C. Federally Listed Animal Species

1. DELTA GREEN GROUND BEETLE (*ELAPHRUS VIRIDIS*)

a. Description and Taxonomy

Taxonomy.— The delta green ground beetle (*Elaphrus viridis*) (Coleoptera: Carabidae), was named and described over 120 years ago from a single specimen sent to Dr. George Horn (Horn 1878). "California" was the only locality information supplied by the original collector, A.S. Fuller (Andrews 1978). Despite its spectacular and unmistakable appearance, nearly a century later this beetle was still an enigma to entomologists. The species was known only from the single specimen in the Harvard Museum of Comparative Zoology and remained a mystery until 1974, when a student from the University of California at Davis incidentally rediscovered it in Solano County at Jepson Prairie.

Goulet and Smetana (1997) discussed the genus *Elaphrus*. Lindroth (1961) rejected an application of *Elaphrus viridis* by Csiki (1927) as invalid since he felt it clearly referred to a color variation of *Elaphrus riparius*. Goulet (1983) revised the tribe Elaphrini and retained the delta green ground beetle in the genus *Elaphrus*. The specific name of *viridis* also has been retained.

Description and Identification.— Although beetles of the genus *Elaphrus* superficially resemble tiger beetles (Cicindelidae), they belong to the ground beetle family Carabidae. The delta green ground beetle is approximately 0.6 centimeter (0.25 inch) in length, and is typically colored in brilliant metallic green and bronze (**Figure II-33**), with two slightly different color forms. Most adults are metallic green with bronze spots on the elytra (first pair of wings, which in beetles are hardened and act as a protective covering), but some adults lack the spots and are nearly uniform metallic green (Goulet 1983, Serpa 1985). The larvae are generally similar to other carabid larvae, and have hardened exterior surfaces with a metallic sheen (Goulet 1983).

The range of the delta green ground beetle overlaps with other ground beetles such as *Elaphrus californicus*, *E. finitimus*, and possibly *E. mimus* (Goulet 1983, D. Kavanaugh pers. comm.). Adult delta green ground beetles can easily be distinguished from related species by their brilliant metallic colors, which are unique among California *Elaphrus*, and by the lack of outlined pits on the elytra (Goulet 1983).

In addition, the delta green ground beetle is the only known California *Elaphrus* species whose adults are active during the winter (Goulet 1983, H. Goulet pers.

comm., D. Kavanaugh pers. comm.). Adult males can be differentiated from females by bundles of white sticky pads, called holdfasts, located at the base of the tarsus (terminal leg segment) on the underside of their front legs, which serve to keep the male in position during mating (D. Kavanaugh pers. comm.).

b. Historical and Current Distribution

Historical Distribution.—Although the historical distribution of the delta green ground beetle is unknown, the widespread loss and disruption of wetlands and grassland habitat in California's Central Valley since the mid-1800s (Frayer *et al*. 1989; also see below) suggest that the range of this vernal pool-associated species has been reduced and fragmented by human activities, especially agricultural and water uses. The delta green ground beetle, therefore, may have inhabited a much larger range than it does presently, but significant losses of Central Valley wetlands and the lack of comprehensive insect surveys in California over the past century, in addition to the delta green ground beetle's cryptic coloration (coloration adapted for concealment) and its habit of hiding in vegetation or cracks in mud, make it difficult to estimate the former historical range of this species. It is conceivable that the invasion of California's native grasslands by various introduced exotic plant species has adversely affected the delta green ground beetle by altering the vegetation structure of its habitat, shading, soil texture, the seasonal pattern of soil moisture, and perhaps most importantly, the types and abundance of its prey, during both adult and larval stages.

Current Distribution.—To date, the delta green ground beetle has only been found in the greater Jepson Prairie area in south-central Solano County, California (**Figure II-34**). Six occurrences are presumed extant and one is presumed extirpated (California Natural Diversity Database 2005). One of two sites where Dr. Fred Andrews collected the species in 1974 and 1975 was later diked and plowed, likely extirpating the species from that site. There have been unconfirmed reports of the delta green ground beetle from a wildlife preserve in the Sacramento Valley, in the general vicinity of the Sutter Buttes. We consider these reports unlikely at this time, but they merit investigation.

Figure II-33. Photograph of a delta green ground beetle (*Elaphrus viridis*) (© Dr. David H. Kavanaugh, reprinted with permission from the California Academy of Sciences)

c. Life History and Habitat

Life History.—Much about the life cycle of the delta green ground beetle remains a matter of speculation, based on observations of similar species or educated guesses from limited data. The delta green ground beetle is believed to produce one brood per year (H. Goulet pers. comm., D. Kavanaugh pers. comm.). Goulet (1983) speculated that adults emerge from diapause (a period of dormancy or delayed development) and females lay their eggs in early winter. From that point onward, other than occasional observations of larvae, the species largely disappears from view until active adults reappear the following winter.

Goulet's laboratory work on delta green ground beetles, using larvae collected in 1982, demonstrated seven stages in the life cycle: egg, three larval instars (stages in the development of insect larvae between molts), pre-pupa, pupa, and adult. In the laboratory, each stage prior to the adult takes about 5 to 7 days, for a total development time of about 35 to 45 days (Goulet 1983, U.S. Fish and Wildlife Service 1985*a)*. Adults presumably live for 9 to 12 months or longer.

Larvae of the delta green ground beetle are seldom seen due to their small size and perhaps also because they hide under dense vegetation or in cracks in the ground. It is also difficult to differentiate them from other ground beetle larvae in the field. Their vision appears to be good, and they respond to large moving objects by freezing in place (R. Arnold pers. comm., H. Goulet pers. comm., D. Kavanaugh pers. comm., L. Serpa pers. comm.). Like the adults, larvae appear to hunt mostly by sight. Based on their morphology, a few observations, and comparisons with related species, the larvae are almost certainly predaceous, feeding on other small invertebrates they encounter, including springtails (order Collembola) (L. Serpa pers. comm.). Kavanaugh speculates that, as the available habitat becomes dry, delta green ground beetle larvae crawl into cracks in the soil in preparation for pupation (D. Kavanaugh pers. comm.). Some carabid species are known to burrow as deep as 45 centimeters (18 inches) in hard clay soil to overwinter (Thiele 1977). Fissures, sometimes as deep as 38 to 44 centimeters (15 to 18 inches), form each year in the Jepson Prairie area as a result of the high clay-content soils drying and shrinking after the rains stop in late spring. According to Kavanaugh's hypothesis, pupation in the delta green ground beetle takes place deep in these cracks in the ground, and these individuals survive the hot, dry summer and fall as diapausing pupae.

Adult delta green ground beetles presumably emerge from pupation after the onset of winter rains. Adults are active during the winter-spring wet season, and are most commonly observed in February, March, and April. These diurnal beetles are most likely to be observed on sunny days when the temperature is between 17

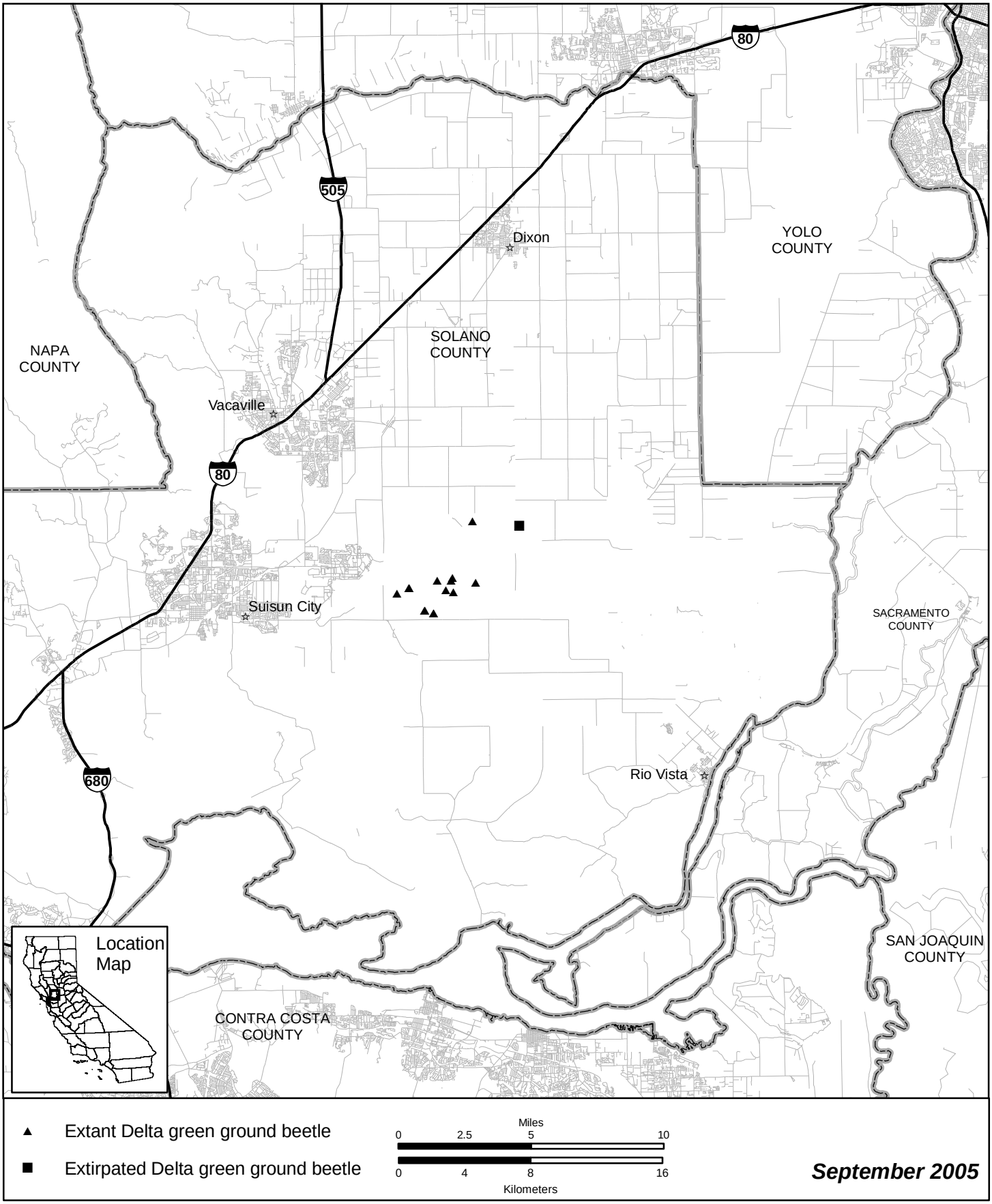

Figure II-34. Distribution of Delta green ground beetle (*Elaphrus viridis*).

and 21 degrees Celsius (62 and 70 degrees Fahrenheit), and the wind is less than 13 kilometers (8 miles) per hour (L. Serpa, pers. comm. 2004). Surviving individuals may enter another diapause, as adults, in late spring or early summer. Whether adults may live for more than 1 year is unknown.

The mechanism by which the delta green ground beetle encounters the opposite sex is important but poorly known. Work by Serpa suggests that males know when a female is in their vicinity, even when they can not see her. They seem to slow up and search more diligently, possibly using olfactory cues, but unless there is a direct sighting, the male will not find the female (L. Serpa *in litt*. 1997). Serpa (1985) observed six copulations that ranged from about 1 to 3 minutes in duration. A single female was observed to mate with one male once and another male twice during a 30-minute period. It is not known whether individuals discriminate on the basis of color pattern (spotted versus unspotted) in mating (L. Serpa *in litt*.1997). Based on observations of related species, both sexes may mate several times during their lifespan.

Little or nothing is known about the sites or requirements for egg-laying by the delta green ground beetle, its fecundity (reproductive output) or survivorship (probability of survival to various ages), details of larval habitat, ecology, behavior, prey, or sites or requirements for pupation (R. Arnold pers. comm., H. Goulet pers. comm., D. Kavanaugh pers. comm., L. Serpa pers. comm.). These gaps in our knowledge of the species and all of its life history stages constitute significant deficiencies, and seriously inhibit the planning and implementing of recovery actions for the species. Some of the additional research necessary to fill these gaps is discussed under Research Needs at the end of this account.

Goulet (1983) suggested that both larvae and adults of the delta green ground beetle are generalized predators able to eat many different kinds of prey. An important food source for the adults is springtails, although Serpa (1985) indicated that one common dark gray species may not be palatable to the delta green ground beetle. These very small, soft-bodied insects are often abundant in moist areas (L. Serpa pers. comm.). Terrestrial larvae of chironomid midges (Diptera: Chironomidae) may also be a food source for both larvae and adults (Goulet 1983, H. Goulet pers. comm.). When springtails are scarce, adult midges are apparently important prey items and the beetles catch ones that happen to crash-land nearby (L. Serpa *in litt*. 1997). Delta green ground beetles have also been observed feeding on a few other beetle larvae of undetermined species (L. Serpa *in litt*. 1997).

