales, Oroville, Llano Seco, and Vina Plains core recovery areas (CNDDDB 2007).

In the Chico core area, an occurrence is known from the Foothill Park Mitigation Area placed under conservation easement by Drake Homes as compensation for a residential development project. In 1996, vernal pool fairy shrimp were present in 97 of the 17 natural and 179 created pools (CNDDDB 2007). Within the Dales core area, one occurrence is recorded in one roadside vernal pool. Land ownership of the roadside vernal pool is unknown (CNDDDB 2007). In the Oroville core area, the shrimp is recorded from one pool within a vernal pool complex where multiple pools were surveyed. Additional small occurrences are located outside of the core area, close to the City of Oroville (CNDDDB 2007). In the Llano Seco core area, vernal pool fairy shrimp have been found in two of 24 vernal pools at the Seco Unit, and Llano Seco Ranch portions of the Sacramento NWR Complex (J. Silveira, Service, *in litt.* 2007). Within the Vina Plains core area, two occurrences are protected within the vernal pool complex on the Vina Plains preserve, which is managed by TNC and was established in 1982. Eleven records in the core area are from California Department of Transportation (Caltrans) right-of-ways along Highway 99, another record is from roadside ditches on an adjoining road (CNDDDB 2007).

Southeastern Sacramento Valley Vernal Pool Region: There are 116 vernal pool fairy shrimp occurrences within this region, with occurrences in the Beale, Western Placer, Mather, Cosumnes/Rancho Seco, Southeastern Sacramento Valley, and Stone Lakes core recovery areas.

The Beale core area occurrence record describes a portion of the vernal pool complex on the western portion of Beale Air Force Base (AFB). At Beale AFB, vernal pool crustaceans are provided protection based on their status as a federally-listed species. Surveys of 1,000 vernal pools at Beale AFB in 1995 and 1996 found vernal pool fairy shrimp in 134 of the pools (Jones and Stokes 1998).

There are approximately 40 occurrence records in the Lincoln and Roseville areas of western Placer County, in or in close proximity to the Western Placer County core recovery area (CNDDDB 2007). The most westerly edge of Placer County is primarily converted to rice production and currently does not contain much vernal pool habitat. However, vernal pool fairy shrimp that are not yet recorded in CNDDDB have been found in several additional scattered pools within the western county during surveys for proposed development (ECORP 2006a, 2006c; D. C. Rogers, Ecoanalysts, *in litt.* 2007). Western Placer County has numerous existing open-space, wetland mitigation, and other preserves. The shrimp has been recorded from approximately 10 privately or publicly-owned vernal pool, wetland mitigation, or open-space preserves within this portion of the county (CNDDDB 2007). Four (10 percent) of the CNDDDB occurrences for this core area are multiple records at the Wildlands Inc., Orchard Creek Conservation Bank (CNDDDB

2007; Wildlands, Inc. 2007), where the shrimp has been recorded from 2 of 170 pools surveyed within the bank (CNDDDB 2007).

There are 10 occurrences of vernal pool fairy shrimp within the Mather core area; one is within the Keifer Landfill expansion footprint and two are threatened by gravel mining. Several sites are located on conservation lands that were set aside to offset development activities. The Cosumnes/Rancho Seco core area includes extensive vernal pool habitat, including a number of protected sites. Occurrences in the Mather and Cosumnes/Rancho Seco core areas are within the boundaries of the Draft South Sacramento Habitat Conservation Plan (HCP) (Sacramento County 2005). The South Sacramento HCP authors note that numerous surveys related to development projects have been conducted in and adjacent to the proposed HCP plan area, but that the area has not been thoroughly surveyed for the vernal pool fairy shrimp (Sacramento County 2005). Other areas where the vernal pool fairy shrimp has been identified, in addition to the sites previously listed, include the Perry Ranch Mitigation Bank, Beach Lake Mitigation Bank, Bufferlands, Sunrise-Douglas Conservation Bank, Churchill-Downs Mitigation; Arroyo Seco Mitigation Bank, Florin Park, Mather Field Regional Park, and the Rancho Seco Preserve (Sacramento County 2005; CNDDDB 2007).

The Southeastern Sacramento Valley core area has one known occurrence of vernal pool fairy shrimp from a ditch bordering the railroad tracks. And within the Stone Lake core area, the vernal pool fairy shrimp was found in 5 pools by Sugnet and Associates in 1993 (CNDDDB 2007).

Southern Sierra Foothills Vernal Pool Region: The Southern Sierra Foothills vernal pool region includes six core recovery areas where the vernal pool fairy shrimp has been located, including the San Joaquin, Fresno, Merced, Madera, Table Mountain, and Cottonwood Creek core areas. There 108 vernal pool fairy shrimp occurrences in this region.

Within the San Joaquin core area, one occurrence is known from a 100-acre parcel of unprotected private land. The Merced core area has two records, each for a pool in the Kelsey Reservoir vicinity; both locations are on private lands (CNDDDB 2007).

The Madera core area has been the focus of extensive surveys for vernal pool crustaceans within the last 10 years due to the development of the UC Merced campus and associated community within the area. The eastern portion of Merced County, where the core area is located, consists primarily of large, privately owned ranches, and contains the state's premier remaining acreage of intact alluvial fans and terraces (Vollmar 2002). A substantial portion of the vernal pools and playas that occur within the region are within large, contiguous blocks of natural, intact vernal pool habitat (Jones and Stokes 2007). There are 76 CNDDDB records for this core area. The vernal pool fairy shrimp occupies a high percentage of surveyed pools in some portions of the planning area; 37 CNDDDB records were established for 636 occupied pools out of 713 pools present on the UC Merced planning area alone (Jones and Stokes 2007; CNDDDB 2007). Surveys have also been conducted on 12 ranches incorporating 44,223 acres located within the eastern portion of the core area (Helm and Vollmar 2002). The ranches capture most of the geographic diversity and the range of geologic diversity of the region, and are located within centers of mapped high-density vernal pool habitat (CDFG 1988 in Vollmar 2002). In the ranchland surveys, the shrimp occurred on all ranches, and were found in 509 of 1,291 individual pools and

swales surveyed. Ranches in the central and southern portion of the core area supported higher densities of shrimp than those in the northern portion of the study area (Helm and Vollmar 2002). Known occurrences of the vernal pool fairy shrimp within the Madera core area include the 11,109-acre Flying M Ranch, the 3,085-acre Ichord Ranch, and the 5,400-acre Virginia Smith Trust property.

Within the Fresno core area, 10 occurrence records include a complex at Millerton New Town, 8 occurrence records within proposed mitigation sites, and one additional pool where the shrimp were located. The CDFG also reports new unprocessed occurrence records for a proposed project on Highway 41 within a complex with known occurrences (D. McGriff, CDFG, *in litt.* 2007). The several additional occurrences in the general vicinity of the core area include one record for a 2-foot by 10-foot puddle in a canal easement that contained 3 shrimp and was reported as a small remnant of the vernal pool habitat that was previously located at the site (CNDDDB 2007). The others are isolated by roads and development (CNDDDB 2007).

The Table Mountain core area provides two occurrence records for relatively isolated pools on Big Table and Kennedy Table. In the Kings core area, the Sand Creek Conservation Bank has 23 acres of natural vernal pools where the vernal pool fairy shrimp has been found. There are four CNDDDB records for the Cottonwood Creek core area, and one occurrence at the Stone Corral Ecological Preserve (CNDDDB 2007).

Lake-Napa Vernal Pool Region: In the 2002-2003 winter season, the shrimp was detected in one pool at the Napa Airport in the Napa River core area at the southeast edge of the Lake-Napa Vernal Pool Region. Although additional pools were sampled at the site, no other pools were found to contain branchiopods (CNDDDB 2007). The shrimp were not detected during subsequent wet-season surveys in 2004 and 2005 (Jim Wallace, pers. comm. 2007). To our knowledge, the shrimp has not been found in other areas of the region, despite surveys of the vernal pools on the Santa Rosa Plain and elsewhere in the region (D.C. Rogers, *in litt.* 2007).

Livermore Vernal Pool Region: There are 12 occurrences in this region. The Altamont Hills core area has eight occurrences; four of which are in areas planned for development (CNDDDB 2007). One occurrence is located on Wildands' Byron Conservation Bank and the adjacent Contra Costa County lands at the Byron Airport (CNDDDB 2007). In addition, portions of the 1,400-acre Vasco Caves Preserve and the 507-acre Brushy Peak Preserve are within this core recovery area, and contain known occurrences of the species in the small rock pools on sandstone outcrops. The small depressions represent an atypical habitat, which is found only in the Altamont Hills core area. The pools are generally less than one meter in diameter and each contain only a few shrimps (Eriksen and Belk 1999). The endangered longhorn fairy shrimp, *Branchinecta longiantenna*, also inhabits the rock pools within these parks. Although both species are present, they do not occur together within the same pool (Eriksen and Belk 1999). The number of rock pools in which the vernal pool fairy shrimp has been found at the parks has not been quantified. The parks are multiple-use parks, and the pools are not regularly monitored for the presence of specific species (Steve Bobzein, pers. comm. 2007). There are three additional occurrences having single pools, and one additional occurrence with multiple pools present within the region.

Solano-Colusa Vernal Pool Region: There are 28 vernal pool fairy shrimp occurrences from this vernal pool region. Vernal pool habitats have been surveyed on the Sacramento, Colusa, and Delevan portions of the Sacramento NWR within the Sacramento NWR recovery area. Although not recorded in CNDDDB, the vernal pool fairy shrimp has been found in one of approximately 40 pools surveyed on 140 acres of habitat on the three refuges (Joe Silveira, Service, *in litt.* 2007).

Within the Dolan core area, the only occurrence of the vernal pool fairy shrimp is recorded on the Dolan Ranch Conservation Bank (CNDDDB 2007). The 2003 and 2004 monitoring reports for the bank indicate that vernal pool fairy shrimp are present in only one pool within the Dolan Ranch Conservation Bank. Most pools are occupied by the endangered vernal pool tadpole shrimp, a known predator of vernal pool fairy shrimp (Wildlands 2004 and 2005; Service 2007). Within the Vacaville core area, the vernal pool fairy shrimp was found in 26 of 649 wetlands that were surveyed at the North Village project site (CNDDDB 2007).

Ten records are known from the Jepson Prairie core area. Three records are for three of the pools at the Burke Ranch. The shrimp was also found in 13 pools scattered through the North Village Mitigation Site, from 3 artificial and 4 natural pools located at the Burke Property Open Space Preserve adjacent to housing and Travis AFB, from vernal pools at the Portrero Hills Landfill, and from four other locations, including Caltrans and railroad right-of-ways (CNDDDB 2007). There are additional locality records on lands in the general vicinity of the core area, including around seven natural and three artificial pools on various portions (or on the border) of Travis AFB. The amount of suitable vernal pool fairy shrimp habitat that is protected within this core recovery area has not been quantified at this time. Within or adjacent to this core area, the Wilcox Ranch property, the Elsie Gridley Conservation Bank, and the proposed Burke Ranch Conservation Bank (currently under review by the Service) are known to harbor the shrimp. Of these sites, all but the Burke Ranch property are protected under conservation easements. There are a number of other properties within this core area that are preserved, or proposed for preservation, and may provide suitable habitat for the vernal pool fairy shrimp, including: Muzzy Ranch, Campbell Ranch Conservation Bank, North Suisun Conservation Bank, and CDFG's Barker Slough Ecological Reserve and Calhoun Cut Ecological Reserve. These preserved areas are protected for the benefit of a variety of natural habitats and native species, including vernal pools and vernal pool species; however, the amount of suitable vernal pool fairy shrimp habitat within these preserved areas has not been quantified.

San Joaquin Valley Vernal Pool Region: Twenty-nine CNDDDB occurrences are known from this vernal pool region. Three occurrence records are known from the Caswell core recovery area. All records are located in adjacent sections roughly ten miles west of Modesto, on or adjacent to the Mapes Ranch (CNDDDB 2007). One occurrence record is for one small pool at the base of a transmission line, where 10 individual shrimp were observed. The occurrences are on a portion of the Mapes Ranch that was purchased by the Federal government for inclusion within the San Joaquin River NWR, part of the San Luis NWR Complex (D. Woolington, Service, pers. comm.2007). Vernal pool fairy shrimp were detected in only one pool during refuge surveys in 1999 (K. Griggs, Service, *in litt.* 2007).

Within the Grasslands Ecological core area, four occurrences document the presence of the shrimp within portions of the San Luis NWR Complex. The shrimp have been identified in 29

(4.6 percent) of 638 surveyed vernal pools within various portions of the refuge complex within this core area (K. Griggs, Service, *in litt.* 2007). An additional occurrence within the Grasslands Ecological core area documents the shrimp from vernal pools on the 333-acre Vieira-Sandy Mush Road Conservation Bank, which is currently selling vernal pool preservation credits (CNDDDB 2007). The shrimp is present in 38 of approximately 220 pools within approximately 26 acres of habitat. Vernal pool fairy shrimp have also been identified at the Great Valley Grasslands State Park, which is adjacent to the San Luis NWR.

Within the Pixley core area, vernal pool fairy shrimp were found in vernal pools on the Two Well Unit of the Pixley NWR in 1993. The current status of the shrimp at the refuge is unknown. The refuge has 1,300 acres of annual grassland containing numerous small playas and 36 acres of northern claypan vernal pools. The vernal pools found on the Pixley NWR are not classic vernal pools but may represent a transition zone from prominent vernal pools further north in the valley and no pools in the southern end of the valley. Two additional occurrences document the shrimp on unprotected private lands within the core area (CNDDDB 2007).

Within the Cross Creek core area, the shrimp is documented from one pool on private lands (CNDDDB 2007).

