II. BIOLOGY OF COVERED SPECIES

A. Federally Listed Plant Species

1. *CASTILLEJA CAMPESTRIS* SSP. *SUCCULENTA* (FLESHY OWL'S-CLOVER)

a. Description and Taxonomy

***Taxonomy*.**—Owl's-clovers are members of the figwort or snapdragon family (Scrophulariaceae). Hoover (1936*a*) first named fleshy owl's-clover, giving it the scientific name *Orthocarpus campestris* var. *succulentus.* The type specimen had been collected at Ryer, in Merced County. Hoover (1968) raised fleshy owl's-clover to the rank of species and assigned it the name *Orthocarpus succulentus*. Chuang and Heckard (1991) reconsidered the taxonomy of *Orthocarpus* and related genera. Based on floral morphology, seed morphology, and chromosome number, they transferred many species into the genus *Castilleja*. Furthermore, they determined that the appropriate rank for fleshy owl's-clover was as a subspecies of field owl's-clover (*Castilleja campestris*). Thus, the scientific name currently assigned to fleshy owl's-clover is *Castilleja campestris* ssp. *succulenta*, whereas field owl's-clover is *Castilleja campestris* ssp. *campestris* (Chuang and Heckard 1991). Another common name for fleshy owl's-clover is succulent owl's-clover (Skinner and Pavlik 1994).

***Description and Identification*.**— *Castilleja campestris* ssp. *succulenta* (**Figure II-1**) has rather intricate flowers, with the corolla consisting of two lips. The flower has four sepals that are fused at the base, creating the calyx tube. Together, all the flowers plus the bracts comprise the inflorescence. The plant has erect or decumbent stems up to 30 centimeters (11.8 inches) long. The stems are usually unbranched and without hairs. The leaves at the base of the stem are small and scale-like, whereas those on the upper stem are 1.5 to 4 centimeters (0.6 to 1.6 inches) long, lance-shaped, not lobed, thick, fleshy, and easily broken. The bracts are green, similar to but shorter than the upper leaves, and longer than the flowers. Overall, the inflorescence may occupy as much as half of the plant's height and be 2 to 3 centimeters (0.8 to 1.2 inches) wide. *Castilleja campestris* ssp. *succulenta* has a diploid chromosome number of 24 (Chuang and Heckard 1993).

The brittle leaves are a key characteristic for identification of *Castilleja campestris* ssp. *succulenta*. The most similar taxon is *C. campestris* ssp. *campestris*. *Castilleja campestris* ssp. *campestris* has branched stems; thin, flexible, non-fleshy leaves; larger, lighter yellow flowers; a stigma that protrudes

Figure II-1. Illustration of *Castilleja campestris*. Reprinted with permission from Abrams (1951), Illustrated Flora of the Pacific States: Washington, Oregon, and California, Vol. III. © Stanford University Press.

beyond the upper lip of the flower; a lower anther sac that is no more than one-third the size of the upper; and more rounded seeds. *Castilleja campestris* ssp. *campestris* occurs farther north than *C. campestris* ssp. *succulenta* (Hoover 1937, Hoover 1968, Heckard 1977, California Department of Fish and Game 1986). Other *Castilleja* species have lobed leaves and bracts, and the bracts are often colored.

b. Historical and Current Distribution

Historical Distribution.—Between 1937 and 1986, *Castilleja campestris* ssp. *succulenta* was reported from 33 localities (Hoover 1937, Hoover 1968, California Natural Diversity Data Base 2005), all in the Southern Sierra Foothills Vernal Pool Region (Keeler-Wolf *et al.* 1998). Sixteen of those occurrences, including the type locality, were in eastern Merced County. Six occurrences each were in Fresno and Madera Counties and five others were in Stanislaus County (California Natural Diversity Data Base 2003) (**Figure II-2**).

Current Distribution.—Through August 2005, the California Natural Diversity Data Base (2005) had catalogued 91 occurrences of *Castilleja campestris* ssp. *succulenta* (catalogued as succulent owl's clover). About one-third of these occurrences are records from Merced County, catalogued in association with rare plant and wildlife surveys of eastern Merced County grass and ranch lands conducted during 2001 by a team of consultants to the County and California Department of Fish and Game (Vollmar 2002).

Of the 91 total data base occurrences, 90 are presumed to be extant, lacking any evidence to the contrary. One occurrence in Fresno County is considered to be "possibly extirpated" (California Natural Diversity Data Base 2005) because the site had been disced when it was last visited in 1981. Another unreported (to the data base) site in Fresno County may also be extirpated (J. Stebbins *in litt.* 2000*a*). Currently, among the 91 reported occurrences, 70 percent are in Merced County, 12 percent are in Fresno County, 10 percent are in Madera County, 5 percent are in Stanislaus County, and 1 percent is in San Joaquin County (M. Trask *in litt.* 1993, EIP Associates 1994, C. Witham *in litt.* 2000*b*, California Natural Diversity Data Base 2003). All but one of these occurrences are in the Southern Sierra Foothills Vernal Pool Region; one San Joaquin County site is in the Southeastern Sacramento Valley Vernal Pool Region (Keeler-Wolf *et al.* 1998).