While dispersal is considered to be important for carabid beetles with low population densities (den Boer 1971) such as the delta green ground beetle (R. Arnold pers. comm., D. Kavanaugh pers. comm., L. Serpa pers. comm.), no

research has determined the extent or success of delta green ground beetle dispersal. Flying, rather than walking, would enable the species to locate widely distributed but localized complexes of vernal pools amidst grasslands. Goulet suggests that adult delta green ground beetles may be good fliers (H. Goulet pers. comm.), although the few observations of flight in the field have not strongly supported this view. In one observation, a delta green ground beetle that was released after being confined for photographing took five short flights of 8 centimeters (3 inches) or less over the period of an hour before it finally managed to fly out of the area (Serpa 1985). Before each flight attempt, it would orient its wing covers directly perpendicular to the sun, in an apparent attempt to increase its body temperature. It would then run rapidly up nearby 1- to 2.5-centimeter (0.4- to 1-inch) plants and take flight. On the sixth flight it obtained a height of 2 meters (6.5 feet) and had traveled a linear distance of about 5 meters (16 feet) before it was lost from sight in the glare of the sun. Additional evidence of flight comes from the discovery of one beetle drowning about 18 centimeters (7 inches) from shore, and the finding of several beetles in Olcott Lake that were 4, 7, and 35 meters (13, 23, and 115 feet) from shore. Another observation in the same general area noted a previously undisturbed individual seen flying a short distance (D. Kavanaugh pers. comm.). A third record occurred when an individual was observed after a section of cracked mud was lifted from the East Olcott Lake bed. The delta green ground beetle remained still for about 3 to 5 minutes, then walked about 5 centimeters (2 inches), raised its elytra slightly and flew away. Its flight was described as rather slow and lumbering, at a height of about 2.2 meters (7 feet) for a distance of about 15 meters (50 feet) (McGriff 1987, D. McGriff pers. comm.). Dispersal may occur only within a very restricted season, time of day (or night), or set of environmental conditions. No large migratory movements of the delta green ground beetle are known.

The delta green ground beetle has also been seen swimming on top of the water in Olcott Lake (R. Arnold pers. comm., L. Serpa pers. comm.), and moving through standing water in smaller pools that required short swimming bouts between emergent plants (L. Serpa *in litt*. 1997). Although swimming may not be very effective as a long-distance dispersal mechanism for these small beetles, it may be an important adaptation to the seasonally wet and hydrologically dynamic ecosystem of the Jepson Prairie.

Collection records since 1974 indicate that adults may be found from early February until mid-May, depending on the weather, but some have been seen as early as late fall (R. Arnold pers. comm.). While most carabids are nocturnal, the delta green ground beetle and *Elaphrus* in general are active during the daytime, with the earliest sightings around 7:40 a.m., and continue moving until after sunset (Serpa 1985). Observations by several researchers (R. Arnold pers. comm., L. Eng pers. comm., H. Goulet pers. comm.) suggest that activity may be

temperature- and wind-dependent. In February and March 1982, adults were active when ambient air temperature at 2 centimeters (0.6 inch) above ground was at least 23 degrees Celsius (73 degrees Fahrenheit). Most adults were observed during midday hours (11:00 am to 3:00 pm) when winds are typically minimal. However, Serpa has reported delta green ground beetle activity at lower temperatures (Serpa 1985). Activity periods of the larvae are not well known (R. Arnold pers. comm., H. Goulet pers. comm.).

Serpa (1985) observed golden-haired dung flies (*Scatophaga stercoraria*), a saldid bug (Hemiptera: Saldidae), and a crab spider (Thomisidae) attacking adults several times, but they always released the delta green ground beetles after a second or two of contact. Serpa speculated that shorebirds are not significant predators because delta green ground beetles freeze when they see large objects move, and are so cryptically colored that they are almost impossible to see when they are not moving. As in other carabids, the delta green ground beetle stridulates (produces noise by rubbing wings together), which may serve as additional defense when captured by shorebirds (Serpa 1985). California tiger salamanders might prey on the larvae of the delta green ground beetle.

Habitat.—The delta green ground beetle lives in areas of grassland interspersed with vernal pools including several larger vernal pools (sometimes called playa pools or vernal lakes), such as Olcott Lake. Such playa pools typically hold water for longer durations than smaller vernal pools, from the onset of the rainy season through mid-summer. In south-central Solano County where the species is found, these playa pools contain former marine or lacustrine clays, as classified in the Pescadero soil series. Other common soil series in the surrounding grasslands are Antioch, San Ysidro, and Solano (Bates 1977). Critical habitat for the delta green ground beetle has been designated, and is described in the Conservation Efforts section below.

The preferred microhabitat of the delta green ground beetle is not well understood. Researchers have usually found adults around the margins of vernal pools and in bare areas along trails and roadsides (U.S. Fish and Wildlife Service 1985*a)*, where individuals often hide in cracks in the mud and under low-growing vegetation such as *Erodium* sp. (filaree) (Arnold 1983) and *Navarretia leucocephala* ssp. *bakeri* (Baker's navarretia) (L. Serpa pers. comm., C. Witham, pers. comm.). Arnold speculates that *N. leucocephala* ssp. *bakeri* may be a good habitat indicator for the delta green ground beetle (R. Arnold pers. comm.). In 1985, over 200 delta green ground beetles were observed near Olcott Lake and other nearby vernal lakes or pools (L. Serpa, pers. comm. 2004). Over 80 percent of these individuals were within 1.5 meters (4.9 feet) of the water's edge where soil conditions were very moist and very low growing vegetation provided cover of 25 to 100 percent (Arnold 1989).

The extent to which the delta green ground beetle also uses the grasslands beyond the less vegetated areas where it is usually seen remains unknown. The cryptic coloration of the species against the brilliant green of the early spring grass, its small size, and hiding behavior all hinder detection of the animal in dense vegetation (Arnold 1983). The fact that individuals have occasionally been found along trails far from water suggests that they may range into the grassland. The delta green ground beetle's habitat may vary with the amount and frequency of rainfall. When the vernal pools become too full, the beetles are apparently pushed back away from the pool margins, and could then occur more widely in the grasslands surrounding Olcott Lake and the other pools. At high water, the remaining suitable habitat would include trails, road shoulders, and other areas of depauperate vegetation that were adequately dry. There might be a gradual retreat to the borders of the playa pools after the waters have receded (Arnold 1983, D. Kavanaugh pers. comm., L. Serpa pers. comm.). The delta green ground beetle's habitat requirements for oviposition, larval development, and pupation are almost completely unknown. In the absence of studies, it nevertheless appears likely that the grassland matrix surrounding suitable areas of vernal pools or playa pools has habitat value for the species.

Community Association.—The delta green ground beetle is found at the Jepson Prairie, which represents the best remaining example of native bunchgrass prairie in the Central Valley (Jepson Prairie Preserve Docent Program 1998). The 634-hectare (1,566-acre) Jepson Prairie Preserve, also known as the Dozier Trust, contains stands of *Nassella pulchra* (purple needlegrass), *Poa* spp. (bluegrass), and *Melica californica* (melic grass) in a mosaic of claypan vernal pools. Like many California grasslands today, aggressive introduced grasses and forbs including *Avena* spp. (wild oats), *Bromus* spp., *Hordeum* spp. (barley), *Lolium* spp. (ryegrass), and *Erodium* spp., dominate much of the Jepson Prairie (Jepson Prairie Preserve Docent Program 1998).

The greater Jepson Prairie supports a substantial number of rare and sensitive plants and animals including *Tuctoria mucronata*, *Neostapfia colusana*, conservancy fairy shrimp, and California clam shrimp (*Cyzicus californicus*) (Jepson Prairie Preserve Docent Program 1998). Habitat suitable for the delta green ground beetle is present on agricultural lands between Travis Air Force Base and Jepson Prairie Preserve, and the beetles are known to occur throughout this region (L. Serpa, pers. comm. 2004).

d. Reasons for Decline and Threats to Survival

Most species addressed in this recovery plan are threatened by similar factors because they occupy the same vernal pool ecosystems. These general threats, faced by all the covered species, are discussed in greater detail in the Introduction

section of this recovery plan. Additional, specific threats to delta green ground beetle are described below.

A significant concern is that, due to its extremely limited distribution and population, the delta green ground beetle is vulnerable to impacts on its habitat. The species presently occupies less than 2,800 hectares (7,000 acres) (L. Serpa, pers. comm.), and measured population densities of the species are perennially low (Arnold 1983, L. Serpa *in litt*. 1997). Population estimates of the species in the wild are difficult to obtain, but in total, less than a few hundred individuals have been recorded since their rediscovery in 1974, and only about 50 specimens are known from various entomology collections worldwide. Recently, numbers of delta green ground beetles appear somewhat lower than in previous years, although such a trend has not been statistically validated (L. Serpa *in litt*. 1997, L. Serpa pers. comm.). Changes in vegetation management, specifically the temporary removal of managed grazing, have been suggested as an explanation for the apparent decline.

Another continuing threat is related to natural gas exploration and production. Natural gas reserves occur in subterranean pockets in the Jepson Prairie area, and exploratory drilling for these reserves could pose a threat. In addition, such drilling may necessitate new roads and related infrastructure, resulting in other potential indirect impacts. Also, ditches operated in association with Olcott Lake may drain it too rapidly to support the preferred habitat for the beetle (L. Serpa *in litt*. 1997, L. Serpa pers. comm.). Small ditch systems such as this exist in many parts of the greater Jepson Prairie (L. Serpa pers. comm., R. Thorpe pers. comm., K. Williams pers. comm., C. Witham pers. comm.) and may pose continuing threats.

There is some evidence indicating that the absence of grazing can have negative effects on the delta green ground beetle. At Olcott Lake, the number of delta green ground beetles observed decreased after a fence was erected to exclude sheep from the southern margin of the lake (the sheep were excluded to abate the impacts that the sheep were having on the population of endangered *Neostapfia colusana* in Olcott Lake) (C. Witham pers. comm., R. Reiner pers. comm.). With the exclusion of sheep, the previously grazed margin of the southern shore now has become overgrown with nonnative plants (L. Serpa pers. comm., C. Witham pers. comm.). On adjacent land used by sheep, the springtail prey of the delta green ground beetle seem to be more plentiful, as does the beetle itself (L. Serpa *in litt*. 1997, L. Serpa pers. comm.).

The adverse consequences from a lack of grazing are clearly tied to the dominance of invasive nonnative plants in the greater Jepson Prairie ecosystem. Extensive growth of nonnative grasses and forbs, which is often accompanied by

development of a thatch of dead plant material on the ground and in the shallower portions of vernal pools, may threaten the delta green ground beetle because the thatch may inhibit its normal foraging and other behavior and affect the availability of prey.

Sheep grazing currently appears to be more compatible with delta green ground beetle populations than cattle grazing. Cattle tend to stand in and walk through shallow water in large numbers, and will churn and pockmark the margins of vernal and playa pools. Cattle also tend to create relatively steep, 15- to 30-centimeter (6- to 12-inch) high banks around the pools, altering the gentle muddy slope that the delta green ground beetle prefers (Serpa 1985). Sheep, in contrast, do not tend to stand or walk in water, and do not cause equivalent impacts to the pool margins (Serpa 1985, R. Arnold pers. comm., L. Serpa pers. comm.). However, the greater damage to the beetle microhabitat observed in cattle areas could also be due to a difference in soil type, since not all pools in cattle areas suffer this degradation (L. Serpa, pers. comm. 2004).

The maintenance and monitoring of fuel pipelines and electricity transmission lines are ongoing activities that may pose a threat to the delta green ground beetle. A Pacific Gas & Electric Company/Pacific Gas Transmission Company natural gas pipeline is buried along the western edge of the Jepson Prairie Preserve, and a pipeline expansion project was completed in 1992.

After the spring of 1997, erosion that was aggravated by the presence of a gas pipeline corridor required repair to prevent a drainage ditch from headcutting into a vernal pool and potentially draining it. High voltage electric transmission lines cross the greater Jepson Prairie in several locations, including lines that cross Olcott Lake, critical habitat, and the Jepson Prairie Preserve. Impacts to the delta green ground beetle from ongoing operations and maintenance activities and periodic replacement of the conductors (wires) are unknown. Future construction of new pipelines and electric transmission lines also may pose a threat to delta green ground beetles.

Illegal collecting poses a potential threat to delta green ground beetles. Beetle collecting is the pastime of a small but dedicated group of amateur and professional entomologists. Most of these collectors are conservation-minded, but a small minority collects obsessively or for financial gain without regard for law. The extent of illegal collecting of the delta green ground beetle is unknown, but the attractive appearance of the species and its rarity are likely to make it a target for unscrupulous collectors.

Sludge application could present a threat to delta green ground beetles. Solano County produces sludge at its wastewater treatment plants, and has recently

approved this material for use as a soil amendment/fertilizer in grasslands in Solano County. Certain restrictions on grazing and food production apply to treated sites. Private landowners between Travis Air Force Base and Jepson Prairie Preserve have proposed a setback of 30 meters (100 feet) from vernal pools for sludge applications in this area; however, the high concentration of vernal pools in this area may make this infeasible due to their close proximity (R. Scoonover pers. comm.). There is presently no requirement that sludge be disced into the ground after application, as in Yolo County. The nutrients in sludge are likely to aggravate problems with invasive nonnative plant growth due to increased availability of nutrients. Water quality concerns also may exist if sludge is applied to pasture lands with vernal pools (R. Scoonover pers. comm.). The addition of sludge would probably be extremely detrimental to the delta green ground beetle, since the beetle is only found in areas with low growing plants. The vegetation around the vernal pools would still be stimulated even with a much larger setback than the one proposed, and the higher and denser plants would make it much more difficult for the beetles to move about and catch their prey. In addition, until we know much more about the needs of the delta green ground beetle, the entire vernal pool grassland matrix within the beetle's range needs to be considered as habitat; protection of the vernal pools alone is insufficient (L. Serpa, pers. comm. 2004).