Central Coast Vernal Pool Region: There are 32 occurrences reported from this vernal pool region. In 1993, Sugnet and Associates recorded vernal pool fairy shrimp in one pool in the San Benito core area, but the Service has not received further information about the site. The other occurrences within this region are on the Fort Hunter Liggett Army Reserve Base in the Fort Hunter-Liggett core area. Branchiopod surveys in 1995 established presence of the shrimp in natural and artificial vernal pools on base. Artificial vernal pools consist of tire ruts, road ditches and puddles, and other artificially-created wetlands (CNDDDB 2007).

Carrizo Vernal Pool Region: Twenty-two occurrence records are established for this vernal pool region. Within the North and South Carrizo Plain core area, an occurrence was recorded in 1985 for one site with three pools. In this core area, Bureau of Land Management personnel have surveyed approximately 100 pools in and around the Carrizo Plains National Monument, but have identified vernal pool fairy shrimp at only one additional pool. Both sites are located outside the Carrizo Plains National Monument, on privately-owned parcels that are about 20 acres in size (A. Kuritsubo, BLM, pers. comm. 2007).

Two of three occurrence records from the Paso Robles core area are located at a hatchery and turkey farm that document the presence low shrimp numbers in two ponds that are threatened by overgrazing (CNDDDB 2007). The third occurrence documents multiple pools surrounded by vineyards and threatened by land conversion (CNDDDB 2007).

All 16 records from the Central Coast Ranges core area are at the Camp Roberts California National Guard Installation, including 12 records from artificial wetlands, such as ruts and ditches that have been created by military operations in vernal pool grasslands (CNDDDB 2007).

Santa Barbara Vernal Pool Region: There is one CNDDDB occurrence for this vernal pool region. The record is for an isolated pool in the Los Padres National Forest (in the Ventura County core

area). Presence of the shrimp was last verified in 1989. The Forest Service has discovered one additional site. The Los Padres National Forest has assumed 751 acres of occupied habitat in consultations with the Service; however, occupancy has been verified at only the one site in the last 10 years. The Los Padres National Forest is planning to initiate a project to map potential habitat and conduct surveys for vernal pool crustaceans (Service 2001; USFS 2005). Within the region, several additional localities with vernal pool fairy shrimp have been documented since listing: at the Unocal Tank Farm in San Luis Obispo, at the Santa Maria Airport, and in 58 of 140 surveyed pools at Vandenberg AFB. At Vandenberg AFB, the majority of sites are artificial in that they are ponded water on roads or along railroad toe drains. Surveys indicate that the majority of sites in the cantonment area are unoccupied, while sites removed from major roadways are more likely to harbor fairy shrimp (Ecoanalysts, Inc. 2006), and numerous sites appear to be degraded.

Western Riverside Vernal Pool Region: The Skunk Hollow, Santa Rosa Plateau, and San Jacinto-Hemet core recovery areas are located within this vernal pool region, providing two CNDDDB occurrence records. The Western Riverside vernal pool region records are separated from recorded localities to the north by over 170 miles (Eriksen and Belk 1999). With the exception of the Santa Rosa Plateau area, most pools within this region have been destroyed or are greatly disturbed (Service 1998). At the time of listing, one isolated 33-acre pool was known within a thin strip of remnant disturbed coastal sage habitat in the Skunk Hollow core area. The pool, which is the largest remaining valley vernal pool in southern California, is now located on the 140-acre Barry Jones Wetland Mitigation Bank (CNDDDB 2007; CNLM 1997). Although presence of the vernal pool fairy shrimp has been established at this location by identification of cysts, no living animals have been found in the pool (Eriksen and Belk 1999). Since listing, vernal pool fairy shrimp cysts have also been found in an additional pool within the same local watershed (S. Brown, Service, *in litt.* 2007). To our knowledge, no active vernal pool fairy shrimp have been collected from either pool.

The 9,000-acre Santa Rosa Ecological Preserve in the Santa Rosa Plateau core area contains 13 pools located on several mesas. Several additional pools are located on private lands in the area. The vernal pool fairy shrimp has been detected in seven pools on the Santa Rosa Ecological Preserve (Serpa 1995 a and b; Angelos 1997 and 1998).

Since listing, vernal pool fairy shrimp have been found in the Stowe pool, within the Salt Creek Vernal Pool Complex in the San Jacinto-Hemet core area (CNDDDB 2007; C. Patterson *in litt.* 1998). The Stowe Pool is on private property, and is the only pool in the complex known to be occupied by the species (S. Brown, Service, *in litt.* 2007). The unlisted versatile fairy shrimp, a widespread fairy shrimp species (Simovich and Fugate 1992, Eriksen and Belk 1999), is present in the Stowe Pool (C. Patterson *in litt.* 1998) and the Skunk Hollow Pool (Eriksen and Belk 1999). The unlisted Santa Rosa Plateau fairy shrimp (*Linderiella santarosae*) is present on the Santa Rosa Plateau, and the endangered Riverside fairy shrimp (*Streptocephalus woottoni*) is found in the Skunk Hollow and Field Pools (Eriksen, Claremont Colleges, *in litt.* 1988). At March AFB in western Riverside County, surveys of vernal pool habitat have identified only the versatile fairy shrimp (Arnold 1995). Surveys of vernal pool habitat along the Upper Salt Creek drainage did not detect vernal pool fairy shrimp, although the versatile fairy shrimp was detected in several pools (RECON 1995).

II.C.1.c. Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

The vernal pools of California and Oregon occur primarily on alluvial fan terraces of the Pleistocene epoch (see Holland 1978; Borgias *et al.* 1999). In Oregon, the vernal pool fairy shrimp is found at the Agate Desert landform in the Rogue River basin (Borgias *et al.* 1999). Borgias and Patterson (1999) assessed the quality, abundance, and distribution of vernal pool landforms remaining in the Agate Desert region and determined that the Agate Desert vernal pools formerly covered 32 square miles, centered where White City has been built. Only 5,000 acres of the vernal pool habitat remain today in varying states of degradation, with approximately 60 percent destroyed due to residential, commercial, and industrial development and an additional 10-15 percent compromised due to habitat fragmentation. The remaining habitat either is altered by historical land uses or occurs on the edges of the landform where vernal pools are only occasionally present (Borgias and Patterson 1999; Service 2002; Service 2006a).

In California, the primary vernal pool habitat forms a discontinuous ring around the margins of the Central Valley. The majority of pools are found on the older alluvial terraces along the eastern margin of the valley, but there is also vernal pool habitat on high terraces on the eastern sides of the inner coast ranges and an extra band through the valley center. Several counties (Glenn, Colusa, and Yolo) lack substantial areas of hardpan soils and have little flat land that is not in agriculture, so have little potential habitat for the shrimp. Tehama, Yuba, Solano, and Madera counties have the highest-density areas of vernal pools, while Sacramento, Merced, and Fresno counties have many areas with high-density pools. Yuba, Placer, Sacramento, and Madera counties have the highest average densities of the 20 Central Valley counties (Holland 1978). These areas of high-density habitat are likely to be especially important to the population dynamics of vernal pool crustaceans such as the vernal pool fairy shrimp (Bonte *et al.* 2004; Keagy and Schreiber 2005). Vernal pool complexes are typified by a range of aquatic habitats, although some locales have more pools of one type (e.g., small, shallow, and short-lived, or playa-type pools, etc.) than other areas (Holland 1998a). The vernal pool fairy shrimp typically inhabits smaller, shallower pools within vernal pool complexes (Eriksen and Belk 1999). Most occurrences (65.4 percent) of the vernal pool fairy shrimp are found on high terrace (old terrace) landforms (Helm 1998). Up to 85 percent of vernal pools may lack large vernal pool crustaceans, but within occupied wetland types, 80 percent of vernal pool fairy shrimp occur in vernal pools rather than other seasonal wetlands such as alkali pools (Helm 1998).

Vernal pool habitat has decreased dramatically since settlement of California, and is still decreasing. Holland (1978) estimated, based on aerial photographs, that only 12 to 33.3 percent of the Central Valley's original vernal pool habitat remained at the time of his study. In 1996, Holland (1998a) remapped the distribution of vernal pool habitats in the Central Valley, utilizing updated aerial photography with improved resolution. Mapping showed that Fresno, Sacramento, and Yuba counties showed marked reductions in the extent of vernal pool habitat over the 20-year period between studies. Although Holland found evident habitat fragmentation, he also quantified an overall increase in extant vernal pool habitat. He attributed the paradoxical result to improved resolution in the later mapping effort, to the fact that some photos he used were almost 10 years old, and to reduced agricultural production of federally-subsidized grain

exports, along with retirement of marginal lands, including wetlands, from production (Holland 1998a). To quantify additional changes in land use in vernal pool habitat, Holland (1998b) further updated this work using July 1997 satellite imagery. He illustrated the loss of between 0.2 and 6.2 percent of each county's vernal pool habitat per year, within the range of the shrimp in the Central Valley. While Contra Costa County showed no loss of vernal pool habitat, Merced County lost an average of 3,032 acres per year and Tehama County lost over 1,055 acres per year. Between 1972 and 1993, Sacramento County lost around 30,500 acres of vernal pool habitat. Based on this updated mapping, Holland (1998b) estimated that extant vernal pool landscapes throughout the Central Valley had fallen below 1,000,000 acres, or roughly one quarter of the valley's estimated original vernal pool habitat.

In California's Central Coast Ranges, vernal pool habitats are more thinly distributed than in the Central Valley, with only 42,488 acres of vernal pool habitat occurring out of a total of 9,574,099 acres in the region (Holland 2003). Habitat patches are smaller and more isolated; however, in this area loss of vernal pool habitat also appears to be accelerating. Holland (2003) recorded a 2-3 percent per annum loss rate between 1994 and 2000, and almost a 12 percent loss between 2000 and 2001, with the loss often due to agricultural conversion (to hay or vineyards).

II.C.1.d. Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Virtually all of the taxonomic work on branchiopods to date has relied on morphological characters rather than genetic analysis to distinguish the species, including the vernal pool fairy shrimp (Grosberg 2002). Initial genetic analysis of the fairy shrimp genus, *Branchinecta*, included vernal pool fairy shrimp, but included samples from only nine California localities between Tehama and Riverside Counties (Fugate 1992), and did not include the Oregon population. The Service is not aware of new information on the genetic make-up or trends in genetic variation for this species.

II.C.2. Five-Factor Analysis

II.C.2.a. Present or threatened destruction, modification or curtailment of its habitat or range:

The present and threatened loss or modification of habitat due to urban development, water supply/flood control projects, landfill projects, road development, and agricultural land conversion were identified as the primary threats to this species in the 1994 listing rule. Habitat degradation from agricultural and human-related changes to vernal pool hydrology was listed as an additional threat (59 FR 48136).

Consistent with the 1994 rule, the largest continuing threat to this species is the loss and modification of habitat due to urban development, agricultural conversion, and infrastructure construction, especially along the periphery of urban areas. The human population of California is expected to increase to 58 million, almost double the 1990 State population, by 2040 (Field *et al.* 1999). Between 1994 and 2005, the Service's Sacramento Fish and Wildlife Office engaged in section 7 consultations for projects with impacts to approximately 50,000 acres of vernal pool

habitat, which includes both the vernal pools (wetted acres) and the surrounding uplands. This total includes the loss of 25,000 acres of vernal pool habitat to residential, commercial, and industrial development (Service 2005a). This loss is expected to continue as urban boundaries expand further through high and low terrace formations on the east and west sides of the Central Valley. In Oregon, as in California, the main threat to the species is the direct loss of vernal pool habitat due to urban development and infrastructure construction. The Medford, Oregon area, where the species is found, grew by 29.5 percent between 1990 and 2000 (U. S. Census Bureau 2007). The Service works with Federal, State, and local agencies, and with private project proponents, to minimize effects to listed vernal pool species, and to compensate for the loss of habitat through preservation of vernal pool habitat elsewhere and through creation (or restoration) of an equal acreage of vernal pool habitat. The results of these compensation efforts are covered below under the Habitat Conservation heading.

This section summarizes the existing threats and conservation efforts implemented to reduce them over the currently known habitat of the vernal pool fairy shrimp. A detailed description of the species' status in each of the 13 vernal pool regions where it is found is included the Appendix.

Habitat Threats

Loss and Modification of Habitat Associated with Urban Development

Within the range of the vernal pool fairy shrimp, cities that are rapidly expanding into vernal pool habitat where the shrimp are found include, but are not limited to, White City/Medford (Oregon), and Redding, Chico, Yuba City/Marysville, Roseville, Lincoln, Sacramento, Vacaville, Livermore, Los Banos, Paso Robles, and Hemet, California. For example, the City of Roseville in Placer County grew by 78.6 percent between 1990 and 2000 (U.S. Census Bureau 2007). Roseville and Lincoln are in the immediate vicinity of the Western Placer County core recovery area, an area noted for its relatively high densities of vernal pools. The growth in this county is resulting in the loss and fragmentation of an important region of high density vernal pool habitat. The City of Folsom, near Sacramento, also experienced a high growth rate (74.1 percent) between 1990 and 2000. The one recorded occurrence of the shrimp from this area may be protected within a conservation bank, but appears to be isolated from other extant occurrences by urban development (CNDDDB 2007). Vernal pool fairy shrimp sites in the Mather core area, within Sacramento's urban development boundary, are currently threatened by the rapid increase in surrounding development (Sacramento County 2005). Development pressure is also increasing in counties (and core recovery areas) that have retained larger, unfragmented acreages of extant vernal pool habitat. For example, in Yuba County several large-scale developments are proposed to the southwest and east of the Beale core recovery area: a proposed 3,300-acre mixed-use development on ranchlands southwest of Beale AFB is predicted to add more than 18,000 people to the County population (Laughlin 2007); another 1,028-acre mixed-use development is proposed adjacent to the southwest border of Beale AFB (S. Morey, CDFG, *in litt.* 2006); and the Yuba Highlands Area Plan would develop approximately 3,000 acres immediately northeast of Beale AFB (Yuba Foothill Associates, LLC 2006). Land immediately to the west of the extant vernal pool habitat at Beale AFB has been converted to rice production in past years, so no longer retains vernal pool habitat.