This information, and especially the recent records, confirm that the primary area of concentration for *Castilleja campestris* ssp. *succulenta* is in eastern Merced County, especially just northeast of the City of Merced. In particular, many of the known occurrences are between La Paloma Road and Highway 140, east of Yosemite Lake. In addition to the proposed University of California campus area and related community, this area includes the Flying M Ranch and other ranch land. In addition, *C. campestris* ssp. *succulenta* was found in 296 vernal pools in the proposed campus and community area during recent surveys of 34 percent of that area (EIP Associates 1999). A later study of vernal pool habitat in the campus lands area, using a different reporting format that is not directly comparable, nevertheless also found *C. campestris* ssp. *succulenta* at significant levels (3 to 6 percent of the habitat area) (Jones and Stokes 2003). Moreover, Vollmar (2002) concluded that this listed plant is likely to be found throughout much of the range land portion of the eastern Merced County survey area, wherever there are better-developed, dense, interconnected vernal pools, and that this study area clearly represents a very important geographical region for the conservation of *C. campestris* ssp. *succulenta*.

Other occurrences in Merced County are somewhat farther to the north and south. In addition, a secondary area of concentration is located in southern Madera County and northern Fresno County, from just west of Highway 41 east to Academy and north to Miller's Corner, with 17 occurrences. Also, two smaller areas of concentration, which include five occurrences each but contain large numbers of plants, are near Cooperstown in Stanislaus County and the "tabletop" mountains near Millerton Lake in Fresno and Madera Counties. Other more scattered occurrences include two at Castle Airport northwest of Merced, one near Wildcat Mountain in Fresno County, and one in San Joaquin County. Significant areas of suitable habitat remain unsurveyed, particularly in northern Merced County (EIP Associates 1999) and between the northern Stanislaus County and northern San Joaquin County sites (J. Stebbins *in litt.* 2000*b*). Thus, additional occurrences are likely to be found if further surveys similar to those reported by Vollmar (2002) are conducted.

c. Life History and Habitat

Reproduction and Demography.—*Castilleja campestris* ssp. *succulenta* is an annual plant. As with many related species, it is a hemiparasite, meaning that it obtains water and nutrients by forming root grafts with other host plants but manufactures its own food through photosynthesis (Chuang and Heckard 1991). Research on hemiparasitism has focused on related species of *Castilleja*, but not specifically on *C. campestris* ssp. *succulenta*. Many different plants can serve as hosts for a single species or even a single individual of *Castilleja*. Seeds of *Castilleja* species do not require the presence of a host to germinate, and form root connections only after reaching the seedling stage. Some seedlings can survive to maturity without attaching to a host's roots, but in general reproduction is enhanced by root connections (Atsatt and Strong 1970).

The conditions necessary for germination of *Castilleja campestris* ssp. *succulenta* seeds have not been studied, nor has the timing of seed germination been documented. Flowering occurs in April and May (Skinner and Pavlik 1994). The importance of pollinating insects is not known for certain. Some aspects of *C. campestris* ssp. *succulenta* biology suggest that it may be self-pollinating (Heckard 1977), but many related taxa of *Castilleja* are pollinated by generalist bees (Superfamily Apoidea) (Chuang and Heckard 1991).

Among close relatives that do not require insect pollinators, flower structure and timing of stigma receptivity maximize the chances for self-fertilization and seed set. Even so, insects may transfer some pollen among individual plants and species occurring in the same area. Self-pollinating species of *Castilleja* typically occur as widely scattered individuals, rather than in dense colonies (Atsatt 1970). *Castilleja campestris* ssp. *succulenta* follows this pattern in part, often occurring in many pools within a complex but with fewer than 100 plants per pool. However, *C. campestris* ssp. *succulenta* also may occur in large populations within a single pool (California Natural Diversity Data Base 2003). Little is known about the demography of *C. campestris* ssp. *succulenta*, although population size can fluctuate greatly from year to year. In the few populations where population size was reported for more than 1 year, fluctuations up to two orders of magnitude were noted (California Natural Diversity Data Base 2003).