A final significant concern is the lack of basic life history information for the delta green ground beetle. With such a paucity of life history information, the species may be subject to threats we are unaware of, and the severity of impacts due to the threats discussed above are more or less unknown.

e. Conservation Efforts

The delta green ground beetle was proposed for federal listing on August 10, 1978, as a threatened species with critical habitat (U.S. Fish and Wildlife Service 1978*b*). On March 6, 1979, proposed critical habitat was withdrawn from consideration because of procedural and substantive changes made in 1978 amendments to the Endangered Species Act (U.S. Fish and Wildlife Service 1979). After rules for designation of critical habitat were promulgated (U.S. Fish and Wildlife Service 1980*c*), critical habitat for the species was reproposed (U.S. Fish and Wildlife Service 1980*b*). The delta green ground beetle was federally listed as a threatened species with designated critical habitat on August 8, 1980 (U.S. Fish and Wildlife Service 1980*a*). A recovery plan that included the delta green ground beetle was prepared and approved in 1985 (U.S. Fish and Wildlife Service 1985*a).* Internationally, the delta green ground beetle is listed as "vulnerable" by the International Union for the Conservation of Nature (1983).

Two areas in south-central Solano County, separated by 0.8 kilometer (0.5 mile) and totaling 385 hectares (960 acres), were designated as critical habitat for the delta green ground beetle. The primary constituent elements of this habitat considered to be essential to the conservation and survival of the delta green ground beetle are the vernal pools with their surrounding vegetation, and the land areas that surround and drain into these pools.

Habitat Protection.—On December 31, 1980, approximately 647 hectares (1,600 acres) of land was purchased by The Nature Conservancy from the Southern Pacific Railroad Company and named the Willis Linn Jepson Prairie Preserve, after the noted local botanist and author of the Jepson Manual for plant identification. In 1987, the Jepson Prairie Preserve was declared a National Natural Landmark. The Jepson Prairie Preserve became associated with ongoing research at the University of California at Davis (R. Cole *in litt.* 1983), and part of the University of California Natural Reserve System (formerly the Natural Land and Water Reserve System). The Jepson Prairie Preserve site is used for the study of representative samples of both widespread habitat types and distinctive ecosystems and features of special value for teaching and research, such as the native prairie bunchgrasses, vernal pools, and playa pools.

The Solano County Farmlands and Open Space Foundation took title to the Jepson Prairie Preserve from The Nature Conservancy on September 5, 1997. A revised conservation agreement is expected to be signed by the Solano County Farmlands and Open Space Foundation and the University of California's Natural Reserve System, which will jointly manage the Preserve (P. Muick pers. comm., R. Reiner pers. comm., R. Thorpe pers. comm.).

Next to the population on the Jepson Prairie Preserve, the most significant population of delta green ground beetles is found in playa pools on the western half of the Wilcox Ranch in Solano County (L. Serpa pers. comm. 2004). The beetle also occurs in the playa lakes on the eastern half of the Wilcox Ranch. The Nature Conservancy purchased the 1,178-hectare (2,912-acre) Wilcox Ranch in 2001 and sold the western half of the property (635 hectares [1,570 acres]) to Solano County in 2002. The eastern portion (543 hectares [1,342 acres]) of the ranch is being transferred to The Solano Land Trust and will be protected with a conservation easement (J. Marty pers. comm. 2004). The western portion of the property does not have a conservation easement on it, but the deed restricts development on the property except as needed for runway expansion at Travis AFB (J. Marty pers. comm. 2004). If runway expansion occurs, it would likely negatively impact the delta green ground beetle population.

A 23-hectare (57-acre) parcel at the western side of the B & J Landfill property (previously mentioned) serves as a delta green ground beetle mitigation site for a

previous B & J Landfill expansion. Currently there is one existing mitigation bank and several other banks are in the review process that potentially provide habitat for the delta green ground beetle. Two of these mitigation banks are adjacent to the Jepson Prairie Preserve. One such location includes the existing 65-hectare (160-acre) Campbell Ranch Compensation Bank located just northwest of the Jepson Prairie Preserve. No delta green ground beetles were observed on this site during surveys conducted in 1990 (Arnold 1990), 1994 (Geier and Geier Consulting, Inc. 1994), or 1999 (C. Witham pers. comm.). However, suitable habitat for this species may be present. A second property referred to as the Burke Ranch Potential Conservation Site encompasses over 567 hectares (1,400 acres). A 320-acre parcel located within the Burke Ranch Site is protected under a conservation easement as compensation for construction of the North Village development project near Vacaville in Solano County (U.S. Fish and Wildlife Service 2002b). No delta green ground beetle surveys have been conducted on this site; however, potential habitat exists on the site. The remainder of the Burke Ranch Site is under consideration for a preservation bank, mitigation bank, conservation easement or a combination of these strategies (C. Witham pers. comm.). The Burke Ranch Site is located about 1 kilometer (0.62 mile) northwest of the Jepson Prairie Preserve. During surveys conducted in 1999, seven delta green ground beetles were observed along the edge of a modified playa-type vernal pool on the Burke Ranch Site (C. Witham pers. comm.). Other land acquisitions for conservation are in process.

Habitat Management.—Efforts are underway to control invasive nonnative plants within the Jepson Prairie Preserve. Grazing, prescribed fire, and hand application of herbicides are some of the tools being investigated to help control nonnative plants (J. Meisler pers. comm., R. Thorpe pers. comm., C. Witham pers. comm., K. Williams pers. comm., Jepson Prairie Preserve Docent Program 1998).

Although the relationship between fire and the delta green ground beetle has not yet been established, the delta green ground beetle may prefer an open canopy habitat (Arnold 1983), and therefore, fire may improve its habitat. The literature suggests that fire, which kills certain plants and removes dead plant litter, favors some native plant species and disfavors some problematic nonnative plants. However, as stated previously, seasonal application of any disturbance regime should be considered with respect to native versus nonnative species. On the Jepson Prairie, late-spring burning appears to reduce thatch and nonnative annual grasses while promoting native grasses and forbs (Jepson Prairie Preserve Docent Program 1998). Prescribed burning has been conducted on Jepson Prairie Preserve for over a decade (B. Leitner *in litt*. 1984). Although the burns typically did not take place in habitat known to contain delta green ground beetles, it was viewed as a “neutral to beneficial” practice for maintenance of the sensitive

species and resources on the Preserve, including the delta green ground beetle and its habitat (R. Reiner pers. comm., L. Serpa pers. comm., C. Witham pers. comm.). Burns typically take place when the grasses have dried sufficiently. Thus, such burns may not adversely affect the species because it is inactive and presumably deep underground when burns occur (D. Kavanaugh pers. comm.). No quantitative data are available on the effects of prescribed burning on the species.

In 1997, the Solano County Farmlands and Open Space Foundation received a 3-year CalFed grant to restore riparian habitat along Barker Slough and Calhoun Cut, control nonnative plants, and enhance native plant species in grasslands (Jepson Prairie Preserve Docent Program 1998). Such restoration initiatives will likely benefit native species including the delta green ground beetle.

Research.—Relatively little research has been conducted on the delta green ground beetle. Most of the information available on the ecology of this species is a result of opportunistic observations. Through laboratory studies, Goulet (1983) documented aspects of the development of delta green ground beetles from the egg stage to adulthood. Systematic surveys, population monitoring, and demographic monitoring have not been conducted yet.

Arnold (1989) conducted an analysis of habitat features associated with delta green ground beetle observations. Habitat variables were measured at sites where delta green ground beetles were observed, and also at selected sites within four habitat types: vernal lakes, vernal pools, grasslands, and bare ground areas. Discriminant function analysis then was used to identify variables and habitats most associated with delta green ground beetle locations. In 1989, 13 delta green ground beetle localities were strongly associated with vernal lake habitat. Habitat variables most strongly associated with delta green ground beetle observations were *Navarretia* cover, proximity to water, *Frankenia* cover, *Downingia* cover, and soil type. Among the variables least associated were sheep dung concentrations and annual grass cover.

As indicated earlier, some research has been conducted on habitat management strategies in the Jepson Prairie Preserve. This research has not been conducted specifically for the delta green ground beetle, but instead is intended to help conserve a suite of native plant and animal species, including a number of rare ones. A primary goal of this research is the control of invasive exotic plant species (J. Meisler pers. comm.).

2. CONSERVANCY FAIRY SHRIMP *(BRANCHINECTA CONSERVATIO)*

a. Description and Taxonomy

Taxonomy.—The Conservancy fairy shrimp (*Branchinecta conservatio*) was described by Eng, Belk, and Eriksen (Eng *et al.* 1990). The type specimens were collected in 1982 at Olcott Lake, Solano County, California. The species name was chosen to honor The Nature Conservancy, an organization responsible for protecting and managing a number of vernal pool ecosystems in California, including several that support populations of this species.

Description and Identification.—Conservancy fairy shrimp look similar to other fairy shrimp species (**Box 1**- Appearance and Identification of Vernal Pool Crustaceans). Conservancy fairy shrimp are characterized by the distal segment of the male's second antennae, which is about 30 percent shorter than the basal segment, and its tip is bent medially about 90 degrees (Eng *et al.* 1990). The female brood pouch is fusiform (tapered at each end), typically extends to abdominal segment eight, and has a terminal opening (Eng *et al.* 1990). Males may be from 14 to 27 millimeters (0.6 to 1.1 inch) in length, and females have been measured between 14.5 and 23 millimeters (0.6 and 0.9 inch) long.

Conservancy fairy shrimp can be distinguished from the similar looking midvalley fairy shrimp (*Branchinecta mesovallensis*) by the shape of two humps on the distal segment of the male's second antennae (Belk and Fugate 2000). The midvalley fairy shrimp's antennae is bent such that the larger of the two humps is anterior (towards the head), whereas this same hump in the Conservancy fairy shrimp is posterior (towards the tail). Females of these two species differ in the shape of their brood pouches. The brood pouch of the midvalley fairy shrimp is pyriform (pear-shaped) and extends to below abdominal segments three and four, as opposed to segment eight in Conservancy fairy shrimp (Belk and Fugate 2000).

b. Historical and Current Distribution

Historical Distribution.—The historical distribution of the Conservancy fairy shrimp is not known. However, the distribution of vernal pool habitats in the areas where the Conservancy fairy shrimp is now known to occur were once more continuous and larger in area than they are today (Holland 1998). It is likely the Conservancy fairy shrimp once occupied suitable vernal pool habitats throughout a large portion of the Central Valley and southern coastal regions of California.

Box 1. Appearance and Identification of Vernal Pool Crustaceans

Most of the vernal pool crustacean species discussed in this draft recovery plan are similar in their general physiology and appearance. All 5 species of fairy shrimp, the Conservancy fairy shrimp (*Branchinecta conservatio*), longhorn fairy shrimp (*Branchinecta longiantenna*) vernal pool fairy shrimp (*Branchinecta lynchi*), midvalley fairy shrimp (*Branchinecta mesovallensis*), and California fairy shrimp (*Linderiella occidentalis*), have delicate elongate bodies, large stalked compound eyes, and 11 pairs of phyllopods, or swimming legs. Phyllopods (phyllo = leaf, poda = feet) also function as gills, absorbing dissolved oxygen as they are moved through the water (branchio = gill, poda = feet). Fairy shrimp use their phyllopods to swim or glide upside-down by means of complex, wavelike beating movements. Fairy shrimp do not have a hard shell, a characteristic of the order to which they belong, the **order Anostraca (**an = without, ostraca = hard plate or shell) .

Distinguishing one fairy shrimp species from another is difficult. Fairy shrimp identification is based upon recognition of tiny physical characteristics, many of which can only be seen with a microscope. Species generally are identified by characteristics of the male's antennae, and by the size and shape of the female's brood pouch. Eriksen and Belk (1999) developed a key to identify fairy shrimp species found in California. Although we describe some of the identifying characteristics of different fairy shrimp species in this draft recovery plan, successful identification generally requires formal training.

The vernal pool tadpole shrimp (*Lepidurus packardi*) is quite different in appearance from the fairy shrimp. This species is a member of the **order Notostraca** (noto = back, ostraca = shell), and possesses a hard shell. The shell is large, flattened, and arched over the back of the tadpole shrimp in a shield-like manner. This structure gives the tadpole shrimp its unique, tadpole-like appearance, which easily distinguishes it from the fairy shrimp.

Current Distribution.—The Conservancy fairy shrimp is known from a few isolated populations distributed over a large portion of California's Central Valley and in southern California (**Figure II-35**). In the Northeastern Sacramento Valley Vernal Pool Region (Keeler-Wolf *et al*. 1995), four populations are clustered around the Vina Plains area in Tehama and Butte Counties. Conservancy fairy shrimp populations are also found in the Solano-Colusa Vernal Pool Region on the greater Jepson Prairie area in Solano County, at the Sacramento National Wildlife Refuge in Glenn County, and in the Tule Ranch unit of the California Department of Fish and Game Yolo Basin Wildlife Area, in Yolo County. In the San Joaquin Valley Vernal Pool Region, Conservancy fairy shrimp are found in the Grasslands Ecological Area in Merced County, and at a single location in Stanislaus County. In the Southern Sierra Foothills Vernal Pool Region, the species is known from the Flying M Ranch, the Ichord Ranch, and the Virginia Smith Trust lands in eastern Merced County. The Conservancy fairy shrimp is found outside the Santa Barbara Vernal Pool Region at two locations on the Los Padres National Forest in Ventura County.

c. Life History and Habitat

Life History.—Like other species discussed in this recovery plan, the life history of the Conservancy fairy shrimp is uniquely adapted to the ephemeral conditions of its vernal pool habitat. Helm (1998) found that the life span and maturation rate of the Conservancy fairy shrimp did not differ significantly from other fairy shrimp species under the conditions he observed. Helm (1998) found that Conservancy fairy shrimp reached maturity in an average of 46 days, and lived for as long as 154 days. However, aquatic invertebrate growth rates are largely controlled by water temperature and can vary greatly (Eriksen and Brown 1980, Helm 1998). Conservancy fairy shrimp produce one large cohort of offspring each wet season (Eriksen and Belk 1999).