Habitat Loss and Modification due to Agricultural Conversion

Conversion of vernal pool habitat to intensive agriculture continues to contribute to the decline in vernal pools. From 1992 to 1998, 125,591 acres of grazing land was converted to other agricultural uses in the Central Valley (Service 2005a). Between 1994 and 2005, the Sacramento Fish and Wildlife Office reviewed projects converting 15,000 acres of vernal pool habitats to intensive agriculture (Service 2005a). The Service's strategy is to minimize impacts of such losses by including terms and conditions in section 7 consultations that, in part, provide for compensation that provides for the preservation and long-term management of a greater acreage of vernal pool habitat elsewhere for the benefit of listed species (Service 2005a). Agricultural conversion threatens vernal pool fairy shrimp in the Northwestern Sacramento Valley, Southeastern Sacramento Valley, San Joaquin Valley, Solano-Colusa, Southern Sierra Foothills, and Carrizo Vernal Pool Regions (CNDDDB 2007). For example, in Yuba County, the Yuba County Water Agency has proposed to construct a new canal along the western edge of Beale AFB that would deliver irrigation water for agricultural conversion (to rice, orchards, and irrigated pasture) to 12,000 acres of currently undeveloped pasture and fallow rangeland in the southeastern portion of the county (Yuba County Water Agency, *in litt.* 2006). In Merced County, croplands (row crops, orchards, and vineyards) are concentrated to the immediate west of the Madera core recovery area. Since the early 1990s, the lands in that portion of the county north of the Merced River have experienced a rapid, eastward expansion of almond orchards and vineyards onto vernal pool terrace landforms that were formerly used for grazing (Vollmar 2002).

The new UC Merced campus is currently in construction within the Madera core area on the relatively pristine Merced alluvial fan cap. Build-out of the UC Merced campus and associated university community will result in the permanent loss of approximately 3,116 acres of land supporting vernal pool habitat, of which 116 wetted acres are occupied vernal pool fairy shrimp habitat (Jones and Stokes 2007). However, approximately 45 percent of this land had already been converted to some agricultural and urban land uses, and another 19 percent of the area lands may have been degraded by existing roads and land conversions (Jones and Stokes 2007). The new university is expected to bring increased development to Merced County. The U.S. Army Corps of Engineers (USACE) regulatory branch currently has applications for more than 38 proposed projects that would fill wetlands within and around the Merced, Madera, and Grasslands Ecological Area core areas, although most of the projects have not yet been permitted (J. MacLean, USACE, *in litt.* 2007). The proposed projects range from developments to specific area plans for aggregate mining, road widening, airport expansion, and orchard development. In addition to land conversion planned under permits, in Merced County the Service is currently investigating the destruction or degradation of at least 3,664 acres of vernal pool habitat that has occurred in the last several years to create orchards or other development (J. Jorgensen, Service, *in litt.* 2007). Such unpermitted conversion from rangeland to orchards, vineyards, rice production, and other agriculture is expected to be a substantial, but unquantified threat to the vernal pool fairy shrimp throughout its range.

Habitat Loss and Modification due to Construction of Infrastructure

Vernal pool fairy shrimp occurrences within road right-of-ways are threatened by road maintenance and road-widening activities. In Butte County a series of pools within the right-of-

way along Highway 99 are threatened by road maintenance activities (CNDDDB 2007), while proposed road-widening and freeway development threaten habitat for the species along this and other roads within the county (Service 2005b; Service 2006b). In other areas, development of infrastructure is threatening extant vernal pool complexes. In the UC Merced planning area of Merced County, development of new roadways and associated infrastructure will result in the loss of extant vernal pool habitat (Jones and Stokes 2007). In the Solano-Colusa vernal pool region road-widening activities on Highway 12 will result in direct and indirect effects to the shrimp (Service 2004a). Consultation between the Service and project proponents focuses on compensation for the loss of vernal pool habitat at the project site through the preservation of vernal pool habitat elsewhere (generally at a ratio of 3 acres preserved for each acre of direct and indirect effects), and through the restoration or creation of an equal acreage of vernal pool habitat to the acreage affected (Service 2004a, see also Mead 1998). However, it is unclear whether the vernal pools within the conserved habitat provide equivalent conditions for the vernal pool fairy shrimp as the pools in the habitat that is lost (Wacker and Kelly 2004).

Altered Hydrology

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. In these sites, smaller and shallower pools dry quickly due to evapo-transpiration (Williamson *et al.* 2005). In other vernal pool habitats, the smaller and shallower vernal pools can be buffered against evapo-transpiration loss by perched aquifers (Williamson *et al.* 2005). Many vernal pools located on duripan or claypan in the Central Valley appear to be supported by perched aquifers (Rains *et al.* 2006). In these hydrological features, seasonal surface water and perched groundwater hydrologically connect uplands, vernal pools, and streams at the catchment scale. Perched groundwater discharges from uplands to vernal pools thereby stabilize the pools and cause them to remain inundated for longer periods than would be the case if they were recharged only by precipitation. The greater watershed can supply 25 to 60 percent of the water needed to fill pools to the margin; however, individual vernal pools display markedly different hydrology due to variations in topography and soil properties near each pool (Williamson *et al.* 2005). Accordingly, 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 (Rains *et al.* 2006). It is possible that remnant vernal pools within altered landscapes, and especially a high density of created vernal pools, may not have adequate surface and/or subsurface flows to adequately maintain vernal pool fairy shrimp through reproduction.

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 evapo-transpiration at the vernal pools (Marty 2005). In areas near the urban boundary, cattle-grazing is often discontinued in anticipation of land use changes (C. Martz, CDFG, pers. comm. 2006). 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 evapo-transpiration rates. The change in

vernal pool inundation due to loss of grazing is an emerging threat for vernal pool species, especially in the Sacramento Valley (C. Martz, CDFG, pers. comm. 2006). Vernal pool inundation has been reduced by 50-80 percent in the southeastern Sacramento Valley when grazing is discontinued (Marty 2005). In annual grasslands that are not mowed or grazed, the smaller and shallower pools that are typical habitat for the vernal pool fairy shrimp may lose their wetland characteristics over relatively short periods of time. Such pools may be easily missed when assessing potential vernal pool habitat. Overgrazing may also modify vernal pools through increased sedimentation and nutrient inputs, and is listed as a threat for some occurrences (CNDDDB 2007). However, the Service is not aware of specific new information on effects of overgrazing to vernal pool crustaceans.

Invasive nonnative plants are a threat to natural vernal pool hydrology in a number of lands under public or private conservation management, including the Stone Lake Preserve, Camp Roberts, the Santa Rosa Plateau, and Skunk Hollow vernal pools, and numerous small remnant parcels of vernal pool habitat (Jones and Stokes 2005; S. Brown, Service, *in litt.* 2007; C. Witham, CNPS, pers. comm. 2006; B. Treiterer, Service, pers. comm. 2007). At Camp Roberts several vernal pool areas were completely fenced to create “exclosures” to protect them from military activities and sheep grazing. Vernal pool monitors subsequently discovered that medusa-head (*Taeniatherum caput-medusae*), an invasive nonnative grass, had established in the exclosures where it threatened habitat quality for vernal pool fairy shrimp, and possibly served as a seed source to further invasion of areas outside of exclosures (Jones and Stokes 2005). At Vina Plains and Big Table Mountain, the increase of nonnative grasses has also been attributed to the lack of grazing. 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 (Wells *et al.* 1997). Without treatment, the density of nonnative herbaceous vegetation surrounding pools is expected to increase degradation of vernal pool habitat through loss of water and contamination (see contaminants discussion in II.C.2.e.).

Threats to Small Habitat Parcels

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 (CNDDDB 2007). As discussed above, 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 (Service 2006a). 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 (CNDDDB 2007). Increased periods of inundation can reduce habitat suitability for the vernal pool fairy shrimp as they are commonly found in only the smaller shorter-lived pools (Eriksen and Belk 1999). Vernal pool fairy shrimp occurrences on small conservation banks and preserves are often subject to the same threats as occurrences on unprotected, fragmented habitat (ECORP 2006b). Small unprotected and protected parcels may be particularly susceptible to degradation by nonnative species, particularly when the parcels are located in a matrix of development and are associated with chronically disturbed transportation corridors (Zedler and

Black 2004). In western Riverside County, the few known occurrences of vernal pool fairy shrimp are located on remnant vernal pool habitat within a generally urban/suburban landscape, and are threatened by habitat modification due to residential development, infrastructure construction, discing, and hydrological changes, even where pools are protected (Service 1998; S. Bell, TNC, pers. comm. 2003). The vernal pools on the Agate Desert Preserve in Oregon are threatened by the indirect effects of adjacent land use, including alteration of hydrology (David Evans and Associates 2001 in Service 2006a). In addition, development of off-site banks may not meet the functional equivalence of the original wetlands ecosystems (see discussion in Wacker and Kelly 2004).

Habitat Conservation

Strategies to protect and recover the vernal pool fairy shrimp rely primarily on preservation and restoration/creation of vernal pool habitat (Service 2005a). Approximately 13,000 acres of vernal pool habitats, including mitigation banks, have been set aside for the vernal pool fairy shrimp as a term and condition of Endangered Species Act section 7 consultations (Service 2005a). In Oregon the shrimp is protected on TNC's Agate Desert, Rogue River Plains, and Whetstone Savannah Preserves, and receives some protection on Bureau of Land Management, Bureau of Reclamation, and State lands (totaling approximately 1,650 acres) (Borgias *et al.* 1999; Service 2005a; Service 2006a). In California, conservation lands are scattered throughout the Central Valley (Service 2005a). In the Northwestern Sacramento Valley Vernal Pool Region, the Stillwater Plains and Thomes Creek preserves provide protected habitat for the shrimp (Service 2005a). In the Redding area the increased price of land along the urban front in the last several years has provided an unexpected threat to preservation of vernal pool habitat by reducing the land-purchasing capability of conservation and governmental organizations (C. Martz, pers. comm. 2006).

In the Northeastern Sacramento Valley region, the Vina Plains Preserve and private mitigation sites provide protected habitat. Within the Southeastern Sacramento Valley region, a variety of private mitigation lands and banks, conservation easements, protected lands along the Cosumnes River (Bureau of Land Management and The Nature Conservancy), and Beale AFB provide varying degrees of protection for the shrimp. In the Grasslands Ecological core area, the San Luis NWR Complex and state park lands include areas of vernal pool habitat that are protected from development. In the Southern Sierra region, mitigation lands and CDFG preserves protect the species, and in Eastern Merced County ongoing negotiations are resulting in conservation easements for large acreages of valuable habitat for the shrimp. In the Solano-Colusa region, several State and private preserves in the Jepson Prairie area provide protection for the species. In the Livermore vernal pool region, several occurrences of the shrimp are located on County and State park lands. Within the Central Coast region, vernal pool fairy shrimp are relatively protected from direct habitat loss by virtue of their location on military bases. In the Santa Barbara region, the few pools that are located on the Los Padres National Forest are protected from development due to their location on public lands. Finally, in Western Riverside County, pools where the species is present are protected on the Santa Rosa Plateau and at Skunk Hollow (Service 2005a; CNDDDB 2007).

Partnerships with private landowners and businesses are resulting in the preservation of conservation lands in or near core recovery areas. Large expanses of ranchlands containing extant vernal pool habitat are being placed under conservation easement in southeast Sacramento County and in the Madera core area of Merced County (Jones and Stokes 2007). Such large expanses of vernal pool habitat should better preserve the integrity of vernal pool fairy shrimp populations by preserving large intact blocks of habitat with a full, natural range of vernal pool sizes and types. However, in other cases the protection of vernal pool habitats within conservation banks and preserves may not adequately protect the rare landform types associated with specific species or meet the functional equivalence of the original wetlands ecosystems (see discussion in Wacker and Kelly 2004). Although the majority of vernal pool characteristics present at project sites are replicated at the corresponding conservation sites, when original and compensation locations are compared at the landscape scale across all development projects, the relatively rare pool types, such as Northern Volcanic Mudflow pools, are decreasing while “drainageway” pools, a less specialized pool type with lower species richness, are becoming more common (Wacker and Kelly 2004). Although projects have occurred fairly equally on high and low terrace sites, past compensation sites have been established disproportionately on low terrace formations (Wacker and Kelly 2004). Such shifts in availability of landform types could have negative consequences for persistence of the vernal pool fairy shrimp, although the degree of risk is unknown.

Although preserves and conservation banks have been set aside for the protection of vernal pool habitats, some protected lands may be impacted by management decisions that could favor one federally-listed vernal pool species over another. For example, creation of vernal pools that are larger or deeper than those utilized by the vernal pool fairy shrimp could favor the endangered vernal pool tadpole shrimp over the endangered vernal pool fairy shrimp (see species needs in Helm 1998; Eriksen and Belk 1999). Preserve areas that conserve and/or create vernal pool habitat in close proximity to permanent waters may facilitate the introduction of nonnative predators, such as mosquitofish and nonnative game fish, into vernal pool habitat. In preserves within the urban matrix, the shrimp could also be negatively affected by increased access to off-road-vehicle recreation, trespass, and dumping of toxins, especially at locations that do not have routine management presence. On some lands that are protected from development, including conservation banks, vernal pool fairy shrimp may be impacted by management decisions or design of vernal pool habitat features (Wildlands, Inc. 2007; J. Marty, TNC, pers. comm. 2006).

Vernal pool fairy shrimp are currently covered under four different completed Habitat Conservation Plans (HCP) authorized under section 10 of the Endangered Species Act: the Western Riverside County Multiple Species HCP, the San Joaquin County Multiple Species HCP, the Natomas Basin HCP, and the Kern Water Bank HCP. Three of these HCPs are expected to have little effect on the vernal pool fairy shrimp because few or no known occurrences are within the covered area. The area covered by the Kern Water Bank includes alluvial terraces, but the vernal pool fairy shrimp is not known to occur in the HCP area (CNDDDB 2007). There are three known occurrences of vernal pool fairy shrimp in San Joaquin County (CNDDDB 2007). The San Joaquin County Multiple Species HCP provides compensation for loss of vernal pool habitat, but there is no requirement that the replacement habitat be occupied by a specific species. However, no incidental take of the shrimp has been documented to date from the San Joaquin County Multiple Species HCP. San Joaquin County purchased

10.34 vernal pool preservation credits at the Fitzgerald Conservation Bank upon start-up of the HCP. Loss of vernal pool habitat under the plan is compensated at a ratio of two to one for preservation of wetted acres, one to one for creation of wetted habitat, and three to one for loss of upland acres (K. Torell, San Joaquin Council of Governments, *in litt.* 2007).