Habitat and Community Associations.—*Castilleja campestris* ssp. *succulenta* occurs in Northern Claypan and Northern Hardpan vernal pools (Sawyer and Keeler-Wolf 1995) within annual grassland communities (California Natural Diversity Data Base 2003). The plant is known from both small and large pools (EIP Associates 1999, J. Stebbins *in litt.* 2000*a*). Although not all pools occupied by this taxon have been studied in detail, Stebbins *et al.* (1995) collected data on six occupied pools in Fresno and Madera Counties. Some were typical "bowl-like" pools, whereas others were more similar to swales. Approximate pool area ranged from 0.03 to 0.65 hectare (0.07 to 1.61 acres), depth from 30 to 38 centimeters (11.8 to 15.0 inches), and pH of the soil underlying the pools from 5.00 to 6.24 (Stebbins *et al.* 1995). This subspecies has been reported from pools with both long and short inundation periods (EIP Associates 1999) and from both shallow and "abnormally deep" vernal pools, but approximate depth of these pools was not given (California Natural Diversity Data Base 2003).

The soil types have not been determined for all of the sites where *Castilleja campestris* ssp. *succulenta* occurs. At the one site in the Southeastern Sacramento

Valley Vernal Pool Region, the soil is San Joaquin sandy loam. Soil series supporting *C. campestris* ssp. *succulenta* in the Southern Sierra Foothills Vernal Pool Region include Amador, Anderson, Corning, Fallbrook, Hideaway, Keyes, Pentz, Ramona, Redding, San Joaquin, Vista, and Yokohl, as well as the Pollasky-Montpellier complex. Soil textures at those sites range from extremely stony loam to loamy clay. In the proposed University of California-Merced campus and community area, 81.4 percent of the individual pools where this taxon was found were on Redding gravelly loam, 9.5 percent were on Corning gravelly sandy loam, 6.4 percent were on Corning gravelly loam, 1.7 percent were on Keyes gravelly loam, 0.7 percent were on Keyes gravelly clay loam, and 0.3 percent were on Pentz loam (EIP Associates 1999).

Populations of *Castilleja campestris* ssp. *succulenta* have been reported from elevations of 24 meters (80 feet) at the San Joaquin County site to 700 meters (2,300 feet) at Kennedy Table in Madera County (California Natural Diversity Data Base 2003). Plants most commonly reported as occurring with *C. campestris* ssp. *succulenta* are *Lasthenia fremontii* (Fremont's goldfields) (EIP Associates 1999), *Downingia* spp. (downingia), *Mimulus tricolor* (three-colored monkey-flower), *Plagiobothrys stipitatus* (vernal pool popcorn flower), and *Eryngium* spp. (coyote-thistle) (California Natural Diversity Data Base 2005). Other plants featured in this recovery plan that have been reported growing with *C. campestris* ssp. *succulenta* are: *Neostapfia colusana, Orcuttia inaequalis, O. pilosa, Gratiola heterosepala* (EIP Associates 1999, California Natural Diversity Data Base 2005), and *Eryngium spinosepalum* (EIP Associates 1994).

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 *Castilleja campestris* ssp. *succulenta* are described below.

One significant specific threat is the proposed construction of the new University of California campus in Merced County. This project, plus associated residential development and access roads, are threats to the primary and relatively extensive population in that area. Of the 12 occurrences recorded in the California Natural Diversity Data Base on the proposed campus and associated community, 4 are in the area that is expected to be developed within the next 15 years; these 4 occurrences include 226 of the 296 occupied pools (76 percent) in the University planning area (EIP Associates 1999). Additional urban developments that threaten many other known occurrences include planned housing subdivisions in Fresno, Madera, and San Joaquin Counties; a freeway expansion in Madera

County; and a proposed landfill in Fresno County (U.S. Fish and Wildlife Service 1997*a*, J. Stebbins *in litt.* 2000*b*, California Natural Diversity Data Base 2003).

Exclusion of grazing from sites that have been grazed historically may increase the threat of competition with nonnative plants. About two-thirds of the reported occurrences of the species, including those at the University of California-Merced site, were subject to cattle grazing when first discovered (EIP Associates 1999, California Natural Diversity Data Base 2003). Grazing should be monitored, and adjusted as needed, to maintain and enhance the species. Grazing may not be appropriate for all populations. Consideration of the possible negative effects to *Castilleja campestris* ssp. *succulenta* should be given before grazing is introduced into a population that has not been previously grazed.

Threats due to alterations in natural hydrology include the Merced County Stream Channel Project proposed by the U.S. Army Corps of Engineers (U.S. Fish and Wildlife Service 1997*a*) and proposed enlargement of Burns Reservoir in Merced County (California Natural Diversity Data Base 2003), which collectively threaten seven occurrences of *Castilleja campestris* ssp. *succulenta*. Expansion of agricultural operations threatens three occurrences in Fresno and Madera Counties that are surrounded by orchards, vineyards, or citrus groves (California Natural Diversity Data Base 2003). A proposed gravel mine threatens one occurrence of *C. campestris* ssp. *succulenta* in Fresno County. Two other occurrences, at the former Castle Air Force Base in Merced County, are threatened by excavation to remove soil that was contaminated by lead from skeet shooting (California Natural Diversity Data Base 2003).