Habitat.—The Conservancy fairy shrimp occurs in vernal pools found on several different landforms, geologic formations and soil types. At the Vina Plains in Tehama County, the species occurs in pools formed on Peters Clay soil on the volcanic Tuscan Formation. At Jepson Prairie, the Conservancy fairy shrimp is found in large playa-like depressions on deep alluvial soils of Pescadero Clay Loam on Basin Rim landforms. Vernal pools that contain Conservancy fairy shrimp in the Los Padres National Forest tend to occupy atypical habitat settings that are located under a pine forest canopy instead of an annual grassland. They have been observed in vernal pools ranging in size from 30 to 356,253 square meters (323 to 3,834,675 square feet) (Helm 1998). Observations suggest this species often is found in pools that are relatively large, and turbid (King *et al.* 1996, Helm 1998, Eriksen and Belk 1999). Helm (1998) found the mean size of pools supporting this species to be 27,865 square meters (299,936 square feet),

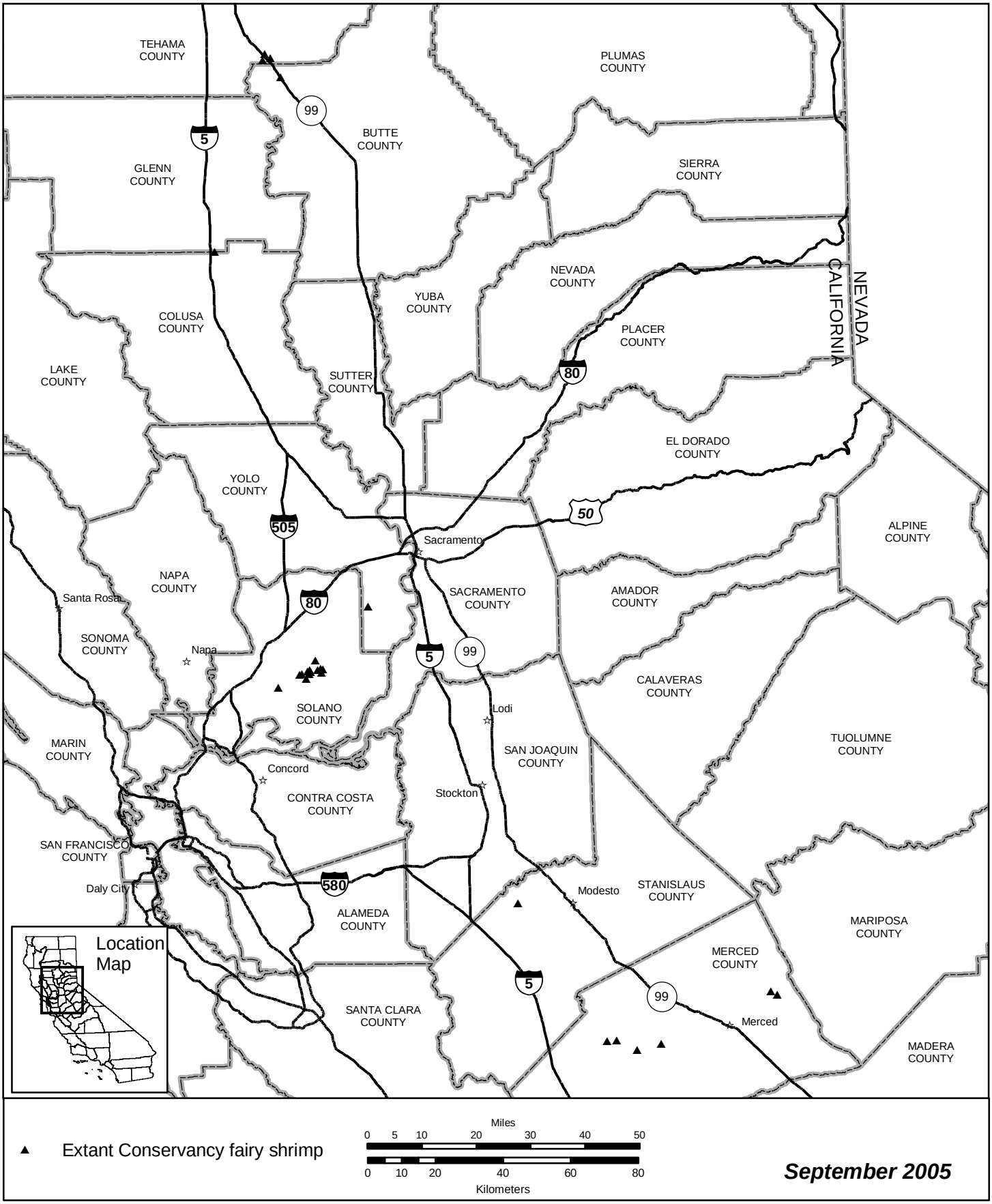

Figure II-35. Distribution of Conservancy fairy shrimp (*Branchinecta conservatio*).

much larger than the average mean size of all other species he observed. Syrdahl (1993) found positive correlations between Conservancy fairy shrimp occurrence and large pool surface areas. The species has been found at sites that are low in alkalinity (16 to 47 parts per million) and total dissolved solids (20 to 60 parts per million), with pH near 7 (Barclay and Knight 1981, Syrdahl 1993, Eriksen and Belk 1999). Conservancy fairy shrimp have been found at elevations ranging from 5 to 1,700 meters (16 to 5,577 feet) (Eriksen and Belk 1999), and at water temperatures as high as 23 degrees Celsius (73 degrees Fahrenheit) (Syrdahl 1993).

Community Associations.—Conservancy fairy shrimp co-occur with several other vernal pool crustacean species addressed in this recovery plan, including the vernal pool fairy shrimp, the California fairy shrimp, and the vernal pool tadpole shrimp (King *et al.* 1996, Helm 1998, Eriksen and Belk 1999). These species may all be found in one general location, however, they have rarely been collected from the same pool at the same time (Eriksen and Belk 1999). In general, Conservancy fairy shrimp have very large populations within a given pool, and is usually the most abundant fairy shrimp when more than one species is present (Helm 1998, Eriksen and Belk 1999). The Conservancy fairy shrimp is a prey species for the vernal pool tadpole shrimp (Alexander and Schlising 1997), as well as a variety of insect and vertebrate predator species. The Conservancy fairy shrimp also co-occurs with several plants found in large vernal pools addressed in this recovery plan, including *Neostapfia colusana* and various *Orcuttia* species.

d. Reasons for Decline and Threats to Survival

Most species addressed in this recovery plan are threatened by similar factors because they occupy the same vernal pool ecosystems. These general threats, faced by all the covered species, are discussed in greater detail in the Introduction section of this recovery plan. Additional, specific threats to Conservancy fairy shrimp are described below.

In the Northeastern Sacramento Vernal Pool Region, Conservancy fairy shrimp are threatened by highway expansion on Caltrans land where they occur in Butte County. In the Solano-Colusa region, Conservancy fairy shrimp populations are protected from development on some locations at the Jepson Prairie Preserve, however, specific management and monitoring for the species is not currently conducted at these sites. Additional occurrences of the species on private land in this region are threatened by development, particularly in the rapidly urbanizing areas of Fairfield and Vacaville. In the Southern Sierra Foothills region, the

species is known from the Flying M Ranch, on University of California lands, and on the Ichord Ranch where it is currently threatened by indirect and cumulative effects associated with the development of the University of California, Merced campus.

e. Conservation Efforts

On September 19, 1994, the final rule to list the Conservancy fairy shrimp as endangered was published in the *Federal Register* (U.S. Fish and Wildlife Service 1994*a)*. In 2005, critical habitat was designated for the Conservancy fairy shrimp and several other vernal pool species in *Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon; Evaluation of Economic Exclusions From August 2003 Final Designation; Final Rule* (U.S. Fish and Wildlife Service 2005).

Within the Northeastern Sacramento Vernal Pool Region, the Conservancy fairy shrimp is protected at the Vina Plains preserve owned by the Nature Conservancy. In the Solano-Colusa Vernal Pool Region the Conservancy fairy shrimp is protected on lands within the Jepson Prairie Ecosystem, including the Burke Ranch and the Jepson Prairie Preserve owned by the Solano County Open Space and Farmland Conservancy and jointly managed by the University of California Reserve System at the Sacramento National Wildlife Refuge in Glenn County and in the Tule Ranch unit of the California Department of Fish and Game Yolo Basin Wildlife Area, in Yolo County. In the San Joaquin Vernal Pool Region, Conservancy fairy shrimp populations are protected at Grasslands Ecological Area on State and federally owned lands, and on the Arena Plains National Wildlife Refuge and the San Luis National Wildlife Refuge in Merced County (California Natural Diversity Database 2005). Although Conservancy fairy shrimp populations are protected from development on these locations, specific management and monitoring for the species may not be currently conducted at these sites.

3. LONGHORN FAIRY SHRIMP (*BRANCHINECTA LONGIANTENNA*)

a. Description and Taxonomy

Taxonomy.—The longhorn fairy shrimp (*Branchinecta longiantenna*) was first collected in 1937, but was not formally described until 1990 (Eng *et al.* 1990). The longhorn fairy shrimp is named for its relatively long antennae. The type specimen was collected from a sandstone outcrop pool on the Souza Ranch in Contra Costa County, California.

Description and Identification.—Although longhorn fairy shrimp generally look similar to other fairy shrimp species (see **Box 1**- Appearance and Identification of Vernal Pool Crustaceans), this species is easily identified by the male's very long second antennae, which is about twice as long, relative to its body, as the second antennae of other species of *Branchinecta.* Longhorn fairy shrimp antennae range from 6.7 to 10.4 millimeters (0.3 to 0.4 inch) in length (Eriksen and Belk 1999). Females can be recognized by their cylindrical brood pouch, which extends to below abdominal segments six or seven. Mature males have been measured between 12 and 21 millimeters (0.5 to 0.8 inch) in length, and females range from 13.3 to 19.8 millimeters (0.5 to 0.8 inch) in length (Eng *et al.* 1990).

Longhorn fairy shrimp are easily distinguished from other fairy shrimp by the male's extremely long second antennae (Eng *et al.* 1990). Female longhorn fairy shrimp may be confused with alkali fairy shrimp (*Branchinecta mackini*), but there are no dorsal outgrowths on the thoracic segments of longhorn fairy shrimp females, while these structures are present in alkali fairy shrimp females (Eng *et al.* 1990).

b. Historical and Current Distribution

Historical Distribution.—The distribution of the longhorn fairy shrimp may never have extended into the northern portion of the Central Valley or into southern California. Extensive surveying of vernal pool habitats in southern California has never revealed populations of longhorn fairy shrimp. There is some evidence that temperatures may not be warm enough for the species to mature in the northern portions of the Central Valley. However, it is likely the longhorn fairy shrimp was once more widespread in the regions where it is currently known to occur, and in adjacent areas such as the San Joaquin and Southern Sierra Foothill Vernal Pool Regions, where habitat loss has been extensive.