The Natomas Basin HCP supports habitat for the shrimp in the form of roadside ditches and seasonal wetlands. The majority of the potential habitat for the species within the plan area is artificial in origin and lacks linkages to larger intact habitat areas (i.e., vernal pool grasslands), thereby limiting the value of the plan area to the continued existence of the species (City of Sacramento *et al.* 2003). To date, the plan covers one location where the shrimp have been identified, and is expected to result in the incidental take of 1.58 acres of wetted vernal pool habitat. The Service does not know of any other sites for vernal pool fairy shrimp within the HCP boundaries (Helm Biological Consulting 2005b; Gibson and Skordal 2006).

The occurrences of the vernal pool fairy shrimp in western Riverside County are under the umbrella of the Western Riverside County Multiple Species HCP (S. Brown, Service, *in litt.* 2007). The Western Riverside County Multiple Species HCP is a large-scale, multi-jurisdictional HCP that addresses 146 listed and unlisted “Covered Species,” including the vernal pool fairy shrimp, within a 1,260,000-acre plan area. The Western Riverside County Multiple Species HCP plan area includes 42,349 acres of potential vernal pool habitat, based on computer modeling of soil types. However, other than the occurrences mentioned previously, the extent to which the vernal pool fairy shrimp occurs in these habitats is not known (Service 2004b; S. Brown, Service, pers. comm. 2007). In the Service’s biological opinion for the Western Riverside County Multiple Species HCP, we concluded that the proposed conservation strategy would allow 25,832 acres of potential habitat to become unsuitable for the shrimp, while the strategy would adequately protect the remaining 16,517 acres of potential habitat within the Western Riverside County Multiple Species HCP conservation area. The Western Riverside County Multiple Species HCP includes a policy that calls for avoidance and conservation of vernal pool habitats where feasible, and mitigation of unavoidable impacts to a level that is biologically equivalent or superior to avoidance. The Service has determined that the policy will minimize the impact of any habitat loss on covered species such as the vernal pool fairy shrimp. Known occurrences of the shrimp could be impacted by several covered activities, including the construction of the Butterfield Stage Road and the extension of Stowe Road through the Salt Creek Vernal Pool Complex (Service 2004b). The Western Riverside County Multiple Species HCP has not yet been fully implemented, and the conservation objectives for this species have not yet been achieved.

The East Contra Costa County HCP has not yet been finalized, although the Service published a notice of availability for public review of the HCP’s environmental impact statement in the Federal Register on March 9, 2007 (72 FR 10781). Within the East Contra Costa County HCP area, most vernal pools are thought to be either on public lands, such as the Vasco Caves Regional Preserve, or near the Byron Airport where most of the vernal pools have been preserved in perpetuity. Of 604 acres of seasonal wetland complexes and undetermined wetlands identified in the study area, up to 131 acres would be lost to covered activities, while the planned preserve system would protect an estimated 129 to 168 acres of seasonal wetlands, much of which is considered to be suitable habitat for the area’s three listed vernal pool crustaceans

(*Branchinecta lynchi*, *B. longiantenna*, and *L. packardi*). An additional estimated 104 to 163 acres of seasonal wetland complexes will be restored within the reserves. Two acres of habitat will be preserved and one acre will be restored for each acre lost (Jones and Stokes 2006).

Summary of Habitat Threats

In summary, 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 within 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.

Of the total 400 records present in the CNDDDB (2007), approximately 53 percent are located on private lands. Land ownership for 18.5 percent is unknown. About 15 percent of recorded occurrences are on Federal lands, including 13 percent on Department of Defense installations and 2 percent on public lands managed by the U.S. Forest Service, the U.S. Bureau of Reclamation, the U.S. Bureau of Land Management, and the Western Area Power Administration. About 9 percent of occurrences are on lands owned by local governments and other local entities, including 7 percent owned by the California Department of Transportation (Caltrans) or on Caltrans right-of-ways. About 3.5 percent of the occurrences are located on lands preserved specifically for natural resources, including National Wildlife Refuges, State Wildlife Areas, and State Parks, and 1.5 percent on preserves owned and/or managed by the CDFG or TNC. Of the total recorded occurrences, approximately 13 percent, including records with “private” and “unknown” ownership, are known from privately-owned open-space, conservation, or mitigation preserves (CNDDDB 2007). Thus, about 18.5 percent of all known occurrences are located on Federal and State public lands that are not subject to large scale land-type conversion, and an additional 14.5 percent are protected on State or privately owned preserves. The ownership and protected status of an unknown number of these occurrences may have changed since they were recorded in CNDDDB. For example, CNDDDB occurrences recorded on the Mapes Ranch in San Joaquin County are now part of the San Joaquin River National Wildlife Area (D. Woolington, Service, pers. comm. 2007).

II.C.2.b. Overutilization for commercial, recreational, scientific, or educational purposes:

Overutilization of this species for commercial or other purposes was not known to be a threat at the time of the 1994 final rule, and it is not addressed in the 2005 Recovery Plan recovery

criteria. We are not aware of any information that would suggest that it has become a threat since listing.

II.C.2.c. Disease or predation:

The 1994 final rule to list the vernal pool fairy shrimp stated that there were no known diseases affecting this species. The listing rule also noted that the fairy shrimp is a food item in the diet of migratory waterfowl and other native animals, but that naturally occurring predation was not considered a threat to the continued existence of the species (59 FR 48136).

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. Bullfrogs require permanent water for breeding; however, during the rainy season juvenile bullfrogs disperse readily into vernal pool complexes from permanent waters and can spend several weeks or more at pools consuming aquatic invertebrates. In such cases, bullfrogs have been documented to selectively prey on macro-crustaceans (e.g. vernal pool tadpole shrimp, *Lepidurus packardii*, and clam shrimp, *Cyzicus californicus*) and coleopterans (beetles), even when other prey is more abundant (Service 1994; Balfour and Morey 1999). Under natural conditions, California streams and rivers sustained wide annual fluctuations in water volume and generally were not permanent in nature, thereby preventing influxes of nonnative aquatic species (Moyle and Light 1996). Opportunities for bullfrog dispersal into vernal pool ecosystems have increased as 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 (Balfour and Morey 1999). 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. Although bullfrog predation of clam shrimp has been documented (Balfour and Morey 1999), the Service is not aware that predation of vernal pool fairy shrimp has been documented at this time. Bullfrogs, fish and crayfish have been noted as potential threats to the species at several national wildlife refuge holdings (CNDDDB 2007).

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 fairy shrimp. The use of mosquitofish (*Gambusia affinis*) to control mosquito larvae may be an emerging threat for the 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. Although undisturbed vernal pools do not provide a significant breeding source for mosquitoes; mosquitoes are known to occur in significant numbers in vernal pools where the aquatic community or the habitat has been disturbed or degraded (Wright 1991, Service 1994). Mosquitofish are typically stocked into waters that are near to human-occupied areas if mosquito larvae become abundant. In California, fish stocking practices vary by mosquito control district; with the trend away from stocking habitats where federally-listed species could be present (Alameda County Mosquito Abatement Control District 2007). Mosquito and vector control districts also provide mosquitofish to the public, although guidelines generally stipulate that the public put the fish only in artificial waters (Contra Costa MVCD 2007). Mosquitofish have also dispersed into vernal pools from nearby permanent

waters (Griggs *et al.* 1991). Introduced mosquitofish have been shown to significantly reduce fairy shrimp abundance when introduced to pools with active shrimp (Leyse *et al.* 2004). The vernal pool fairy shrimp is a cool-water species (Eriksen and Belk 1999), so should generally pass through its active life-phase before mosquito and vector control districts in the Central Valley stock the mosquitofish in spring. However, mosquitofish are routinely stocked in rice fields and are abundant in canals and other permanent water sources within the vicinity of extant vernal pool habitat. Under normal winter weather conditions when the vernal pool fairy shrimp are active, mosquitofish could invade vernal pool habitats via flows from swales, drainages, and flooding. Small numbers of adult mosquitofish can significantly reduce abundance of fairy shrimp within five weeks (Leyse *et al.* 2004), so the mosquitofish could potentially be a substantial threat at sites where the fish are able to move into vernal pools from nearby canals or other permanent water sources, or where they are placed into temporary waters during the shrimp's active period, especially because the vernal pool fairy shrimp is seldom abundant (Eriksen and Belk 1999).

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 within 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.

II.C.2.d. Inadequacy of existing regulatory mechanisms:

The final rule listing the vernal pool fairy shrimp found that the existing regulatory mechanisms were inadequate to protect the shrimp. No State or local laws and regulations had been passed to protect the vernal pool fairy shrimp or the other three vernal pool crustacean species included in the rule, and other regulatory mechanisms needed to conserve vernal pools were found to have been inadequate and ineffective (59 FR 48136).

The Federal Endangered Species Act: The Endangered Species Act of 1973, as amended (Act), is the primary Federal law that provides protection for the vernal pool fairy shrimp since its listing as a threatened species in 1994. 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. Since 1994, the Service's Sacramento Fish and Wildlife Office has completed section 7 consultations on impacts to almost 50,000 acres of vernal pool habitat (containing both pools and the supporting upland habitat), including direct impacts to over 1,314.5 acres of wetted vernal pool habitat and indirect impacts to 194.0 acres of wetted vernal pool habitat (Service 2007). The projects have included residential developments, highway-widening projects, pipeline and canal projects, among others. Consultations were primarily with the U.S. Army Corps of Engineers (Corps) for Clean Water Act permit applications.

If a Federal agency is not involved in a proposed project, and federally-listed wildlife may be taken as part of the project, then the project proponent is responsible for obtaining an incidental take permit pursuant to section 10(a)(1)(B) of the Act. The Service may issue such a permit

upon completion of a satisfactory habitat conservation plan (HCP) for the listed species that would be taken by the project. In addition to the completed HCPs discussed under Factor A (section II.C.2.a.), the Service is in the process of negotiating HCPs in a variety of counties, including Jackson County in Oregon, and Placer and Sacramento counties in California.

If the vernal pool fairy shrimp were removed from the Federal List of Threatened and Endangered Wildlife, it could be incidentally afforded protection of the Act where it co-exists with other protected vernal pool species. In western Riverside County the shrimp co-occurs with the Riverside fairy shrimp, *Streptocephalus wootoni*, which is listed as endangered under the Act. However, the two species are only documented to co-occur in two locations. In both of those locations, the vernal pool fairy shrimp is known only from the presence of its cysts (Eriksen and Belk 1999; S. Brown, Service *in litt.* 2007). In southeastern Contra Costa County, the vernal pool fairy shrimp might be afforded some incidental protection where it co-occurs in the Slanted Rocks area on sandstone outcrops with the endangered longhorn fairy shrimp, although the two species have not been observed in the same pool (Eriksen and Belk 1999). In other locations, the two species typically inhabit different vernal pool landform types (Helm 1998), so protection of the longhorn fairy shrimp is not likely to provide incidental protection to the vernal pool fairy shrimp. The remaining federally-listed branchiopods, the Conservancy fairy shrimp and the vernal pool tadpole shrimp, typically inhabit deeper and longer-lasting pools than those in which the vernal pool fairy shrimp is often found, so are not likely to afford substantial incidental protection to the species. The threatened California tiger salamander (*Ambystoma californiense*) also inhabits longer-lasting pools than are usually frequented by the vernal pool fairy shrimp, so is not likely to provide incidental protection. The shrimp would not be afforded incidental protection by the endangered slender Orcutt grass (*Orcuttia tenuis*), as the grass only occurs in deep pools. The Service does not have sufficient information at this time to determine whether the vernal pool fairy shrimp, if delisted, would be afforded any incidental protection by the presence of other federally-listed vernal pool plants.

Federal Clean Water Act: Section 404 of the Clean Water Act (CWA) may afford some protection to the vernal pool fairy shrimp. The Corps issues permits for the discharge of dredged or fill material into navigable waters of the United States. 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. In the past, vernal pools have been classified as Corps jurisdictional waters under the CWA. The CWA requires project proponents to obtain a permit from the Corps before initiating many types of activities (such as grading or discharge of soil) that could harm vernal pool habitat. Project proposals that would adversely modify less than one acre of habitat are considered authorized. The vernal pool fairy shrimp typically inhabits small and shallow vernal pools, so if the shrimp were delisted, its habitat might be particularly vulnerable to loss. The CWA exempts discing and other farming and ranching practices, and grazing, from regulation, so damage to vernal pool habitat could potentially accrue from such activities (59 FR 48136).

Recent Supreme Court rulings have called into question the Corps’ definition of Waters of the United States. On June 19, 2006, the U.S. Supreme Court vacated two district court judgments that upheld the Corp’s interpretation as it applied to two cases involving “isolated” wetlands. Currently, the Corps regulatory oversight of vernal pools is in doubt because of the “isolated”

nature of the vernal pools. In response to the Supreme Court decision, the Corps and the U.S. Environmental Protection Agency (USEPA) have recently released a memorandum providing guidelines for determining jurisdiction under the CWA. The guidelines provide for a case-by-case determination of a “significant nexus” standard that may protect some, but not all, vernal pool habitat (USEPA and USACE 2007). Potential habitat for vernal pool fairy shrimp, including swales and roadside ditches, will not generally be protected; however, these features are expected to be relatively unimportant to shrimp persistence. The overall effect of the new permit guidelines on loss of vernal pool habitat is not known at this time. In addition to the above, an unquantified but potential source of loss of vernal pool habitat is the unpermitted fill of vernal pool wetlands that results from actions that are completed without the benefit of a required CWA permit.