Current Distribution.—Longhorn fairy shrimp are extremely rare. The longhorn fairy shrimp is known from only a small number of widely separated populations (**Figure II-36**). Sugnet (1993) found only 3 occurrences of the longhorn fairy shrimp out of 3,092 locations surveyed, and Helm (1998) found longhorn fairy shrimp in only 9 of 4,008 wetlands sampled. Longhorn fairy shrimp are currently found in pools located within a matrix of alkali sink and alkali scrub plant communities north and northwest of Soda Lake and at the southern end of the Carrizo Plain National Monument in the Carrizo Vernal Pool Region, in a series of sandstone outcrop pools in the Livermore Vernal Pool Region, and from alkaline grassland vernal pools at the Kesterson National Wildlife Refuge and a roadside ditch located two miles north of Los Banos in the

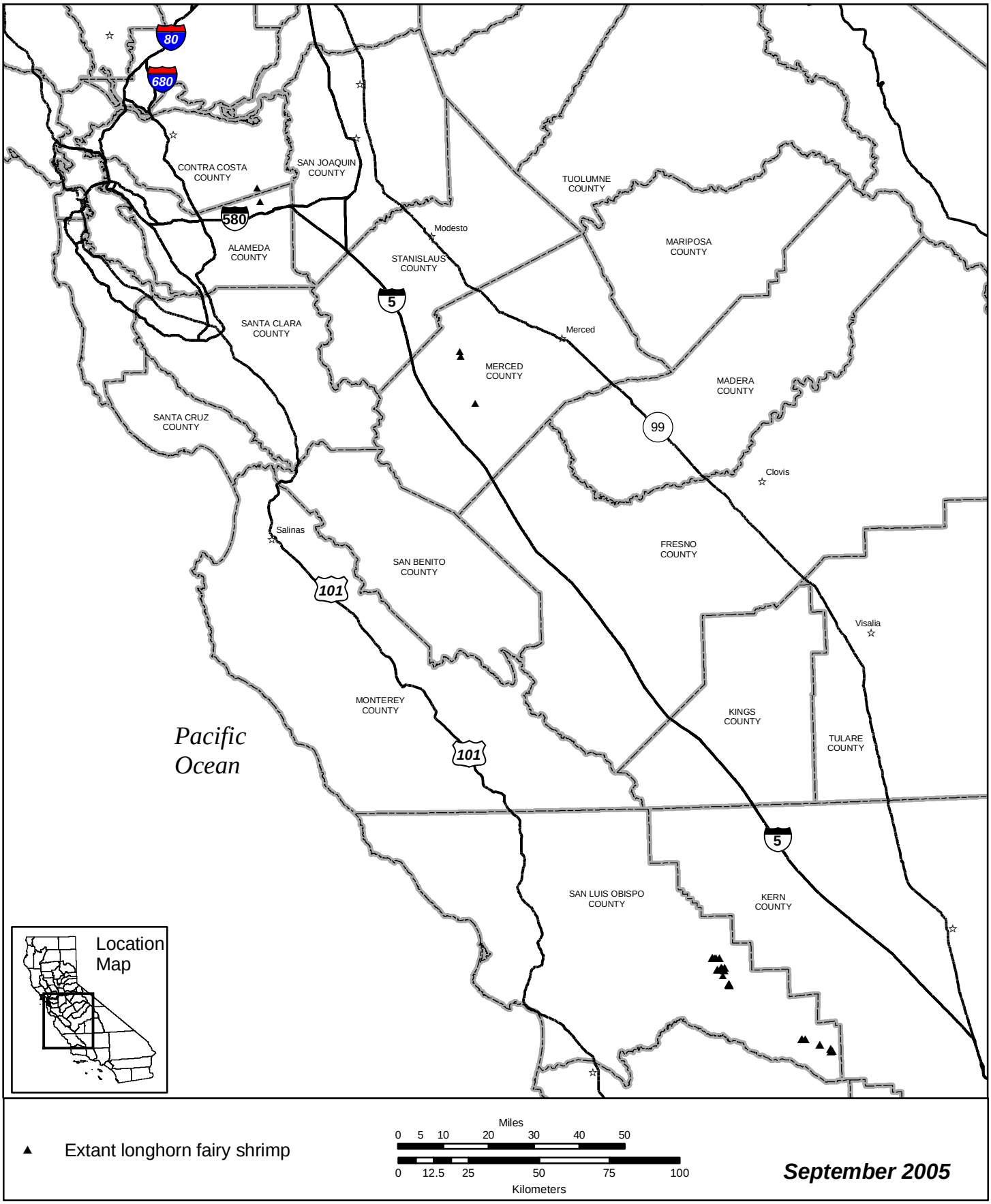

Figure II-36. Distribution of longhorn fairy shrimp (*Branchinecta longiantenna*).

San Joaquin Vernal Pool Region. Lack of surveys throughout much of the San Joaquin valley and in areas between the Carrizo and the Livermore Vernal Pool Regions suggests there may be additional, undiscovered populations of this species. Until research addressing the tolerance of longhorn fairy shrimp to cooler temperatures has been conducted, its presence in northern Central Valley vernal pool regions cannot be ruled out.

c. Life History and Habitat

Life History.—The longhorn fairy shrimp is highly adapted to the unpredictable conditions of vernal pool ecosystems. Longhorn fairy shrimp required a minimum of 23 days, but averaged 43 days, to reach maturity in artificial pools described by Helm (1998). However, Helm (1998) found no significant differences between the life span or reproductive rate of the longhorn fairy shrimp and other species of fairy shrimp he studied.

Habitat.—Although the longhorn fairy shrimp is only known from a few locations, these sites contain very different types of vernal pool habitats. Longhorn fairy shrimp in the Livermore Vernal Pool Region in Contra Costa and Alameda Counties live in small, clear, sandstone outcrop vernal pools. These sandstone pools are sometimes no larger than 1 meter (3.3 feet) in diameter (Eng *et al.* 1990), have a pH near neutral, and very low alkalinity and conductivity (Eriksen and Belk 1999). Water temperatures in these vernal pools have been measured between 10 and 18 degrees Celsius (50 and 64 degrees Fahrenheit). In both the San Joaquin and Carrizo Vernal Pool Regions, the longhorn fairy shrimp is found in clear to turbid, grassland pools (Helm 1998, Eriksen and Belk 1999). These grassland pools may be as large as 62 meters (203.4 feet) in diameter (Eng *et al.* 1990). Water temperatures in the grassland vernal pools are also warmer, between 10 and 28 degrees Celsius (50 to 82 degrees Fahrenheit). The species was most recently observed in a disturbed roadside ditch 2 miles north of Los Banos (California Natural Diversity Data Base 2003). Longhorn fairy shrimp have been found at elevations ranging from 23 meters (75.5 feet) in the San Joaquin Vernal Pool Region to 880 meters (2,887 feet) in the Carrizo Vernal Pool Region.

Community Associations.—The longhorn fairy shrimp has been found in the same general area as the Conservancy fairy shrimp, vernal pool fairy shrimp, California fairy shrimp, versatile fairy shrimp (*Branchinecta lindahli*) and spadefoot toad *(Spea hammondii*) tadpoles at different locations (Eng *et al.* 1990, Eriksen and Belk 1999, J. Darren *in litt*. 2005). Active adult longhorn fairy shrimp have been observed from the same vernal pool as versatile fairy shrimp and spadefoot toad tadpoles on the Carrizo Plain.

d. Reasons for Decline and Threats to Survival

Most species addressed in this recovery plan are threatened by similar factors because they occupy the same vernal pool ecosystems. These general threats, faced by all the covered species, are discussed in greater detail in the Introduction section of this recovery plan. Additional, specific threats to longhorn fairy shrimp are described below.

In the Carrizo Vernal Pool Region, longhorn fairy shrimp habitat near Soda Lake is threatened by activities associated with the occasional placement of a trailer on a parcel and the construction of the associated dirt access road (J. Darren BLM, *in litt.*, 2005). In the Livermore Vernal Pool Region, longhorn fairy shrimp occurrences in the Altamont Pass area in Contra Costa and Alameda Counties may be threatened by ongoing and future wind energy developments (Eng *et al.* 1990). The Souza Ranch area in Contra Costa County is also threatened by wind energy and water storage projects (Eng *et al.* 1990). In the San Joaquin Vernal Pool Region, the longhorn fairy shrimp is protected from development on the Kesterson Unit of San Luis National Wildlife Refuge; however, there are no management guidelines explicitly addressing management of longhorn fairy shrimp at the refuge.

e. Conservation Efforts

On September 19, 1994, the final rule to list the longhorn fairy shrimp as endangered was published in the *Federal Register* (U.S. Fish and Wildlife Service 1994*a)*. In 2005, critical habitat was designated for the longhorn fairy shrimp and several other vernal pool species in *Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon; Evaluation of Economic Exclusions From August 2003 Final Designation; Final Rule* (U.S. Fish and Wildlife Service 2005).

Although there has been a significant amount of research addressing vernal pool habitats, few studies have addressed longhorn fairy shrimp specifically. The longhorn fairy shrimp is difficult to study because of its rarity. Most of what is known about the species is described in Helm (1998), Eriksen and Belk (1999), and Eng *et al.* (1990). Factors that limit the distribution of this species have been suggested in the literature, but have yet to be tested.

In the Carrizo Vernal Pool Region, vernal pool habitat supporting the longhorn fairy shrimp has been protected on the Carrizo National Monument. Longhorn

fairy shrimp populations are regularly monitored by Bureau of Land Management staff. In the San Joaquin Vernal Pool Region, vernal pool habitats occupied by the longhorn fairy shrimp are protected at the Kesterson National Wildlife Refuge.

4. VERNAL POOL FAIRY SHRIMP (*BRANCHINECTA LYNCHI*)

a. Description and Taxonomy

Taxonomy.—The vernal pool fairy shrimp (*Branchinecta lynchi*) was first described by Eng, Belk and Eriksen (Eng *et al.* 1990). The species was named in honor of James B. Lynch, a systematist of North American fairy shrimp. The type specimen was collected in 1982 at Souza Ranch, Contra Costa County, California. Although not yet described, the vernal pool fairy shrimp had been collected as early as 1941, when it was identified as the Colorado fairy shrimp by Linder (1941).

Description and Identification.—Although most species of fairy shrimp look generally similar (see **Box 1**- Appearance and Identification of Vernal Pool Crustaceans), vernal pool fairy shrimp are characterized by the presence and size of several mounds (see identification section below) on the male's second antennae, and by the female's short, pyriform brood pouch. Vernal pool fairy shrimp vary in size, ranging from 11 to 25 millimeters (0.4 to 1.0 inch) in length (Eng *et al.* 1990). Vernal pool fairy shrimp closely resemble Colorado fairy shrimp (*Branchinecta coloradensis*) (Eng *et al.* 1990). However, there are differences in the shape of a small mound-like feature located at the base of the male's antennae, called the pulvillus. The Colorado fairy shrimp has a round pulvillus, while the vernal pool fairy shrimp's pulvillus is elongate. The vernal pool fairy shrimp can also be identified by the shape of a bulge on the distal, or more distant end, of the antennae. This bulge is smaller and less spiny on the vernal pool fairy shrimp. The female Colorado fairy shrimp's brood pouch is longer and more cylindrical than the vernal pool fairy shrimp's. Female vernal pool fairy shrimp also closely resemble female midvalley fairy shrimp. These two species can be distinguished by the number and placement of lobes on their backs, called dorsolateral thoracic protuberances. Vernal pool fairy shrimp have paired dorsolateral thoracic protuberances on the third thoracic segment that are lacking in the midvalley fairy shrimp (Belk and Fugate 2000).

b. Historical and Current Distribution

Historical Distribution.—The vernal pool fairy shrimp was identified relatively recently, in 1990, and there is little information on the historical range of the species. However, the vernal pool fairy shrimp is currently known to occur

in a wide range of vernal pool habitats in the southern and Central Valley areas of California, and in two vernal pool habitats within the "Agate Desert" area of Jackson County, Oregon. The vegetation and land use in its Oregon range are similar to those of northern California's inland valleys.

It is likely the historical distribution of this species coincides with the historical distribution of vernal pools in California's Central Valley and southern Oregon (**Figure II-37**). Holland (1978) estimated that roughly 1,618,700 hectares (4,000,000 acres) of vernal pool habitat existed in the Central Valley prior to the widespread agricultural development that began in the mid-1800s. He found that although the current and historical distribution of vernal pools is similar, vernal pools are now far more fragmented and isolated from each other than during historical times and currently occupy only about 25 percent of their former land area (Holland 1998). The current distribution of the vernal pool fairy shrimp in the Central Valley may be similar to its historical distribution in extent, but remaining populations are now considerably more fragmented and isolated than in pre-agricultural times.

The historical distribution of the vernal pool fairy shrimp in the Central Coast, Carrizo, and Santa Barbara Vernal Pool Regions is not known. The historical distribution of the vernal pool fairy shrimp in southern California may also have been similar to the historical distribution of its vernal pool habitat. Unlike the Central Valley, where vernal pool habitats were historically widespread, vernal pools in southern California were probably always limited in area and extent. Even so, vernal pool habitats in this area were once far more extensive than they are today (Bauder and McMillan 1998, Mattoni and Longcore 1998). In Los Angeles County, the coastal prairie and associated vernal pools may have historically occupied as much as 9,308 hectares (23,000 acres) (Mattoni *et al.* 1997). Vernal pools in San Diego County probably covered 51,800 hectares (128,000 acres) prior to intensive agriculture and urbanization (Bauder and McMillan 1998). The vernal pool fairy shrimp was likely historically present in available vernal pool habitats in Riverside, Los Angeles, Ventura, and Orange Counties. However, vernal pool fairy shrimp are currently absent from San Diego County, despite the presence of vernal pool habitats there. It is possible the vernal pool fairy shrimp is absent from the San Diego Vernal Pool Region as a result of competition with other species, such as the San Diego fairy shrimp. However, this hypothesis has not been formally tested.

Vernal pool habitats in the Agate Desert of southern Oregon historically occupied approximately 12,950 hectares (32,000 acres) (Oregon Natural Heritage Program 1997). The Agate Desert is located in the Rogue/Illinois River Valley region of the Klamath Mountains ecoregion. This area may have also constituted the historical range of the vernal pool fairy shrimp in this region. However, because

Figure II-37. Distribution of vernal pool fairy shrimp (*Branchinecta lynch*i).

the presence of vernal pool fairy shrimp was first documented in 1998, it is possible that additional locations for the species will be found in Oregon in the future.

Current Distribution.—The vernal pool fairy shrimp is currently found in 28 counties across the Central Valley and coast ranges of California, and in Jackson County of southern Oregon. The species occupies a variety of vernal pool habitats, and occurs in 11 of the 17 vernal pool regions identified in California (Keeler-Wolf *et.al*. 1998). Although the vernal pool fairy shrimp is distributed more widely than most other fairy shrimp species covered in this recovery plan, it is generally uncommon throughout its range, and rarely abundant where it does occur (Eng *et al.* 1990, Eriksen and Belk 1999). Helm (1998) found vernal pool fairy shrimp in only 16 percent of pools sampled across 27 counties, and Sugnet (1993) found this species in only 5 percent of 3,092 locations sampled.