National Environmental Policy Act: The National Environmental Policy Act (NEPA) (42 U.S.C. 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 (including natural resources), but NEPA does not require that mitigation alternatives be implemented. 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 through provision of Federal funding or a Federal permit, including CWA and incidental take permits. Although NEPA requires disclosure of the effects of proposed Federal actions, it does not afford direct protection to the vernal pool fairy shrimp.

Sikes Act Improvement Act: In 1997, section 101 of the Sikes Act (16 U.S.C. 670a (a)) was revised to authorize the Secretary of Defense to implement a program to provide for the conservation and rehabilitation of natural resources on military installations. To do so, the Department of Defense was required to work with Federal and State fish and wildlife agencies to prepare Integrated National Resource Management Plans (INRMP) for each facility with significant natural resources. The INRMPs provide a planning tool for future base improvements; provide for sustainable multipurpose use of the resources, including activities such as hunting, fishing, trapping, and nonconsumptive uses; and allow some public access to military installations to facilitate their use. The implementation of these plans is subject to funding availability. For example, monitoring of vernal pools on Camp Roberts has been reduced due to decreased funding (Jones and Stokes 2005). On Department of Defense lands, including Beale, Travis, and Vandenberg Air Force Bases, Camp Roberts, and Fort Hunter Liggett, vernal pool habitat is generally protected from large-scale development. However, the primary purpose for military lands is to provide for military support and training, and vernal pool habitat is subject to impacts from military operations and training. At these bases, however, INRMPs provide direction for project development and for the management, conservation, and rehabilitation of natural resources.

Other Federal Lands: Management plans may also provide direction for management of resources, including the vernal pool fairy shrimp, on National Forests, Bureau of Land Management lands, Bureau of Reclamation lands, and National Wildlife Refuge lands. Apart from the National Wildlife Refuges, which are managed primarily for fish and wildlife resources, these Federal lands have multiple-use management mandates. For example, mining could occur on BLM’s Table Rocks site, although no claims are currently active (Service 2006a). On Federal

lands, effects to vernal pool fairy shrimp are addressed during section 7 consultations, and are based on its status as a threatened species under the Endangered Species Act.

California State Laws: No vernal pool crustaceans are listed under the California Endangered Species Act (CESA). Although the vernal pool fairy shrimp may potentially co-occur with several plants that are listed under State law, CESA only provides protection for known occurrences of the plants until they can be transplanted; therefore, there is no protection for the shrimp's habitat once the plants have been removed. CEQA (chapter 2, section 21050 *et seq.* of the California Public Resources Code) requires State and local 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. However, CEQA itself does not guarantee that conservation measures will be implemented; the lead agency may either require mitigation through changes to a project, or determine that overriding considerations make mitigation infeasible (CEQA Sec. 21002). Therefore, protection of specific species depends on the determination of the lead agency involved. Prior to listing of the vernal pool fairy shrimp, the effectiveness of this statute in protecting vernal pool habitat was not consistent; habitat for the shrimp was typically eliminated without offsetting mitigation measures (59 FR 48136).

Oregon State Laws: The vernal pool fairy shrimp is not listed as a protected species by the Oregon Department of Fish and Wildlife (Service 2006a). The Removal-Fill Law of 1989 (Oregon Revised Statutes 196.800-196.990 in Service 2006a), administered by the Oregon Division of State Lands, does not regulate activities that involve less than 50 cubic yards of fill. Such an amount of fill could seriously degrade many of the smaller vernal pools in which the vernal pool fairy shrimp occur (Service 2006a).

Summary of Existing Regulatory Mechanisms: In summary, without protection under the Act, 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 as 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 the Act.

II.C.2.e. Other natural or manmade factors affecting its continued existence:

Other natural or manmade threats cited in the 1994 final rule were all related to the size of the populations known at the time. Twenty of the 32 populations were comprised of single or less than five pools, and often the populations were remnants of larger, multi-pool populations that originally existed as historical vernal pool complexes. Specifically, the final rule discussed fragmentation of complexes, and noted the larger known populations in Sacramento and Placer counties as being under the threat of fragmentation by multiple proposed projects. Other specific threats were inbreeding depression, genetic drift, and stochastic (random) extinction due to isolation of remaining populations (59 FR 48136). The effects of ORV use and contaminants on vernal pool habitat were considered under Factor A. However, effects of ORV use and

contaminants on vernal pool fairy shrimp life-cycles were not considered. Invasive plants, grazing cessation, and drought/climate change were not identified as threats at the time of listing, and have since been identified as threats to the species.

Fragmentation

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. Consistent with predicted threats in the 1994 listing, in Sacramento and Placer counties, known occurrences of the shrimp have in fact been fragmented by development. In some areas, recent land-banking activities are beginning to protect large blocks of extant habitat for the shrimp in Tehama and Butte counties, in southeastern Sacramento County, and in Eastern Merced County. Species experts have noted the importance of pool complexes versus isolated pools in supporting various species of large branchiopods (Fugate 1992; Eriksen and Belk 1999; Helm and Vollmar 2002; R. Grosberg, UC Davis, *in litt.* 1993). Helm has observed that when a formerly intact vernal pool landscape is fragmented by development, the associated large branchiopod community generally declines through time, although it is unclear whether the decline is due to increased isolation, some other factor, or to a combination of factors (Vollmar 2002). In the Agate Desert area of Oregon, Borgias *et al.* (1999) found that the capacity of pools to support vernal pool fairy shrimp ranged widely in terms of peak abundance for the shrimp in each pool. They suggested that specific pools could be non-self-sustaining “sink” pools, relying on the influx of cysts from the pools with the greatest abundance of shrimp. 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 Service does not know of any studies that have assessed the status of cyst banks within isolated or connected pools. Some occurrence data in CNDDDB (2007) also suggest that shrimp abundance may be quite low in a variety of sites, but we are not aware of any quantified, systematic assessment of abundance.

Inbreeding Depression, Genetic Drift and Stochastic Extinction

The Service does not have any additional information on inbreeding depression or genetic drift within vernal pool fairy shrimp populations. Isolated populations continue to be threatened by stochastic extinction in that unforeseen natural and man-caused catastrophic events may eliminate some sites (Gilpin and Soulé 1998; Goodman 1987), as is discussed further in the preceding paragraph. The status of many occurrences is unknown (CNDDDB 2007), so we cannot quantify the extent to which extinction events have occurred or may occur.

Off-Road Vehicle Use

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. A variety of ORV uses have cumulatively damaged vernal pool habitats within the shrimp’s range (59 FR 48136). 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 (Jones and Stokes 2006). Borgias *et al.* (1999), however, reported fewer vernal pool fairy shrimp present in areas with evidence of heavy off-road vehicle use (Borgias *et al.* 1999). Vernal pools appear to depend on some types of disturbance, such as grazing (Marty 2005). However, fairy shrimp cysts appear to be easily crushed (Hathaway *et al.* 1996), so abundance of the species in affected pools could be reduced by substantial ORV disturbance.

Competitive effects of human disturbance

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 (Simovich and Fugate 1992). 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 (Eriksen and Belk 1999). 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 (Eriksen and Belk 1999; CNDDDB 2007). 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 (Eriksen and Belk 1999).

Contaminants

The introduction of pesticides and other contaminants into vernal pool waters may threaten occurrences of the vernal pool fairy shrimp. In Oregon, 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 (Borgias *et al.* 1999; Service 2006a). Plant decomposition and algal growth can lead to the depletion of dissolved oxygen in natural waters, and can increase sediment toxicity (see discussion in Lee 2007). Depletion of dissolved oxygen can cause complete mortality of gill-breathing aquatic organisms (Horne and Goldman 1994). 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. The runoff and precipitation that fill the pools can include pesticides (i.e., herbicides, insecticides, fungicides). In addition, toxic levels of some compounds accumulate in aquatic stream sediments within the Central Valley (Weston *et al.*

2004; Amweg *et al.* 2005), so may also be a problem in vernal pools. In 2005, 194,310,983 pounds of pesticides (active ingredient) were applied in California. The following counties with habitat for the vernal pool fairy shrimp were among the 10 counties with the highest commercial pesticide application: Fresno, Tulare, San Joaquin, Madera, Monterey, Merced, Ventura, and Kings Counties (California Department of Pesticide Regulation 2005). Although little information exists on the effects of pesticides to the vernal pool fairy shrimp, studies have considered the effects on other crustaceans, including other fairy shrimp species. Tests of lethal pesticide effects to the congeneric San Diego fairy shrimp (*Branchinecta sandiegonensis*) have indicated that it is not particularly sensitive to the insecticide Malathion at likely concentrations in vernal pools. However, the environmental concentrations of the herbicide glyphosate (Roundup), do pose a potential direct risk to survival of the San Diego fairy shrimp, while indirect effects of these two pesticides could also negatively affect it (Ripley *et al.* 2002/2003). Exposure to pesticides may include sub-lethal deleterious effects for a variety of species. Many pesticides interfere with reproductive (endocrine) systems by either interfering with protein formation and/or directly affecting reproductive tissue. Sub-lethal behavioral effects can include erratic swimming, lethargy, decreased predator avoidance, altered foraging, and reduced response to survival cues (C. Johnson, Service, *in litt.* 2007), although the extent to which vernal pool fairy shrimp exhibit specific effects is not known. However, herbicide formulations, although less toxic to invertebrates than insecticides, may lead to retarded growth and concomitant reductions in fecundity for exposed fairy shrimp (Brausch *et al.* 2006). Herbicides may be used on some preserved vernal pool habitats to control invasive plant species (e.g., CNLM 2004a).

Several commonly used pesticide formulations, including the herbicides Karmex (diuron) and Round-up, have been found to be toxic to *Thamnocephalus platyurus*, a fairy shrimp easily hatched in lab beakers and commonly used to test water quality and toxicity (Brausch *et al.* 2006). Pesticide effects can include the effects of the surfactants formulated with the active ingredient. For example, polyethoxylated tallowamine (POEA) is a surfactant that is commonly used in herbicide formulations to increase the efficacy of active ingredients. It is also known to cause alterations in respiratory surfaces of animals. POEA use has increased recently with the advent of “Roundup-Ready” crops; however, its potential effects on aquatic invertebrates are relatively unknown. Brausch and Smith (2007) used *T. platyurus* to assess the acute toxicity of POEA and found it to be extremely toxic at low concentrations.

Pesticides that are found in vernal pools due to atmospheric deposition have been found to be toxic to another vernal pool crustacean, the cladoceran *Ceriodaphnia dubia*. A complex mixture of pesticides (bromoxynil, dicamba, 2,4-D, MCPA, triallate, trifluralin, pentachlorophenol, lindane, and 4,4'-DDT) has been detected in appreciable quantities in dry atmospheric deposits in vernal pools. The toxicity of this pesticide mixture has been determined to be due to the DDT component, which is commonly detected in surface waters (George *et al.* 2003). Concentrations of the pesticide Diazinon found in vernal pools on NWR complexes in the Sacramento and San Joaquin Valleys occur at levels that could have adverse effects on vernal pool species, including the vernal pool fairy shrimp. Detectable levels of Endosulfane, Hexazinone, Trifluralin, and Simazine were also present in sampled pools at levels which could be also be toxic to the shrimp based on known toxicity to other vertebrate and invertebrate species, although their affects on listed vernal pool species have not been studied (Johnson 2005). Other research suggests that

pyrethroid insecticide use in residential and agricultural settings will cause toxicity, and even mortality, to aquatic species (Weston *et al.* 2005). The runoff of these pesticides into aquatic features surrounding residential developments was demonstrated to be a limiting factor for aquatic invertebrates; and was inversely correlated with abundance of resident macro-invertebrates (Weston *et al.* 2005). In Sacramento County where vernal pool habitat (including preserves) is located, recent efforts to combat West Nile Virus have resulted in aerial spraying of 116,140 acres with pyrethroid compounds to control adult mosquitoes (Weston *et al.* 2006). Although tests of pyrethroids have indicated toxicity of the pesticide itself, there is some discussion of the potential for nutrient-caused toxicity in stream sediments to decrease presence of aquatic invertebrates in streams sampled in the Central Valley (Lee 2007), thereby biasing interpretation of experimental results. Based on research results, the California Department of Pesticide Regulation has recently initiated a re-evaluation of certain pesticide products containing pyrethroids (CDPR 2006). The likelihood remains that contaminants pose a potential threat to the shrimp over much of its range.

Drought and Climate Change

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 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; see also 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 depletion of the cyst banks occur. Current monitoring protocols typically require only one survey for vernal pool crustaceans each monitoring year, so cannot determine the frequency with which the shrimp die off before completing reproduction (ECORP 2006b).

Climate change has the potential to adversely affect the vernal pool fairy shrimp through changes in vernal pool inundation patterns and temperature regimes. Climate scientists predict that California's climate will become warmer within the 21st century (Cayan *et al.* 2005, Field *et al.* 1999), although there is still uncertainty about particular regional effects of warming. Potential responses of California ecosystems to climate change fall into three response categories: geographical responses, changes in the way ecological processes work, and changes in the kinds of plants and animals that comprise natural communities (Field *et al.* 1999).

Geographical responses include latitudinal and elevational shifts in species ranges. Scientists expect climate warming to cause shifts in the distribution and abundance of many species (McLaughlin *et al.* 2002). The ability of vernal pool fairy shrimp to survive is likely to depend in part on their ability to disperse to pools where conditions are suitable (Bohanak and Jenkins 2003; Bonte *et al.* 2004). Loss and fragmentation of vernal pool habitat is thought to decrease dispersal ability. Therefore, species range shifts that may be required 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 (Field *et al.* 1999). Remnant suitable habitats, even within conservation banks, may be too far apart to allow dispersal or natural re-colonization after a disturbance (Field *et al.* 1999). Existing preserves in California may not provide the full range of conditions needed to sustain fairy shrimp during variable climatic conditions (Pyke 2004, 2005b).