The Agate Desert of southern Oregon comprises the northern extent of the range of the vernal pool fairy shrimp. Here, vernal pool fairy shrimp are known from the vernal pools within the Agate-Winlo soils of the Agate Desert landform and the Randcore-Shoat soils underlain by lava bedrock on top of Upper and Lower Table Rocks (Helm and Fields 1998). In California, the vernal pool fairy shrimp occurs on the Thomes Creek Ecological Reserve and the Stillwater Plains preservation bank in Tehama County, and at isolated locations in Glenn and Shasta Counties in the Northwestern Sacramento Valley Vernal Pool Region. In the Northeastern Sacramento Valley Vernal Pool Region, the species occurs in the vicinity of Vina plains and the City of Chico in Tehama and Butte Counties, respectively. The greatest number of known occurrences of the vernal pool fairy shrimp are found in the Southeastern Sacramento Vernal Pool Region, where it is found in scattered vernal pool habitats in Placer, Sacramento, and San Joaquin Counties, in the vicinity of Beale Air Force Base in Yuba County, and at a single location in El Dorado County. In the Solano-Colusa Vernal Pool Region, the vernal pool fairy shrimp is known from the vicinity of Jepson Prairie, and the cities of Vacaville and Dixon in Solano County. In the San Joaquin Valley Vernal Pool Region, the vernal pool fairy shrimp is found at the Grasslands Ecological Area in Merced County, at the Pixley National Wildlife Refuge in Tulare County, and at isolated locations in Kings and Stanislaus Counties. In the Southern Sierra Foothills Vernal Pool Region, the vernal pool fairy shrimp is known from the Stone Corral Ecological Reserve and the Hogwallow Preserve in Tulare County and from scattered locations on private land in Stanislaus, San Joaquin, Fresno, Madera, and Merced Counties.

The vernal pool fairy shrimp is also found in isolated patches along the central and southern Coast Range of California. In the Livermore Vernal Pool Region,

the vernal pool fairy shrimp has been found in the Springtown area and in the vicinity of Byron Airport in Alameda and Contra Costa Counties respectively. In the Central Coast region the species has been found in a minimum of 55 wetland pools at Fort Hunter Liggett in Monterey County; at two locations in San Benito County; and at one site 2.5 miles east of the City of Paso Robles. The vernal pool fairy shrimp occurs at a single location in Napa County in the Lake-Napa Vernal Pool Region. In the Carrizo Vernal Pool Region, the vernal pool fairy shrimp has been found in a minimum of 61 pools at Camp Roberts and in the vicinity of Soda Lake on the Carrizo Plain in San Luis Obispo County. In the Santa Barbara Vernal Pool Region, the vernal pool fairy shrimp has been found in Cachuma Canyon in Santa Barbara County, in the Carlsberg vernal pools in Ventura County, and in the Cruzan Mesa vernal pools in Los Angeles County. Vernal pool fairy shrimp have also been found at two locations within the Los Padres National Forest in Ventura County, outside the Santa Barbara Vernal Pool Region. In the Western Riverside County Vernal Pool Region, the species is known to occur at Skunk Hollow and on the Santa Rosa Plateau.

c. Life History and Habitat

Life History.—Vernal pool fairy shrimp are highly adapted to the environmental conditions of their ephemeral habitats. One adaptation is the ability of the vernal pool fairy shrimp eggs, or cysts, to remain dormant in the soil when their vernal pool habitats are dry. Another important adaptation is that the vernal pool fairy shrimp has a relatively short life span, allowing it to hatch, mature to adulthood, and reproduce during the short time period when vernal pools contain water. The vernal pool fairy shrimp can reach sexual maturity in as few as 18 days at optimal conditions of 20 degrees Celsius (68 degrees Fahrenheit), and can complete its life cycle in as little as 9 weeks (Gallagher 1996, Helm 1998). However, maturation and reproduction rates of vernal pool crustaceans are controlled by water temperature and can vary greatly (Eriksen and Brown 1980, Helm 1998). Helm (1998) observed that vernal pool fairy shrimp did not reach maturity until 41 days at water temperatures of 15 degrees Celsius (59 degrees Fahrenheit). Helm (1998) observed six separate hatches of vernal pool fairy shrimp in a single pool within a single wet season, and Gallagher (1996) observed three separate hatches of vernal pool fairy shrimp in vernal pools in Butte County. Helm (1998) found the mean life span of the vernal pool fairy shrimp was significantly shorter than the California fairy shrimp, but not significantly different from midvalley, longhorn, or Conservancy fairy shrimp observed under the same conditions. In larger pools that hold water for longer durations, vernal pool fairy shrimp are capable of hatching multiple times if water temperatures drop to below 10 degrees Celsius (50 degrees Fahrenheit), a necessary environmental cue for vernal pool fairy shrimp cyst hatching

(Gallagher 1996, Helm 1998). Helm (1998) observed vernal pool fairy shrimp living for as long as 147 days.

Habitat.—Vernal pool fairy shrimp exist only in vernal pools or vernal pool-like habitats. Individuals have never been found in riverine, marine, or other permanent bodies of water. Vernal pool habitats form in depressions above an impervious soil layer or duripan. Due to local topography and geology, the depressions are part of an undulating landscape, where soil mounds are interspersed with basins, swales, and drainages. Water movement within complexes allows vernal pool fairy shrimp to move between individual pools. These movement patterns, as well as genetic evidence, indicate that vernal pool fairy shrimp populations exist within and are defined by entire vernal pool complexes, rather than individual vernal pools (Simovich *et al.* 1992, King, *et al.* 1996).

The vernal pool fairy shrimp occupies a variety of different vernal pool habitats, from small, clear, sandstone rock pools to large, turbid, alkaline, grassland valley floor pools (Eng *et al.* 1990, Helm 1998). Although the vernal pool fairy shrimp has been collected from large vernal pools, including one exceeding 10 hectares (25 acres) in area (Eriksen and Belk 1999), it tends to occur primarily in smaller pools (Platenkamp1998), and is most frequently found in pools measuring less than 0.02 hectare (0.05 acre) in area (Gallagher 1996, Helm 1998). The vernal pool fairy shrimp typically occurs at elevations from 10 meters (33 feet) to 1,220 meters (4,003 feet) (Eng *et al.* 1990), although two sites in the Los Padres National Forest have been found to contain the species at an elevation of 1,700 meters (5,600 feet). The vernal pool fairy shrimp has been collected at water temperatures as low as 4.5 degrees Celsius (40 degrees Fahrenheit) (Eriksen and Belk 1999), and has not been found in water temperatures above about 23 degrees Celsius (73 degrees Fahrenheit) (Helm 1998, Eriksen and Belk 1999). The species is typically found in pools with low to moderate amounts of salinity or total dissolved solids (Collie and Lathrop 1976, Keeley 1984, Syrdahl 1993). Vernal pools are mostly rain fed, resulting in low nutrient levels and dramatic daily fluctuations in pH, dissolved oxygen, and carbon dioxide (Keeley and Zedler 1998). Although there are many observations of the environmental conditions where vernal pool fairy shrimp have been found, there have been no experimental studies investigating the specific habitat requirements of this species. Platenkamp (1998) found no significant differences in vernal pool fairy shrimp distribution between four different geomorphic surfaces studied at Beale Air Force Base.

In Oregon, the vernal pool fairy shrimp is found in two distinct vernal pool habitats (Helm and Fields 1998). The species occurs on alluvial fan terraces associated with Agate-Winlo soils on the Agate Desert, and in the Table Rocks

area on Randcore-Shoat soils underlain by lava bedrock. These vernal pool habitats represent the northern extent of Mediterranean vernal pools addressed in this recovery plan, and the northern extent of the range of the vernal pool fairy shrimp.

In the Western Riverside County and Santa Barbara vernal pool regions, the vernal pool fairy shrimp occurs on inland mesas and valleys, on weak to strongly alkaline soils. In the Los Padres National Forest in Ventura County, it is known to occur in atypical habitats that consist of vernal pools located under a *Pinus jeffreyi* (Jeffrey pine)canopy that does not possess a grass understory.

Community Associations.—The vernal pool fairy shrimp occupies the same vernal pool habitats as many of the other species addressed in this recovery plan. Plant species that have been found in the same vernal pool habitats as the vernal pool fairy shrimp include *Astragalus tener* var. *tener, Atriplex persistens, Castilleja campestris* ssp. *succulenta, Chamaesyce hooveri, Eryngium spinosepalum, Gratiola heterosepala, Legenere limosa, Limnanthes floccosa* ssp. *californica, Neostapfia colusana*, all of the *Orcuttia* species, and *Tuctoria greenei*. In Oregon, the vernal pool fairy shrimp is found in the same vernal pool habitats as two listed vernal pool plants, *Lomatium cookii* (Cook's lomatium) and *Limnanthes floccosa* ssp. *grandiflora* (large-flowered woolly meadowfoam). The vernal pool fairy shrimp occupies the same vernal pool habitats as the delta green ground beetle.

The vernal pool fairy shrimp has been found in the same vernal pool habitats as all of the other vernal pool crustaceans described in this recovery plan: the vernal pool tadpole shrimp, California fairy shrimp, the Conservancy fairy shrimp, the longhorn fairy shrimp, and the midvalley fairy shrimp. In Southern California, vernal pool fairy shrimp have been found to co-occur with the Riverside fairy shrimp (*Streptocephalus woottoni*), federally listed as endangered . However, the vernal pool fairy shrimp has rarely been collected from the same pools as other fairy shrimp species (Eng *et al.* 1990, Maeda-Martinez *et al.* 1997, Eriksen and Belk 1999). When coexistence does occur, it has been in longer lived pools, and the vernal pool fairy shrimp are often less abundant than other fairy shrimp species (Eng *et al.* 1990, Gallagher 1996, Eriksen and Belk 1999). Given the apparently wide distribution of this species and its tolerance for a wide range of conditions, it is possible that the absence of the vernal pool fairy shrimp in certain habitats is explained by competitive exclusion by other fairy shrimp (Helm 1998, Eriksen and Belk 1999). Vernal pool tadpole shrimp are predators of vernal pool fairy shrimp, whereas vernal pool fairy shrimp feed on algae, bacteria, protozoa, rotifers, and bits of detritus.

The vernal pool fairy shrimp occurs in the same vernal pool habitats as the California tiger salamander (*Ambystoma californiense*; federally listed as threatened or endangered, depending upon the subject population) and the western spadefoot toad, a species of concern. Vernal pool fairy shrimp provide an important food source for a number of species, including the western spadefoot toad (Simovich *et al.* 1991). Vernal pool fairy shrimp are also a major prey item for waterfowl, such as ducks (Proctor *et al.* 1967, Krapu 1974, Swanson *et al.* 1974, Silveira 1996). In turn, waterfowl and other migratory birds are important dispersal agents for this and other vernal pool species.

d. Reasons for Decline and Threats to Survival

Most species addressed in this recovery plan are threatened by similar factors because they occupy the same vernal pool ecosystems. These general threats, faced by all the covered species, are discussed in greater detail in the Introduction section of this recovery plan. Additional, specific threats to vernal pool fairy shrimp are described below.

As the California Natural Diversity Database (2003) indicates, 92 occurrences (27 percent) of vernal pool fairy shrimp are threatened by development, and an additional 27 occurrences (7 percent) are threatened by agricultural conversion.

In the Carrizo Vernal Pool Region, vernal pool habitats known to contain the vernal pool fairy shrimp are currently located on Federal land at the Camp Roberts Military Base and at the Carrizo National Monument. Although these areas are not immediately threatened by development, Camp Roberts may be threatened by military activities that alter historical vernal pools characteristics and introduce nonnative plant species. In two of the three plots that were fenced to protect vernal pools from training activities on Camp Roberts, nonnative *Taeniatherum caput-medusae* became more prolific and threatened to diminish the pool area available to fairy shrimp because nonnative plants encroached on pool edges.

In the Central Coast region, the vernal pool fairy shrimp is known only from Federal land on the Fort Hunter Liggett Military Reservation. Training and maintenance activities on this military base also have the potential to degrade some historical wetland habitats that are inhabited by fairy shrimp. In the Livermore Vernal Pool Region, the vernal pool fairy shrimp is located primarily on private land, where it is threatened by development, including expansion of the Byron Airport.

In the Northeastern Sacramento Valley Vernal Pool Region, most of the known occurrences of the vernal pool fairy shrimp are located on Caltrans rights-of-way

and are thus threatened by various future road improvement projects in this region, particularly the future expansion of Highway 99. Additional populations are threatened by commercial and residential development projects. Some occurrences on private land in the Northwestern Sacramento Vernal Pool Region may be threatened by agricultural conversion or development. In the Southeastern Sacramento Vernal Pool Region, the vernal pool fairy shrimp is threatened by urban development. Both Sacramento and Placer Counties are currently developing Habitat Conservation Plans to address growth in the region.

In the San Joaquin Valley region, the vernal pool fairy shrimp is found primarily on private land where it is threatened by direct habitat loss, including urban development and agricultural conversion.

Refer to the Draft Santa Rosa Plains Recovery Plan (in development) for information regarding threats facing the vernal pool fairy shrimp in the Santa Rosa Vernal Pool Region, as identified by Keeler-Wolf *et .al*. (1998).

In the Solano-Colusa region, the vernal pool fairy shrimp is threatened by development on the private property where it occurs.