The likely impacts of climate change on ecological processes are closely connected to availability of water. Vernal pools in California's Central Valley are particularly sensitive to slight increases in evaporation or reductions in rainfall due to their shallowness and seasonality (Field *et al.* 1999). 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 with less runoff in spring and summer, more winter flooding, and drier summer soils, thereby altering the seasonality and duration of vernal pool hydration (Cayan *et al.* 2005, Field *et al.* 1999). 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. Although vernal pool fairy shrimp mature relatively fast, they are able to produce more eggs when water conditions are suitable for a longer period of time (see Eriksen and Belk 1999; Helm 1998). Climate change is expected to lead to increased variability in precipitation (McLaughlin *et al.* 2002), 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.

The species active in each of California vernal pools is expected to change over time (Field *et al.* 1999; Pyke 2005b). Presence of vernal pool fairy shrimp appears to be associated with precipitation patterns and other climate factors, including temperature and aridity (Eriksen and Belk 1999; Graham 2003; Jones and Stokes 2006). Although the specific effects of climate change on the vernal pool fairy shrimp are unknown, the effect of warming temperatures on winter storm events and pool conditions have the potential to adversely affect this species. The shrimp may disappear from some areas to be replaced by more tolerant species. Changes in precipitation could alter marginal pools towards more or less favorable periods of inundation (Pyke 2005a). Climate change may also result in the alteration of vernal pool habitats through changes to water chemistry of pools due to increases in carbon dioxide from the atmosphere (Field *et al.* 1999) and decreased precipitation (Graham 2003), thereby affecting suitability of pools for specific species (Eriksen and Belk 1999; Graham 2003). Inter-annual population fluctuations might be amplified by changes in precipitation and could lead to rapid extinctions of individual populations, even where populations are already known to fluctuate widely (McLaughlin *et al.* 2002). It is also possible that fairy shrimp species could be buffered from extinction due to the presence of cyst banks, although the extent of this protection is unknown (Bohanak and Jenkins 2003).

II.D. Synthesis

We have no information indicating that threats to the vernal pool fairy shrimp have decreased since the time of listing in 1994 (59 FR 48136). Although progress is being made in protecting remaining large expanses of land from development in some regions, threats such as habitat loss and fragmentation have continued in every vernal pool region (potentially with the exception of the Lake-Napa region) since listing. The primary threats to the species continue to be the modification, destruction, and degradation of suitable habitat, and the resulting habitat fragmentation. Additionally, altered site hydrology, inappropriate grazing levels (cessation of grazing or overgrazing), nonnative invasive plants, and related issues such as thatch build-up, contaminant runoff into vernal pools, and drought and climate change are also major threats. While predation by nonnative species has not been quantified, it could pose a substantial threat to specific occurrences. However, the magnitude of this threat remains unclear. Even on protected lands, new and emerging threats have been identified in the form of hydrologic alteration resulting from invasive nonnative plants. Other new threats include the cessation of grazing in areas of vernal pool habitat, threats from nonnative mosquitofish, and threats due to climate change and drought.

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 (CNDDDB 2007), although the number of occurrences that are currently extant is unknown. An unknown portion of these records were established based on surveys at sites for proposed projects, so may no longer be extant, although compensation measures have minimized effects to the species by creating and preserving occupied vernal pool habitat. Although a new, disjunct cluster of occurrences has been located in Oregon, and new locality records have been established within the shrimp's range (primarily in population centers where the shrimp was previously known), the distribution of the shrimp remains essentially unchanged. It would appear from locality information that the species is more abundant than previously thought; however, records suggest that the shrimp is frequently present only in low numbers, or only present in a small percentage of the pools at a site. Rather than the number of occurrences, the number of complexes, the size of population in each complex, and their connectedness are the key to persistence of the species (R. Grosberg, UC Davis, *in litt.* 1993). In most cases, the Service has no information to indicate that recorded "occurrences" represent demographically independent units that contribute to species viability. We do not yet have better data with which to define populations of this species, so the extent to which individual occurrences contribute to populations of the shrimp is largely unknown. In addition, the long-term viability of the species at most sites is unknown. Vernal pool fairy shrimp resting eggs, or "cysts", are commonly dispersed via waterfowl, other migratory aquatic birds, and vertebrate animals, including humans (Eriksen and Belk 1999). Cysts will hatch into active shrimp if given the appropriate conditions of water temperature and chemistry. Thus 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).

Vernal pool fairy shrimp occurrences continue to be threatened by conversion of natural habitat for urban and agricultural uses. Fragmentation of habitat due to these causes results in isolated occurrences of this species in some core areas. Highly fragmented populations are thought to be

highly susceptible to extirpation due to environmental disturbance. If an extirpation event occurs in a population that has been fragmented, the opportunities for natural re-colonization will be greatly reduced due to physical isolation from source populations. The Service is working with the state and private landowners to protect remaining suitable habitat in large, contiguous blocks; however, purchase of conservation easements is in progress and has not yet been completed.

Both protected and unprotected populations in the Central Valley appear to be increasingly subject to decreased suitability of habitat due to changes in pool inundation associated with intrusion by nonnative plant species, and removal of grazing from grasslands near cities. Remnant habitat is also subject to development-related changes to watersheds. With predicted changes in climate over the next century, variable climatic conditions are expected to place additional strains on vernal pool ecosystems. The vernal pool fairy shrimp may survive prolonged drought due to life history adaptations; however, increases in warm winter storm events may preclude hatching of the species at lower latitudes and/or elevations.

Efforts to preserve and create suitable habitat for the shrimp are ongoing, but most preserves and conservation banks are only newly established, and have not met criteria for successful protection of the shrimp in perpetuity. In addition, sufficient habitat has not been protected to attain the habitat preservation goals of the Recovery Plan. Studies have demonstrated that the protection of vernal pool habitats within conservation banks and preserves may not adequately protect the rare landform types associated with specific species or meet the functional equivalence of the original wetlands ecosystems and may not sustain vernal pool species in the event of a prolonged drought. Therefore, despite protection of vernal pool habitat in conservation areas, available information suggests the distribution of these areas is not yet sufficient to provide for their recovery.

Therefore, based on the reasons summarized above, we conclude that the vernal pool fairy shrimp continues to meet the Endangered Species Act's definition of threatened. We recommend no status change for this species at this time.

III. RESULTS

III.A. Recommended Classification:

- Downlist to Threatened**
- Uplist to Endangered**
- Delist** (*Indicate reasons for delisting per 50 CFR 424.11*):
 - Extinction*
 - Recovery*
 - Original data for classification in error*
- No change is needed**

Threats to the vernal pool fairy shrimp are essentially unchanged since the time of its listing in 1994.

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

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. Recommendations have been identified based on communication with land managers and species experts, and through the process of reviewing the literature, the status of existing records, and determining population-level status of the species.

- 1. 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 within 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 CNDDDB occurrences. The probability of detecting the species under the Service's survey guidelines for vernal pool crustaceans should also be conducted.
- 2. 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. The Service should also work with private landowners for the conservation of habitat for the vernal pool fairy shrimp through conservation easements or other methods.
- 3. 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.
- 4. 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.

Appendix. Status of Vernal Pool Fairy Shrimp in Vernal Pool Regions.

The following paragraphs summarize the status of the vernal pool fairy shrimp in the vernal pool regions where the shrimp is found. Twelve recorded occurrences for the vernal pool fairy shrimp are located in pools that are outside of the defined vernal pool regions.

Klamath Mountains Vernal Pool Region:

Within the Klamath Mountains region, there are three core recovery areas, the Agate Desert, White City, and Table Rocks all clustered within 20 kilometers (12.4 miles) of each other near Medford, Jackson County, Oregon (Borgias and Patterson 1999; Service 2005a). Estimates by the Oregon Natural Heritage Program suggest that the range of the vernal pool fairy shrimp in Oregon has most likely declined by 75 percent (Service 2006a).

In the Agate Desert core recovery area, the shrimp has been found in twenty-six pools located on TNC's 21-hectare (53-acre) Agate Desert Preserve. The shrimp also has been found in thirty-one pools of varying quality at TNC's 58-hectare (144-acre) Whetstone Savannah Preserve and in several pools within TNC's 40-hectare (100-acre) Rogue River Plains preserve. The shrimp have also been found in four pools occurring within the BOR's 62-hectare (154-acre) Agate Reservoir area.

Lands in and around the White City core area consist primarily of remnant parcels of disturbed or degraded vernal pool habitat; few pools have been found to support active shrimp (Borgias *et al.* 1999). The 291-hectare (720-acre) Denman Wildlife Management Area (DWMA) contains the largest known area of vernal pools in the Rogue Valley, but much of the habitat is fragmented or degraded by wood waste (log deck debris) from the timber industry. Vernal pool fairy shrimp were not found in pools affected by wood waste, but were present in several unaffected pools comprising 8 percent of the pools on the DWMA (Borgias *et al.* 1999). Vernal pool restoration was completed on 4.9 ha (12 acres) within the DWMA as part of mitigation for the Medford International Airport in 2003 (Service 2006a).

Vernal pool fairy shrimp also occur in vernal pool habitat underlain by lava bedrock on 129 hectares (320 ac) managed by the BLM at Table Rocks, in the Table Rocks core recovery area. The pools are in an area that is not open to timber development or off-road vehicle use, but is open to mineral entry, although no claims are currently active (Service 2006a).

In Oregon, the lands that are managed specifically for federally-listed vernal pool species, including the vernal pool fairy shrimp, are TNC's Agate Desert and Whetstone Savanna Preserves containing approximately 80 hectares (197 acres) of vernal pool habitats. In addition, the TNC has a conservation easement for a 40-hectare (100-acre) vernal pool habitat area near Sam's Valley. The TNC monitors the populations at these three preserves annually. The properties carry restrictive covenants on the deed that mandate protection of the land in perpetuity, restrict development, and prescribe management of grazing, but allow the owners full access to the land (D. Borgias, pers. comm. 2004 in Service 2006a).

The BOR administers approximately 62 hectares (154 acres) adjacent to Agate Reservoir in cooperation with Jackson County Roads and Parks Services. The area is managed to maximize overall public and resource benefits. The BOR and Jackson County are currently developing a management plan for vernal pools within the 62 hectares (Service 2006a). Compensatory mitigation in the form of restoration for permitted wetland development has resulted in restoration of approximately 26 hectares (65 acres) of vernal pool habitat. The extent to which these areas support the vernal pool fairy shrimp is unclear. Early observation of these restoration sites appears promising, but long term success or failure of the sites has not been determined (Service 2006a).

The Oregon Department of State Lands has received a grant through the Service to assist in the development of a Habitat Conservation Plan (HCP) for vernal pool wetlands within the White City area of the Agate Desert. Approximately 1,133 hectares (2,800 acres) of vernal pool fairy shrimp habitat is being considered for inclusion within the study area; with approximately 16% of that acreage to be developed, 36% to be protected, and an additional 48% that could be protected, depending on funding of conservation incentive programs. The plan has not been finalized, so these figures are preliminary (Service 2006a).

Northwestern Sacramento Valley Vernal Pool Region:

Within the Northwestern Sacramento Valley region, there are a total of 13 CNDDDB occurrence records, including occurrences in the Orland, Red Bluff, Black Butte, Millville Plains, and Redding core recovery areas. The only known record from the Orland core area is located on a PG&E pipeline right-of-way, and is subject to altered hydrology. The Red Bluff core area includes 1 record from the Truckee Creek Restoration Site for the PG&E pipeline. One record is for vernal pool habitat at the Thomes Creek Ecological Reserve, managed by the CDFG, while a third record notes presence of the shrimp in 2 pools at the proposed Hancock Vernal Pool Ecological Preserve (CNDDDB 2007).

The reported occurrence in the Black Butte core area is now protected, as it is within the Blackburn Conservation Bank. It has natural vernal pools from which the shrimp has been reported (Wildlands, Inc. 2007).

Within the Millville Plains core area, the shrimp has been collected from an unknown number of vernal pools along a dirt road on unprotected lands (CNDDDB 2007).

The Redding core area includes one occurrence managed by the BLM, one occurrence from the west side of the Stillwater Gun Club, and one record for pools at the Hawes Ranch (now the Stillwater Plains Conservation Bank) (CNDDDB 2007). The Stillwater Plains Conservation Bank is a relatively new conservation bank. The bank is actively creating and restoring vernal pool habitat to be used as compensation for the loss of vernal pool habitat for vernal pool fairy shrimp and other listed vernal pool species. The bank is being established in phases and has completed endowments, management and monitoring plans, and conservation easements for three phases, providing a total of 649 acres that include restored blue oak woodlands and shrublands; restored creek habitat; and restored, enhanced, and created wetland and vernal pool habitat (ENPLAN

2003; D. Harvey, Service, pers. comm. 2006). Monitoring of the created/restored/enhanced vernal pools in Phase I has been reported for four years (ENPLAN 2003).

Northeastern Sacramento Valley Vernal Pool Region:

There are 24 CNDDDB occurrences records established within this region. Most CNDDDB occurrences are located outside the region's core recovery areas; however, there are occurrences present in the Chico, Dales, Oroville, Llano Seco, and Vina Plains core recovery areas (CNDDDB 2007).

In the Chico core area, an occurrence is known from the Foothill Park Mitigation Area placed under conservation easement by Drake Homes as compensation for a residential development project. In 1996, vernal pool fairy shrimp were present in 97 of the 17 natural and 179 created pools (CNDDDB 2007). Large areas around Chico have been subdivided and urbanized and are unavailable for restoration (CDFG 1998).

Within the Dales core area, one occurrence is recorded in one roadside vernal pool. Land ownership of the roadside vernal pool is unknown (CNDDDB 2007).

In the Oroville core area, the shrimp is recorded from one pool within a vernal pool complex where multiple pools were surveyed. Additional small occurrences are located outside of the core area, close to the City of Oroville (CNDDDB 2007). For example, there are vernal pool fairy shrimp present on the Clay Pit State Off-road Vehicle Park, where they occur in altered habitat and are threatened by vehicle disturbance. The California Department of Parks and Recreation is currently seeking assistance from the Service in addressing these threats. The Dove Ridge Conservation Bank is located outside the core area, but sells preservation and creation credits for loss of vernal pool fairy shrimp habitat within the core recovery areas. The bank has received an amended agreement that would allow it to enlarge vernal pools and swales in order to sell additional credits (Loafer Creek, LLC, undated). Such enlargements could potentially reduce their suitability for vernal pool fairy shrimp, which inhabit relatively shallow pools.

In the Llano Seco core area, vernal pool fairy shrimp have been found in two of 24 vernal pools at the Seco Unit, and Llano Seco Ranch portions of the Sacramento National Wildlife Refuge (NWR) Complex (J. Silveira, Service, *in litt.* 2007).

Within the Vina Plains core area, two occurrences are protected within the vernal pool complex on the Vina Plains preserve, which is managed by TNC and was established in 1982. It has a management and monitoring plan in place. An endowment fund was not established when the preserve was purchased, so funds for preserve operations are obtained each year through private fund-raising efforts. A small portion of the operating funds is received from a lease for on-site livestock grazing. To date, fundraising has been sufficient to fund operations (R. Reiner, TNC, pers. comm. 2006). Eleven records in the core area are from California Department of Transportation (Caltrans) right-of-ways along Highway 99, another record is from roadside ditches on an adjoining road. The Service is unaware of any conservation easements protecting the locations bordering Highway 99, and is not aware of other properties within this core recovery area that are protected for the benefit of vernal pool species.

Southeastern Sacramento Valley Vernal Pool Region:

There are 116 vernal pool fairy shrimp occurrences within this region, with occurrences in the Beale, Western Placer, Mather, Cosumnes/Rancho Seco, Southeastern Sacramento Valley, and Stone Lakes core recovery areas.

The Beale core area occurrence record describes a portion of the vernal pool complex on the western portion of Beale Air Force Base (AFB). At Beale AFB, vernal pool crustaceans are provided protection based on their status as a federally-listed species. Surveys of 1,000 vernal pools at Beale AFB in 1995 and 1996 found vernal pool fairy shrimp in 134 of the pools (Jones and Stokes 1998B). Beale AFB has identified vernal pool preservation areas that are based on the objective of preserving two acres of habitat with federally-listed crustaceans (the vernal pool fairy shrimp and vernal pool tadpole shrimp for every one acre of such habitat removed in their General Plan Development Areas, and on preserving habitat on the same geomorphic surface where the impact occurred. Creation and restoration of habitat is based on a 1:1 restoration/creation to impact ratio. Three on-base vernal pool preservation areas cover 912 acres of vernal pool habitat (Beale AFB 2002). The Service has issued biological opinions to cover losses of suitable habitat for federally-listed vernal pool crustaceans at Beale. To date 28.54 acres of wetted vernal pool crustacean habitat has been created or restored (K. Christopherson, Beale AFB, *in litt.* 2006) to off-set lost habitat. Additional restoration and creation projects are planned to compensate for potential future losses of existing vernal pool acreage. Early vernal pool creation at Beale resulted in some pools that were deeper than natural pools within constituent landforms (J. Marty, TNC, pers. comm. 2006), likely making them more suitable for vernal pool tadpole shrimp. Monitoring of created pools has begun; however, due to abnormally warm winter storms in 2005-2006, monitoring of natural and created pools at Beale did not detect vernal pool fairy shrimp (SRS Technologies 2006). Development of the AFB and management of natural resources are covered in the Beale AFB Integrated Natural Resource Management Plan (INRMP), but preserved and restored sites are not protected by a conservation easement or memorandum of agreement (MOA), and could be subject to changes in management if Federal priorities shift. An MOU between the Service and the AFB has been proposed to protect the vernal pool conservation areas on base; however, it has not yet been completed.

There are approximately 40 occurrence records in the Lincoln and Roseville areas of western Placer County, in or in close proximity to the Western Placer County core recovery area (CNDDDB 2007). The most westerly edge of Placer County is primarily converted to rice production and currently does not contain much vernal pool habitat. However, vernal pool fairy shrimp that are not yet recorded in CNDDDB have been found in several additional scattered pools within the western county during surveys for proposed development (ECORP 2006a, 2006c; Ecoanalysts *in litt.* 2007). Western Placer County has numerous existing open space, wetland mitigation, and other preserves. The shrimp has been recorded from approximately 10 privately or publicly-owned vernal pool, wetland mitigation, or open space preserves within this portion of the county (CNDDDB 2007). Most existing vernal pool preserves are relatively small in size and scattered throughout the western portion of the county. In at least some cases, remaining vernal pool habitat in preserves is fragmented and subject to threats from nonnative grasses, beaver dam construction, and runoff from adjacent developments (ECORP 2006b). Four (10%) of the CNDDDB occurrences for this core area are multiple records at the Wildlands Inc., Orchard Creek

Conservation Bank (CNDDDB 2007; Wildlands, Inc. 2007), where the shrimp have been recorded from 2 of 170 pools surveyed within the bank (CNDDDB 2007).

There are ten occurrences of vernal pool fairy shrimp within the Mather core area, one is within the Keifer Landfill expansion footprint; two are threatened by gravel mining. Several sites are located on conservation lands that were set aside to offset development activities. Proposed and occurring development in and around the core area includes the Sunrise Douglas development proposal, which contains over 500 pools (Sugnet and Associates 1993 in Service 1994: 48141).

The Cosumnes/Rancho Seco core area includes extensive vernal pool habitat. The area includes a number of protected sites, including the Cosumnes River Preserve (TNC, BLM, and the Sacramento Valley Conservancy), Howard Ranch and Valensin Ranches (the Laguna Creek Mitigation Bank), Clay Station Mitigation Bank, and Borden Ranch. The Clay Station and Valensin properties contain both natural and created vernal pools. The status of management plans, endowment funds, and monitoring varies with each bank. A number of banks are currently selling credits to preserve habitat and additional banks are being planned.

Occurrences in the Mather and Cosumnes/Rancho Seco core areas are within the boundaries of the Draft South Sacramento Habitat Conservation Plan (SSHCP) (Sacramento County undated). The SSHCP authors note that numerous surveys related to development projects have been conducted in and adjacent to the SSHCP, but that the area has not been thoroughly surveyed for the vernal pool fairy shrimp (Sacramento County undated). This region is threatened by intensive development and urbanization. However, opportunities to conserve vernal pool fairy shrimp populations are considered to be very high within the SSHCP. Current estimates for the SSHCP planning process are that covered activities within the study area will convert a total of 20,347 acres of vernal pool habitat, including 310 wetted vernal pool acres. The conservation goals are to preserve 1,240 acres of existing vernal pools and 31,638 acres of existing vernal pool grasslands, and to restore 155 acres of wetted vernal pool fairy shrimp habitat within new or existing preserves (Sacramento County undated).

Although there are a number of preserves, parks, and mitigation banks either within or adjacent to the SSHCP study area that have vernal pool fairy shrimp present, not all have conservation easements or funding protecting the species in perpetuity. The amount of suitable vernal pool fairy shrimp habitat within each site has not yet been quantified. Areas where the shrimp have been identified, in addition to the sites previously listed, include the Perry Ranch mitigation bank, Beach Lake Mitigation Bank, Bufferlands, Sunrise-Douglas Conservation Bank, Churchill-Downs Mitigation; Arroyo Seco Mitigation Bank, Florin Park, Mather Field Regional Park, and the Rancho Seco Preserve (Sacramento County undated; CNDDDB 2007).

The Southeastern Sacramento Valley core area has one known occurrence of vernal pool fairy shrimp from a ditch bordering the railroad tracks.

Within the Stone Lake core area, the vernal pool fairy shrimp was found in 5 pools by Sugnet and Associates in 1993 (CNDDDB 2007). The Stone Lake National Wildlife Refuge now holds the easement for a 1400-acre wetland compensation site in the area that includes an area of concentrated created vernal pools constructed among natural vernal pools. The refuge holds the

conservation easement that restricts development on site, while the developer retains the mineral, grazing, and hunting rights on the land. The refuge is managed through grazing. The area has funding in perpetuity, so the refuge receives a small amount for management. The site is adjacent to a major freeway, so the pools are threatened by invasive plant species, primarily yellow star thistle (*Centaurea solstitialis*), perennial pepperweed (*Lepidium latifolium*), and ryegrass (*Lolium* spp.) (B. Treiterer, Service, pers. comm. 2007).

Southern Sierra Foothills Vernal Pool Region:

The Southern Sierra Foothills vernal pool region includes six core recovery areas where the vernal pool fairy shrimp has been located, including the San Joaquin, Fresno, Merced, Madera, Table Mountain, and Cottonwood Creek core areas. There 108 vernal pool fairy shrimp occurrences in this region.

Within the San Joaquin core area, one occurrence is known from a 100-acre parcel of unprotected private land that is adjacent to deep-ripped vineyards, and is threatened by wetland filling and contaminants from adjacent parcels (CNDDDB 2007).

The Merced core area has two records, each for a pool in the Kelsey Reservoir vicinity. Both locations are on private lands. The Service is not aware that any occurrences within the Merced core area are protected.

The Madera core area has been the focus of extensive surveys for vernal pool crustaceans within the last ten years due to the development of the University of California, Merced, campus and associated community within the area. The eastern portion of Merced County, where the core area is located, consists primarily of large, privately owned ranches, and contains the state's premier remaining acreage of intact alluvial fans and terraces (Vollmar 2002). A substantial portion of the vernal pools and playas that occur within the region are within large, contiguous blocks of natural, intact vernal pool habitat (Jones and Stokes 2007). There are 76 CNDDDB records for this core area. The vernal pool fairy shrimp occupies a high percentage of surveyed pools in some portions of the planning area; 37 CNDDDB records were established for 636 occupied pools out of 713 pools present on the UC Merced planning area alone (Jones and Stokes 2007; CNDDDB 2007). Surveys have also been conducted on 12 ranches incorporating 17,897 hectares (44,223 acres) located within the eastern portion of the core area (Helm and Vollmar 2002). The ranches capture most of the geographic diversity and the range of geologic diversity of the region, and are located within centers of mapped high-density vernal pool habitat (CDFG 1988 in Vollmar 2002). In the ranchland surveys, the shrimp occurred on all ranches, and were found in 509 of 1,291 individual pools and swales surveyed. Ranches in the central and southern portion of the core area supported higher densities of shrimp than those in the northern portion of the study area (Helm and Vollmar 2002).

Vernal pool habitat in this core area will be protected to offset the effects of development associated with the UC Campus and related communities. There are two categories of protected properties: Tier 1 properties owned by the University or TNC, and subject to adaptive management and monitoring plans (8,885 acres), and Tier 2 properties that are being placed under conservation easement with the California Rangeland Trust and TNC to protect them from

future development while allowing standard livestock grazing practices (17,188 acres). Tier 2 lands are not subject to outside adaptive management and monitoring (Jones and Stokes 2007).

Known occurrences of the vernal pool fairy shrimp within this core area include the 4,496-hectare (11,109-acre) Flying M Ranch, the 1,248-hectare (3,085-acre) Ichord Ranch, and the 2,185-hectare (5,400-acre) Virginia Smith Trust property. The Virginia Smith Trust property is protected under a conservation easement, while the Flying M Ranch and the Ichord Ranch properties are not protected under conservation easements at this time (J. Vollmar, Vollmar Consulting, pers. comm. 2007). Portions or all of the Flynn Ranch, Knapp Ranch, Nelson Ranch, Cunningham Ranch, and Furey Ranch; and the Drayer Ranch Conservation Bank are protected with conservation easements, although the amount of suitable habitat on the ranches has not been quantified (J. Vollmar, Vollmar Consulting, pers. comm. 2007). The Service is not aware of other sites containing suitable habitat within this core area that are protected for the benefit of vernal pool species.

The Table Mountain core area provides two occurrence records for relatively isolated pools on Big Table and Kennedy Table. One occurrence is on the privately owned Kennedy Table Mitigation Bank, while the other is managed by the CDFG (CNDDDB 2007).

Within the Fresno core area, ten occurrence records include a complex at Millerton New Town, 8 occurrence records within proposed mitigation sites, and one additional pool where the shrimp were located. The CDFG also reports new unprocessed occurrence records for a proposed project on highway 41 within a complex with known occurrences. (D. McGriff, CDFG, *in litt.* 2007). The several additional occurrences in the general vicinity of the core area include one record for a 2 by 10 foot puddle in a canal easement that contained 3 shrimp and was reported as a small remnant of the vernal pool habitat that was previously located at the site (CNDDDB 2007). The others are isolated by roads and development (CNDDDB 2007).

The Sand Creek Conservation Bank, in the Kings core area, has 23 acres of natural vernal pools where the vernal pool fairy shrimp has been found.

There are four CNDDDB records (2007) for the Cottonwood Creek core area; two sites consist of one pool each and are threatened by land conversion. The occurrence at the Stone Corral Ecological Preserve is threatened by excess pool flooding due to urban run off.

Lake-Napa Vernal Pool Region:

In 2002-2003 winter season, the shrimp was detected in one pool at the Napa Airport in the Napa River core area at the southeast edge of the Lake-Napa Vernal Pool Region. Although additional pools were sampled at the site, no other pools were found to contain branchiopods (CNDDDB 2007). The shrimp were not detected during subsequent wet-season surveys in 2004 and 2005 (Jim Wallace, pers. comm. 2007). The pool has not been adversely affected by airport expansion, but is not protected in a preserve. To our knowledge, the shrimp has not been found in other areas of the region, despite surveys of the vernal pools on the Santa Rosa Plain (Vincent Griego, Service, pers. comm. 2007).