In the Southern Sierra Foothills region, the species is threatened by the proposed University of California, Merced campus, which will likely also contribute to significant growth in the region, resulting in additional loss of vernal pool crustacean habitat. Agricultural conversion and flood control projects on Bureau of Reclamation land also threaten the species in this region.

In the Western Riverside County region, vernal pool fairy shrimp populations are threatened by development where they occur on private land in Los Angeles, Ventura, and Riverside Counties. Although other populations in Riverside County are protected at the Santa Rosa Plateau managed by the Nature Conservancy, these habitats may be threatened by the development of adjacent lands (Chester 2000).

In Oregon, vernal pool fairy shrimp occurring on the Agate Desert are threatened by commercial and industrial development, agricultural conversion, and utility projects (Oregon Natural Heritage Program 1997). Over 40 percent of the vernal pool habitats remaining in Oregon have been degraded (Borgias and Patterson 1999). Vernal pool habitats that are protected on the Agate Desert by the Nature Conservancy are threatened by the indirect effects of adjacent land use, including alteration of hydrology (Evans 2000). Vernal pool fairy shrimp populations on the Table Rocks area managed by the Bureau of Land Management are also threatened by direct influences of incompatible land uses. Because the portion of the Table Rocks managed by the Bureau of Land Management is an Area of

Critical Environmental Concern, the pools on land administered by the Bureau of Land Management are in an area that is not available for timber harvest and closed to off-highway vehicle use. Grazing is allowed for 1 month in the spring on Upper Table Rock only. The area is open to mineral entry. There is a single access road to the summit of each of the Table Rocks from adjacent private lands, and an old airplane landing strip is present on Lower Table Rock. The tops of the Table Rocks are closed to motorized vehicles, including aircraft. Threats to the vernal pools on the Table Rocks are primarily a result of recreational use: human trampling in the wet areas near pools and potential change in subsurface or surface flow runoff patterns due to trail construction and/or improvement. The Bureau of Land Management is scheduled to begin development of a management plan for Upper and Lower Table Rocks in 2004.

e. Conservation Efforts

On September 19, 1994, the final rule to list the vernal pool fairy shrimp as threatened was published in the *Federal Register* (U.S. Fish and Wildlife Service 1994*a)*. In 2005, critical habitat was designated for the vernal pool fairy shrimp and several other vernal pool species in *Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon; Evaluation of Economic Exclusions From August 2003 Final Designation; Final Rule* (U.S. Fish and Wildlife Service 2005).

Conservation efforts for the vernal pool fairy shrimp are divided into five broad categorie: regulatory and legal protections, education and outreach, research, conservation planning and habitat protection, and species specific management and monitoring. A brief description of each type of conservation action is provided below.

Regulatory and Legal Protections. The vernal pool fairy shrimp is protected as a threatened species under the Endangered Species Act. The International Union for the Conservation of Nature listed the vernal pool fairy shrimp as vulnerable in the 1996 Red List.

Education and Outreach: The Inland Invertebrate Working group distributes a newsletter devoted to fairy shrimp, the Anostracan News, and works toward disseminating information about the species. In 1998, we published a recovery plan for the vernal pools of Southern California (U.S. Fish and Wildlife Service 1998*b*).

Research: Vernal pool habitats have been the focus of much research, and scientific interest in this unique habitat type has continued to grow. Although there are numerous anecdotal accounts of the habitat requirements of the vernal

pool fairy shrimp, little specific information about the conservation needs of the species has been accumulated.

Conservation Planning and Habitat Protection: Approximately 5,261 hectares (13,000 acres) of vernal pool habitats, including mitigation banks, have been set aside for the vernal pool fairy shrimp specifically as terms and conditions of section 7 consultations. These areas are scattered throughout the Central Valley and represent important building blocks toward recovery of the vernal pool fairy shrimp.

Vernal pool habitats supporting populations of vernal pool fairy shrimp have been protected through a variety of other means. Within the Carrizo Vernal Pool Region, some of the vernal pool fairy shrimp habitat is protected from training and maintenance activities on the Camp Roberts military base.

In the Central Coast region, some of the vernal pools inhabited by fairy shrimp are protected at the Fort Hunter Liggett Military Reservation. In the Livermore Vernal Pool Region, the species occurs on public land in Contra Costa County and in the City of Livermore.

In the Northeastern Sacramento Valley region, vernal pool fairy shrimp are protected on a private mitigation area and on land owned by the Nature Conservancy. Private mitigation lands, the Stillwater Preservation Bank, and the Thomes Creek Ecological Reserve protect the species from direct habitat loss in the Northwestern Sacramento Valley Vernal Pool Region.

In the San Joaquin Valley Vernal Pool Region, vernal pool fairy shrimp are protected at the Grasslands Ecological Area, including Federal and State wildlife refuges in Merced County. In the Solano-Colusa Vernal Pool Region, the vernal pool fairy shrimp is protected on several preserves in the Jepson Prairie area and at Travis Air Force Base in Solano County. Several Habitat Conservation Plans are developing vernal pool preserve plans in the region, including Solano and Yolo Counties.

In the Southeastern Sacramento Valley Vernal Pool Region, vernal pool fairy shrimp occurrences are protected from development at a number of private mitigation areas, mitigation banks, and on the Cosumnes River Preserve's Valensin Ranch property. They also occur on the Howard Ranch, owned by a private rancher but protected by a conservation easement (J. Marty pers. comm. 2004). The species is also protected at Beale Air Force Base in Yuba County, where management and monitoring have recently been implemented (Jones and Stokes 1997). Several Habitat Conservation Plans are developing vernal pool preserve plans in the region, including Sacramento and Placer Counties.

In the Southern Sierra Foothills Vernal Pool Region, the species is protected at the Stone Corral Ecological Reserve. The California Department of Fish and Game recently implemented a 3-year grazing lease on the Stone Corral Ecological Reserve to reduce competitive exclusion of native vernal pool plant species by exotic weeds and invasive native (e.g., *Eleocharis* spp.) plant species, and to enhance the upland native plant species needed by native pollinators. They will be monitoring the Stone Corral Ecological Reserve in conjunction with the grazing lease. The California Department of Fish and Game has also initiated a preliminary sampling program for vernal pool invertebrates on several of the southern San Joaquin Valley California Department of Fish and Game preserves, including the Big Table Mountain Preserve and Stone Corral Ecological Reserve.

In the Western Riverside County Vernal Pool Region, vernal pool fairy shrimp are protected at the Santa Rosa Plateau Preserve, managed by The Nature Conservancy. The Recovery Plan for Vernal Pools of Southern California (U.S. Fish and Wildlife Service 1998b) includes vernal pool habitats containing vernal pool fairy shrimp populations as part of the Riverside Management Area, and establishes recovery strategies and criteria for protecting these habitats. Some of these habitats are also protected through a Habitat Conservation Plan.

In the Santa Barbara Vernal Pool Region, the Recovery Plan for Vernal Pools of Southern California (U.S. Fish and Wildlife Service 1998b) includes habitats containing vernal pool fairy shrimp populations in Los Angeles and Ventura Counties in the Transverse Management area. The recovery plan develops recovery strategies and criteria for listed fairy shrimp species occurring in these habitats. The three known vernal pools that support fairy shrimp on the Los Angles National Forest receive some protection as a result of section 7 consultation requirements that are mandatory for Federal agencies, and additional survey efforts would likely result in local range extensions within the National Forest.

In Oregon, vernal pool fairy shrimp populations are protected on The Nature Conservancy's Agate Desert and Whetstone Savanna preserves, containing approximately 78 hectares (197 acres) of vernal pool habitat. Habitat is also protected from development on property owned by the Bureau of Land Management (129 hectares [320 acres] of vernal pool habitat) and Bureau of Reclamation (60 hectares [150 acres] of vernal pool habitat). The Bureau of Land Management is scheduled to begin development of a management plan for Upper and Lower Table Rock in 2004. The Bureau of Reclamation is scheduled to begin development of a management plan for vernal pool habitat in 2005. A Wetland Conservation Plan is currently being developed to protect vernal pool habitats in the White City region of the Agate Desert.

Site-specific details of the recovery actions for vernal pool fairy shrimp populations in Oregon will be identified as part of a recovery plan for species of the upper Rogue River Valley, which is currently in preparation at our Roseburg Field Office. The Rogue River Valley recovery plan will develop an integrated, ecosystem-based strategy for recovery of vernal pool fairy shrimp and two endangered plant species that are endemic to the area, within the context of the broader recovery strategy identified in this Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon.

5. VERNAL POOL TADPOLE SHRIMP *(LEPIDURUS PACKARDI)*

a. Description and Taxonomy

Taxonomy.—The vernal pool tadpole shrimp was initially described by Simon (1886) and named *Lepidurus packardi*. Linder (1952) maintained *L. packardi* as a valid species. However, in a review of the order Notostraca, Longhurst (1955) reduced this and 18 other species to subspecies of *L. apus* based primarily on the lack of apparent geographic boundaries between *L. apus* and *L. packardi* populations. Lynch (1972) resurrected *L. packardi* to full species status based on further examination of specimens. This is the currently accepted taxonomic status of the vernal pool tadpole shrimp. Recent genetic analysis indicates *L. packardi* is a valid species (King and Hanner 1998).

Description and Identification.—Vernal pool tadpole shrimp, like other members of the Order Notostraca, are known as living fossils because they have changed little in appearance over roughly the last 2 million years, and resemble species found in the fossil record (Longhurst 1955, King and Hanner 1998). Vernal pool tadpole shrimp are distinguished by a large, shield-like carapace, or shell, that covers the anterior half of their body. Vernal pool tadpole shrimp have 30 to 35 pairs of phyllopods, a segmented abdomen, paired cercopods or tail-like appendages, and fused eyes. Mature vernal pool tadpole shrimp range in size from 15 to 86 millimeters (0.6 to 3.3 inches) in length.

Vernal pool tadpole shrimp and other species in the Order Notostraca have remained generally similar in appearance for hundreds of millions of years (Longhurst 1955). However, individuals often vary greatly in appearance, making classification and identification of species difficult (Gurney 1924, Linder 1952, Longhurst 1955, King and Hanner 1998). Recent genetic studies (King and Hanner 1998) may provide the basis for relating genetically detected differences to morphological variation, potentially allowing for the development of a classification key to the genus. Species in the genus *Lepidurus* can be distinguished from members of the similar looking genus *Triops* by the presence of a supra-anal plate between their cercopods, which is lacking in *Triops*. Two

other species of *Lepidurus* are found in California. One, the cryptic tadpole shrimp (*Lepidurus cryptus*), has recently been described (Rogers 2001). This species cannot be differentiated from the vernal pool tadpole shrimp by appearance, but the two species are genetically distinct (King and Hanner 1998, Rogers 2001). The cryptic tadpole shrimp occurs in the Great Basin and intermountain regions of northern California and southern and eastern Oregon, whereas the vernal pool tadpole shrimp occurs in the Central Valley, Delta, and east San Francisco Bay area (Rogers 2001). The cryptic tadpole shrimp is not known to occur within the range of the vernal pool tadpole shrimp as described in the listing rule (U.S. Fish and Wildlife Service 1994*a)*. The other species, *Lepidurus lemmoni*, was described by Holmes in 1894 (Holmes 1894). This species is found in alkali playas high in calcium salts in California in the Mojave Desert in Inyo, Kern, San Bernardino, and Riverside Counties, in the Great Basin in Lassen, Modoc, and Siskiyou Counties, and also in Oregon, but does not co-occur with *L. packardi* (Rogers 2001, C. Rogers *in litt*. 2005). *Lepidurus lemmoni* is distinguished from *L. packardi* by having more than 50 leg pairs (vs. less than 40 in *L. packardi*), and the nuchal organ being placed behind the eyes (vs. between the eyes as in all other *Lepidurus*).

b. Historical and Current Distribution

Historical Distribution.—King *et al.* (1996) suggested that vernal pool tadpole shrimp probably evolved in the Central Valley of California after colonizing large inland lakes during the Pliocene and Pleistocene, approximately 2 million years ago. From the end of the Pleistocene until the mid-1800s, the Central Valley still contained extensive seasonal wetlands, sometimes covering the entire valley (Oakeshott 1978). Holland (1978) estimated that roughly 1,600,000 hectares (4,000,000 acres) of vernal pool habitat existed in the Central Valley during pre-agricultural times. Historically the vernal pool tadpole shrimp was probably distributed over most of these vernal pool habitats. However, surveys in southern portions of California have never revealed vernal pool tadpole shrimp populations, and the species probably did not occur historically outside of the Central Valley and Central Coast regions **(Figure II-38**).

Current Distribution.—The vernal pool tadpole shrimp is currently distributed across the Central Valley of California and in the San Francisco Bay area. The species' distribution has been greatly reduced from historical times as a result of widespread destruction and degradation of its vernal pool habitat. Vernal pool habitats in the Central Valley now represent only about 25 percent of their former area, and remaining habitats are considerably more fragmented and isolated than during historical times (Holland 1998). Vernal pool tadpole shrimp are uncommon even where vernal pool habitats occur. Helm (1998) found vernal pool tadpole shrimp in only 17 percent of vernal pools sampled

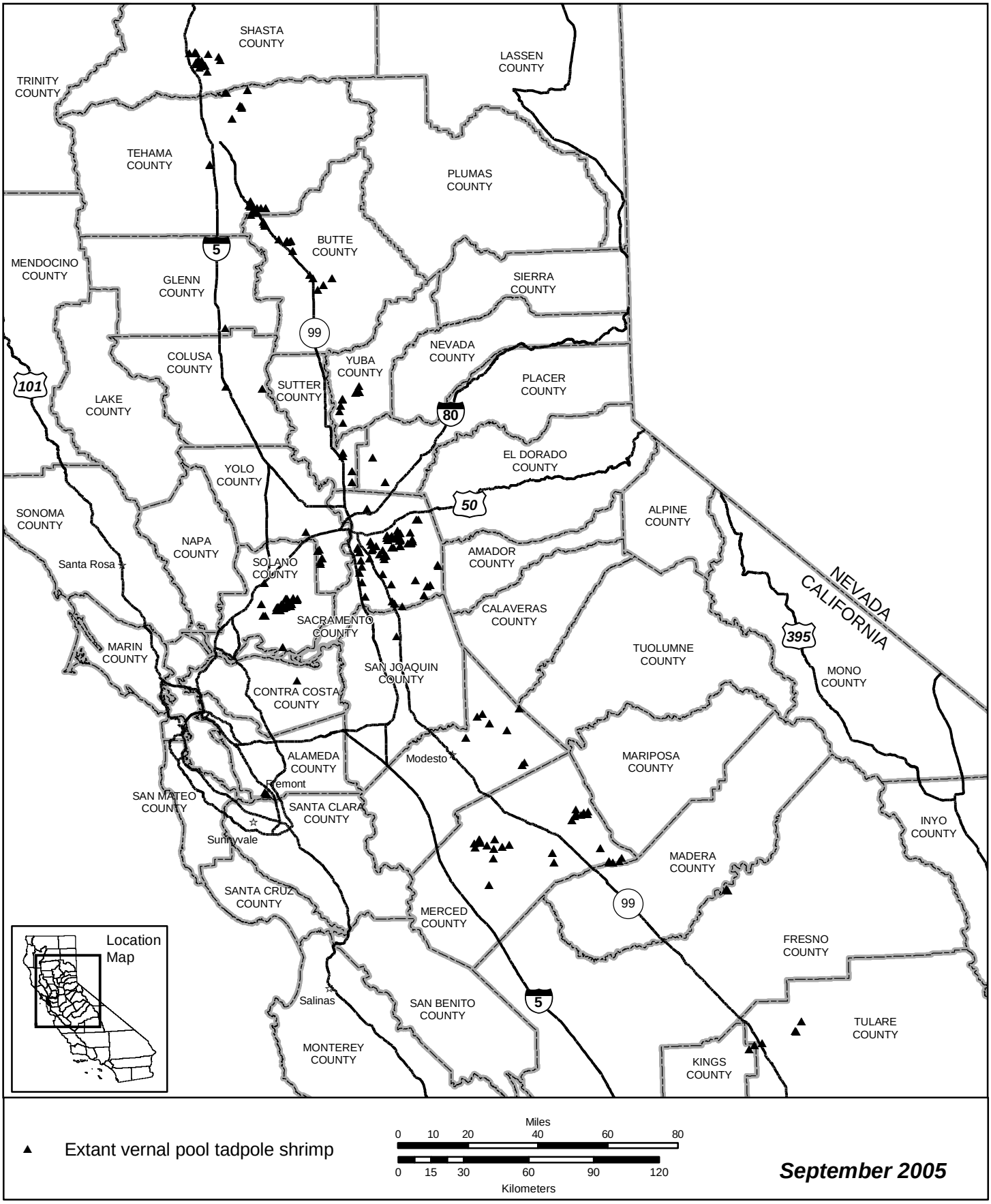

Figure II-38. Distribution of vernal pool tadpole shrimp (*Lepidurus packardi*).

across 27 counties, and Sugnet (1993) found this species at only 11 percent of 3,092 locations. In the Northwestern Sacramento Vernal Pool Region, vernal pool tadpole shrimp are found at the Stillwater Plains and in the vicinity of Redding in Shasta County. In the Northeastern Sacramento Vernal Pool Region, vernal pool tadpole shrimp have been documented on private land in the vicinity of Chico in Butte County and in Tehama County at the Vina Plains Preserve, the Dales Lake Ecological Reserve, and on Caltrans land. The largest concentration of vernal pool tadpole shrimp occurrences are found in the Southeastern Sacramento Vernal Pool Region, where the species occurs on a number of public and private lands in Sacramento County. Vernal pool tadpole shrimp are also known from a few locations in Yuba and Placer Counties, including Beale Air Force Base. In the Solano-Colusa Vernal Pool Region the vernal pool tadpole shrimp occurs in the vicinity of Jepson Prairie, Travis Air Force Base, and near Montezuma in Solano County and on the Sacramento National Wildlife Refuge in Glenn County. In the San Joaquin Vernal Pool Region, vernal pool tadpole shrimp are known from the Grasslands Ecological Area and private land in Merced County and from single locations in Tulare and Kings Counties. In the Southern Sierra Foothills region, the species occurs at the Stone Corral Ecological Preserve in Tulare County, on ranchlands in eastern Merced County, at the Big Table Mountain Preserve in Fresno County, and at a few locations in Stanislaus County. In the Central Coast Vernal Pool Region, the vernal pool tadpole shrimp is found on the San Francisco National Wildlife Refuge and private land in Alameda County.

c. Life History and Habitat

Life History.—Although the vernal pool tadpole shrimp is adapted to survive in seasonally available habitat, the species has a relatively long life span compared to other vernal pool crustaceans. Helm (1998) found that the vernal pool tadpole shrimp lived significantly longer than any other species observed under the same conditions except the California fairy shrimp. Vernal pool tadpole shrimp continue growing throughout their lives, periodically molting their shells. These shells can often be found in vernal pools where vernal pool tadpole shrimp occur. Helm (1998) found that vernal pool tadpole shrimp took a minimum of 25 days to mature and the mean age at first reproduction was 54 days. Other researchers have observed that vernal pool tadpole shrimp generally take between 3 and 4 weeks to mature (Ahl 1991, King *et al.*1996). Ahl (1991) found that reproduction did not begin until individuals were larger than 10 millimeters (0.4 inch) in carapace length. Variation in growth and maturation rates may be a result of differences in water temperature, which strongly influences the growth rates of aquatic invertebrates.

Vernal pool tadpole shrimp have relatively high reproductive rates. Ahl (1991) found that fecundity increases with body size. Large females, greater than 20 millimeters (0.8 inch) carapace length, could deposit as many as 6 clutches, ranging from 32 to 61 eggs per clutch, in a single wet season. Vernal pool tadpole shrimp may be hermaphroditic (Longhurst 1955, Lynch 1966, C. Rogers *in litt.* 2001), and sex ratios can vary (Ahl 1991, Sassaman 1991), perhaps in response to changes in water temperature.

After winter rains fill their vernal pool habitats, dormant vernal pool tadpole shrimp cysts may hatch in as little as 4 days (Ahl 1991, Rogers *in litt*. 2001). Additional cysts produced by adult tadpole shrimp during the wet season may hatch without going through a dormant period (Ahl 1991). Vernal pool tadpole shrimp emerge from their cysts as metanauplii, a stage which lasts for 1.5 to 2 hours. Then they molt into a larval form resembling the adult. Multiple hatching within the same wet season allows vernal pool tadpole shrimp to persist within vernal pools as long as these habitats remain inundated, sometimes for 6 months or more (Ahl 1991, Gallagher 1996, Helm 1998). Vernal pool tadpole shrimp hatching is temperature dependent. Optimal hatching occurs between 10 to 15 degrees Celsius (50 to 59 degrees Fahrenheit), with hatching rates becoming significantly lower at temperatures above 20 degrees Celsius (68 degrees Fahrenheit) (Ahl 1991).

Habitat.—Vernal pool tadpole shrimp occur in a wide variety of ephemeral wetland habitats (Helm 1998). The species has been collected in vernal pools ranging from 2 to 356,253 square meters (6.5 square feet to 88 acres) in surface area (Helm 1998). Some of these vernal pools may be too small to remain inundated for the entire life cycle of the tadpole shrimp, but the vernal pool tadpole shrimp may be able tolerate temporary drying conditions (Helm 1998). Vernal pool tadpole shrimp have been found in pools with water temperatures ranging from 10 degrees Celsius (50 degrees Fahrenheit) to 29 degrees Celsius (84 degrees Fahrenheit) and pH ranging from 6.2 to 8.5 (Syrdahl 1993, King 1996). However, vernal pools exhibit daily and seasonal fluctuations in pH, temperature, dissolved oxygen, and other water chemistry characteristics (Syrdahl 1993, Scholnick 1995, Wiggins 1995, Keeley 1998). Determining the vernal pool tadpole shrimp's habitat requirements is not possible based on anecdotal evidence, and the tolerances of this species to specific environmental conditions have yet to be determined. Although the vernal pool tadpole shrimp is found on a variety of geologic formations and soil types, Helm (1998) found that over 50 percent of vernal pool tadpole shrimp occurrences were on High Terrace landforms and Redding and Corning soils. Platenkamp (1998) found that vernal pool tadpole shrimp presence differed significantly between geomorphic surfaces at Beale Air Force Base, and was most likely to be found on the Riverbank formation.

Population Structure.—King *et al.* (1996) studied genetic variation among vernal pool tadpole shrimp populations at 20 different sites in the Central Valley. They found that 96 percent of the genetic variation measured was due to differences between sites. This result corresponds with the findings of other researchers that vernal pool crustaceans have low rates of gene flow between separated sites, between 0.02 and 2.61 individuals between sites per generation. The low rate of exchange between vernal pool tadpole shrimp populations is probably as a result of the spatial isolation of their habitats and their reliance on passive dispersal mechanisms. However, King *et al.* (1996) also found that gene flow between pools within the same vernal pool complex is much higher, between 0.5 and 14.4 individuals per generation. This finding indicates that vernal pool tadpole shrimp populations, like most vernal pool crustacean populations, are defined by vernal pool complexes and not by individual vernal pools.

Based on genetic differences, King *et al.* (1996) separated vernal pool tadpole shrimp populations into two distinct groups. One group comprised animals inhabiting the floor of the Central Valley, near the Sacramento and San Joaquin Rivers. The other group contained vernal pool tadpole shrimp from sites along the eastern margin of the valley. King *et al.* (1996) concluded that these two groups may have diverged because cyst dispersal by overland flooding recently connected these populations on the valley floor. Populations on the eastern margin of the valley likely experienced less frequent dispersal events, probably through different mechanisms such as migratory birds. King *et al.* (1996) also found that populations in eastern Merced County, in the vicinity of the Flying M Ranch and the proposed University of California Merced campus, were very different from all other populations studied. These researchers concluded, particularly because it is found on very ancient soils, that this group may have been isolated from other populations very early, and further suggested that this population may be a separate species.

d. Reasons for Decline and Threats to Survival

Most species addressed in this recovery plan are threatened by similar factors because they occupy the same vernal pool ecosystems. These general threats, faced by all the covered species, are discussed in greater detail in the Introduction section of this recovery plan. Additional, specific threats to vernal pool tadpole shrimp are described below.

The California Natural Diversity Database (2003) lists 17 occurrences of vernal pool tadpole shrimp as threatened by development. An additional 16 occurrences are reported as threatened by various agricultural conversions. The species is threatened by the encroachment of nonnative annual grasses on the San Francisco

Bay National Wildlife Refuge in the Central Coast region, and by urban development where it is known to occur on private land in Alameda County. In the Northeastern Sacramento Valley region, most of the known occurrences of the vernal pool fairy shrimp are on Caltrans rights of way where they continue to be threatened by road improvement projects related to general urban growth. In addition, the species is known to have been parasitized by flukes (Trematoda) of an undetermined species at the Vina Plains, Tehama County (Ahl 1991). The gonads of both sexes were greatly reduced in size and their body cavities were filled with many young flukes (metacercariae). Ahl (1991) thus concluded that parasitic castration was the major limiting factor affecting reproduction of the vernal pool tadpole shrimp at the Vina Plains. In the Northwestern Sacramento Valley Vernal Pool Region, the vernal pool tadpole shrimp is threatened by development on the few sites on private land where it is known to occur. In the Southeastern Sacramento Vernal Pool Region, extant populations of vernal pool tadpole shrimp are threatened by continued extensive urban development.

In the San Joaquin Vernal Pool Region, the species is threatened by development on private land. In the Solano-Colusa region, the species is threatened by urbanization on private lands.

In the Southern Sierra Foothills Vernal Pool Region, the species is threatened by development of the proposed University of California, Merced campus, which will likely contribute to significant growth in the region, resulting in additional loss of vernal pool crustacean habitat. Populations on the Stone Corral Ecological Reserve may be threatened by pesticide drift from adjacent farmlands.

e. Conservation Efforts

On September 19, 1994, the final rule to list the vernal pool tadpole shrimp as endangered was published in the *Federal Register* (U.S. Fish and Wildlife Service 1994*a*). In 2005, critical habitat was designated for vernal pool tadpole shrimp and several other vernal pool species in *Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon; Evaluation of Economic Exclusions From August 2003 Final Designation; Final Rule* (U.S. Fish and Wildlife Service 2005).

Although conservation efforts have been taken for vernal pool ecosystems in general, very few actions have been taken specifically to benefit the vernal pool tadpole shrimp. An example of one of these actions is the implementation of a grazing program at the Stone Corral Ecological Reserve for the benefit of vernal pool crustaceans. The results of the monitoring program are being monitored by California Department of Fish and Game staff (J. Vance, pers comm. 2005).