Livermore Vernal Pool Region:

There are 12 occurrences in this region. The Altamont Hills core area, has eight occurrences; four of which are in areas planned for development. Other threats to the area vernal pools are off-road vehicle (ORV) use, altered hydrology, and invasive plants (CNDDDB 2007). One occurrence is located on Wildlands' Byron Conservation Bank and the adjacent Contra Costa County lands at the Byron Airport (CNDDDB 2007). In addition, portions of the 1,400-acre Vasco Caves Preserve and the 507-acre Brushy Peak Preserve are within this core recovery area, and contain known occurrences of the species in the small rock pools on sandstone outcrops. The small depressions represent an atypical habitat, which is only found only in the Altamont Hills core area. The pools are generally less than one meter in diameter and each contain only a few shrimps (Eriksen and Belk 1999: 93). The longhorn fairy shrimp, *B. longiantenna*, also inhabits the rock pools within these parks. Although both species are present, they do not occur together within the same pool (Eriksen and Belk 1999). The number of rock pools in which the vernal pool fairy shrimp has been found at the parks has not been quantified. The parks are multiple-use parks, and the pools are not regularly monitored for the presence of specific species (Steve Bobzein, pers. comm. 2007). There are three additional occurrences having single pools, and one additional occurrence with multiple pools present within the region.

Solano-Colusa Vernal Pool Region:

There are 28 vernal pool fairy shrimp occurrences from this vernal pool region. Vernal pool habitats have been surveyed on the Sacramento, Colusa, and Delevan portions of the Sacramento National Wildlife Refuge within the Sacramento National Wildlife Refuge (SNWR) core recovery area. Although not recorded in CNDDDB, the vernal pool fairy shrimp has been found in one of approximately 40 pools surveyed on 140 acres of habitat on the three refuges (Joe Silveira, Service, *in litt.* 2007). SNWR is managed for multiple species and uses. A Comprehensive Conservation Plan will be finalized for the refuge complex in August 2008, and will address management of vernal pool species (J. Silveira, Service, pers comm. 2006).

Within the Dolan core area, the only occurrence of the vernal pool fairy shrimp is recorded on the Dolan Ranch Conservation Bank (CNDDDB 2007). The 2003 and 2004 monitoring reports for the bank indicate that vernal pool fairy shrimp are present in only one pool within the Dolan Ranch Conservation Bank. Most pools are occupied by vernal pool tadpole shrimp, a known predator of vernal pool fairy shrimp, and the bank is authorized to sell credits for the vernal pool tadpole shrimp, but not for the vernal pool fairy shrimp (Wildlands 2004; Wildlands 2005; Service 2007).

Within the Vacaville core area, the vernal pool fairy shrimp was found in 26 of 649 wetlands that were surveyed at the North Village project site (CNDDDB 2007).

Ten records are known from the Jepson Prairie core area. Three records are for three of the pools at the Burke Ranch. The shrimp was also found in 13 pools scattered through the North Village Mitigation Site, from 3 artificial and 4 natural pools located at the Burke Property Open Space Preserve adjacent to housing and Travis AFB, from vernal pools at the Portrero Hills Landfill, and from four other locations, including Caltrans and railroad right-of-ways (CNDDDB

2007). There are additional locality records on lands in the general vicinity of the core area, including around 7 natural and 3 artificial pools on various portions (or on the border) of Travis AFB. The amount of suitable vernal pool fairy shrimp habitat that is protected within this core recovery area has not been quantified at this time. Within or adjacent to this core area, the Wilcox Ranch property, the Elsie Gridley Conservation Bank, and the proposed Burke Ranch Conservation Bank (currently under review by the Service) are known to harbor the shrimp. Of these sites, all but the Burke Ranch property are protected under conservation easements. There are a number of other properties within this core area that are preserved, or proposed for preservation, and may provide suitable habitat for the vernal pool fairy shrimp, including: Muzzy Ranch, Campbell Ranch Conservation Bank, North Suisan Conservation Bank, and the California Department of Fish and Game's (CDFG) Barker Slough Ecological Reserve and the Calhoun Cut Ecological Reserve. These preserved areas are protected for the benefit of a variety of natural habitats and native species, including vernal pools and vernal pool species; however, the amount of suitable vernal pool fairy shrimp habitat within these preserved areas has not been quantified. The Service is not aware of other sites containing suitable habitat within this core area that are protected for the benefit of vernal pool species.

San Joaquin Valley Vernal Pool Region:

Twenty-nine CNDDDB occurrences are known from this vernal pool region. Three occurrence records are known from the Caswell core recovery area. All records are located in adjacent sections roughly ten miles west of Modesto, on or adjacent to the Mapes Ranch (CNDDDB 2007). One occurrence record is for one small pool at the base of a transmission line, where 10 individual shrimp were observed. The occurrences are on a portion of the Mapes Ranch that was purchased by the Federal government for inclusion within the San Joaquin River Refuge, part of the San Luis NWR Complex (D. Woolington, Service, pers. comm. 2007). Vernal pool fairy shrimp were detected in only one pool during refuge surveys in 1999 (K. Griggs, Service, *in litt.* 2007).

Within the Grasslands Ecological core area, four occurrences document the presence of the shrimp within portions of the San Luis NWR Complex. The shrimp have been identified in 29 (4.6%) of 638 surveyed vernal pools within various portions of the refuge complex within this core area (K. Griggs, San Luis NWR, *in litt.* 2007). The San Luis NWR currently manages the refuge to meet multiple-use goals and objectives that include managing and providing habitat for endangered or sensitive species, producing optimum habitat conditions for wintering waterfowl and other migratory birds, maintaining and enhancing the overall biodiversity associated with the existing mix of vegetative communities, providing an area for compatible management-oriented research and education/interpretation and recreational programs (e.g. observation, photography, hunting) (San Luis NWR: <http://www.fws.gov/sanluis/mission.htm>). As long as the San Luis NWR continues to manage the complex for the benefit of vernal pool species, the fairy shrimp will be protected there.

Within the Grasslands Ecological core area, an additional occurrence documents the shrimp from vernal pools on the 333-acre Vieira-Sandy Mush Road Conservation Bank, which is currently selling vernal pool preservation credits (CNDDDB 2007; http://www.fws.gov/sacramento/es/bank_list.htm). The shrimp is present in 38 of approximately 220 pools within approximately

26 acres of habitat. The Vieira-Sandy Mush Road Conservation Bank has a management plan for grazing and the Center for Natural Lands Management is monitoring for presence of vernal pool species at the site (C. Feldheim, CNLM, pers. comm. 2007). Vernal pool fairy shrimp have also been identified at the Great Valley Grasslands State Park, which is adjacent to the San Luis NWR. The park does not have a management plan, but current management practices are designed to maintain vernal pool habitat for the multiple vernal pool plants and animals present within the park (J. Karlton, California Department of Parks and Recreation, pers. comm. 2007). The Service is not aware of other sites containing suitable habitat within this core area that are protected for the benefit of vernal pool species.

Within the Pixley core area, vernal pool fairy shrimp were found in vernal pools on the Two Well Unit of the Pixley NWR in 1993. The current status of the shrimp at the refuge is unknown. The refuge has 1,300 acres of annual grassland containing numerous small playas and 36 acres of northern claypan vernal pools. The vernal pools found on the Pixley NWR are not classic vernal pools but may represent a transition zone from prominent vernal pools further north in the valley and no pools in the southern end of the valley. The Kern NWR Complex completed the Comprehensive Conservation Plan for the Kern and Pixley NWRs in February 2005, before the vernal pool recovery plan was completed. The refuge plan does not provide any management direction for the vernal pool fairy shrimp (http://www.fws.gov/pacific/planning/draft/docs/ca/kern/Final_CCP.pdf, CNDDDB 2007). Two additional occurrences document the shrimp on unprotected private lands within the core area (CNDDDB 2007).

Within the Cross Creek core area, the shrimp is documented from one pool on private lands threatened by land conversion (CNDDDB 2007).

Central Coast Vernal Pool Region:

There are 32 occurrences reported from this vernal pool region. In 1993, Sugnet and Associates recorded vernal pool fairy shrimp in one pool in the San Benito core area, but the Service has not received further information about the site. The other occurrences within this region are on the Fort Hunter Liggett Army Reserve Base in the Fort Hunter-Liggett core area. Branchiopod surveys in 1995, established presence of the shrimp in natural and artificial vernal pools on base. Artificial vernal pools consist of tire ruts, road ditches and puddles, and other artificially-created wetlands (CNDDDB 2007).

Carrizo Vernal Pool Region:

Twenty-two occurrence records are established for this vernal pool region. Within the North and South Carrizo Plain core area, an occurrence was recorded in 1985 for one site with three pools. In this core area, BLM personnel have surveyed approximately 100 pools in and around the Carrizo Plains National Monument, but have identified vernal pool fairy shrimp at only one additional pool. Both sites are located outside the Carrizo Plains National Monument, on privately-owned parcels that are about 20 acres in size (A. Kuritsubo, BLM, pers. comm. 2007).

Two of three occurrence records from the Paso Robles core area are located at a hatchery and turkey farm that document the presence low shrimp numbers in 2 ponds that are threatened by

overgrazing (CNDDDB 2007). The third occurrence documents multiple pools surrounded by vineyards and threatened by land conversion (CNDDDB 2007).

All sixteen records from the Central Coast Ranges core area are at the Camp Roberts California National Guard Installation, including twelve records from artificial wetlands, such as ruts and ditches that have been created by military operations (CNDDDB 2007) in vernal pool grasslands.

Santa Barbara Vernal Pool Region:

There is one CNDDDB occurrence for this vernal pool region. The record is for an isolated pool in the Los Padres National Forest (LPNF) (in the Ventura County core area). Presence of the shrimp was last verified in 1989. The Forest Service has discovered one additional site. The LPNF has assumed 304 hectares (751 acres) of occupied habitat in consultations with the Service; however, occupancy has been verified at only the one site in the last 10 years. The LPNF is planning to initiate a project to map potential habitat and conduct surveys for vernal pool crustaceans (Service 2001 in USFS 2005). Within the region, several additional localities with vernal pool fairy shrimp have been documented since listing: at the Unocal Tank Farm in San Luis Obispo; at the Santa Maria Airport; and in 58 of 140 surveyed pools at Vandenburg AFB. At Vandenburg AFB, the majority of sites are artificial in that they are ponded water on roads or along railroad toe drains. Surveys indicate that the majority of sites in the cantonment area are unoccupied, while sites removed from major roadways are more likely to harbor fairy shrimp (Ecoanalysts, Inc. 2006), and numerous sites appear to be degraded.

Western Riverside Vernal Pool Region:

The Skunk Hollow, Santa Rosa Plateau, and San Jacinto-Hemet core recovery areas are located within this vernal pool region, providing 2 CNDDDB occurrence records. The Western Riverside vernal pool region records are separated from recorded localities to the north by over 170 miles (Eriksen and Belk 1999). With the exception of the Santa Rosa Plateau area, most pools within this region have been destroyed or are greatly disturbed (Service 1998). At the time of listing, one isolated 33-acre pool was known within a thin strip of remnant disturbed coastal sage habitat in the Skunk Hollow core area. The pool, which is the largest remaining valley vernal pool in southern California, is now located on the 140-acre Barry Jones Wetland Mitigation Bank (CNDDDB 2007; CNLM 1997). Although presence of the vernal pool fairy shrimp has been established at this location by identification of cysts, no living animals have been found in the pool (Eriksen and Belk 1999). Since listing, vernal pool fairy shrimp cysts have also been found in an additional pool within the same local watershed (S. Brown, Service, *in litt.* 2007). To our knowledge, no living vernal pool fairy shrimp have been collected from either pool.

The 9,000-acre Santa Rosa Ecological Preserve in the Santa Rosa Plateau core area contains thirteen pools located on several mesas. Several additional pools are located on private lands in the area. The vernal pool fairy shrimp has been detected in seven pools on the Santa Rosa Ecological Preserve (Serpa 1995 a and b; Angelos 1997; Angelos 1998).

Since listing, vernal pool fairy shrimp have been found in the Stowe pool, within the Salt Creek Vernal Pool Complex in the San Jacinto-Hemet core area (CNDDDB 2007; C. Patterson *in litt.*

1998). The Stowe Pool is on private property, and is the only pool in the complex known to be occupied by the species (S. Brown, Service, *in litt.* 2007). The versatile (or Lindahl's) fairy shrimp (*B. lindahli*), a widespread, "weedy" fairy shrimp species (Eriksen and Belk 1999) is present in the Stowe Pool (C. Patterson *in litt.* 1998) and the Skunk Hollow Pool (Eriksen and Belk 1999), while the Santa Rosa Plateau fairy shrimp (*Linderiella santarosae*) is present on the Santa Rosa Plateau, and the endangered Riverside fairy shrimp (*Streptocephalus woottoni*) is found in the Skunk Hollow and Field Pools (Eriksen 1988). At March Air Force Base in western Riverside County, surveys of vernal pool habitat have identified only the versatile fairy shrimp, (Arnold 1995). Surveys of vernal pool habitat along the Upper Salt Creek drainage did not detect vernal pool fairy shrimp, although the versatile fairy shrimp was detected in several pools (RECON 1995).

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Vernal Pool Fairy Shrimp (*Branchinecta lynchi*)

Current Classification Threatened
Recommendation resulting from the 5-Year Review

- Downlist to Threatened**
 Uplist to Endangered
 Delist
 No change is needed

Appropriate Listing/Reclassification Priority Number, if applicable NA

Review Conducted By Sacramento Fish and Wildlife Office staff

FIELD OFFICE APPROVAL:
ACTING

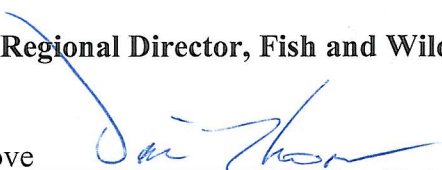
Lead Field Supervisor, Fish and Wildlife Service

Approve  Date SEP 20 2007

REGIONAL OFFICE APPROVAL:

Acting

Lead Regional Director, Fish and Wildlife Service

Approve  Date SEP 20 2007

Acting

Cooperating Regional Director, Fish and Wildlife Service

Concur Do Not Concur

Signature  Date 9/27/07