Threats posed by small population size may also be a significant continuing factor because small size makes populations more vulnerable to extirpation from chance events. Among the 24 populations of *Castilleja campestris* ssp. *succulenta* for which size estimates have been documented, 10 consisted of fewer than 100 plants each at their peak size (J. Stebbins *in litt.* 2000*b*, California Natural Diversity Data Base 2003).

e. Conservation Efforts

We listed *Castilleja campestris* ssp. *succulenta* as threatened on March 26, 1997 (U.S. Fish and Wildlife Service 1997*a*). This taxon has been State-listed as endangered since 1979 (California Department of Fish and Game 1991). The California Native Plant Society considered it to be rare and endangered 5 years earlier (Powell 1974) and still includes *C. campestris* ssp. *succulenta* on its List 1B, noting that it is “endangered in a portion of its range” (California Native Plant Society 2003). In 2005, critical habitat was designated for *C. campestris* ssp. *succulenta* 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).

Three populations of *Castilleja campestris* ssp. *succulenta* fall primarily within designated reserves, on two "tabletop" mountains near Millerton Lake in Fresno County. The Sierra Foothill Conservancy's Big Table Mountain Preserve includes all of one population. The second population is shared between the preserve and the adjacent U.S. Bureau of Land Management property. The third population is within the California Department of Fish and Game's Big Table Mountain Preserve. A cooperative group consisting of the California Department of Fish and Game, California Department of Parks and Recreation, Sierra Foothill Conservancy, U.S. Bureau of Land Management, and U.S. Bureau of Reclamation is developing a management and monitoring plan for Big Table Mountain. Initial efforts include a study on grazing as a means to control nonnative grasses while comparing population trends of threatened and endangered species in grazed and ungrazed portions of the tableland (M. Griggs *in litt*. 2000, J. Darren, BLM, *in litt.*, 2005).

A fourth population is found on a nearby tabletop, occurring partly on U.S. Bureau of Land Management land and partly on privately-owned land. Previously the site was seriously overgrazed, leading the U.S. Bureau of Land Management to erect fences to exclude cattle from the tabletop, with variable success (A. Franklin *in litt.* 1993). The management and monitoring plan for the other nearby tabletop vernal pools could be easily modified to include this fourth population.

At least seven occurrences of *Castilleja campestris* ssp. *succulenta* on the Flying M Ranch in Merced County are protected from development by a conservation easement negotiated between the landowner and The Nature Conservancy (U.S. Fish and Wildlife Service 1997*a*). Several other occurrences are in public ownership but are not necessarily protected from development, nor are they managed for the benefit of this or other vernal pool taxa. These occurrences include (1) the extensive populations on the proposed University of California campus in Merced County, (2) a large population on property acquired by the California Department of Transportation for mitigation purposes in Madera County (Stebbins *et al.* 1995, California Natural Diversity Data Base 2003), (3) two small populations on Castle Airport, formerly Castle Air Force Base, in Merced County (California Natural Diversity Data Base 2003), (4) a small population on U.S. Bureau of Reclamation property that is managed by the

Madera Irrigation District (Stebbins *et al.* 1995, California Natural Diversity Data Base 2003), and (5) the small population in San Joaquin County that is on land used for educational purposes by the University of California Cooperative Extension (California Natural Diversity Data Base 2003).

2. *CHAMAESYCE HOOVERI* (HOOVER'S SPURGE)

a. Description and Taxonomy

Taxonomy.—Hoover's spurge is a member of the spurge family (Euphorbiaceae). This plant was originally named *Euphorbia hooveri*, based on a specimen collected by Hoover in Yettem, Tulare County (Wheeler 1940). At that time, the genus *Euphorbia* was viewed as comprising several subgenera, including *Chamaesyce* and *Euphorbia*. Webster (1975) subsequently elevated the subgenus *Chamaesyce* to the rank of genus based on growth patterns and physiology. The currently accepted scientific name, *Chamaesyce hooveri*, was validated when Koutnik (1985) published the new combination.

Several other species of *Chamaesyce* have ranges similar to that of *Chamaesyce hooveri* and may occur in the same habitats. *Chamaesyce ocellata* ssp. *ocellata* (yerba golondrina) is yellowish-green, has untoothed leaves, and lacks appendages on the glands. *Chamaesyce ocellata* ssp. *rattanii* (Stony Creek spurge) has hairy stems and leaves and the gland appendages are entire. *Chamaesyce serpyllifolia* (thyme-leaved spurge) also has entire appendages and further differs from *C. hooveri* in microscopic characters of the female flower (Wheeler 1941, Munz and Keck 1959, Koutnik 1993).

Description and Identification.—*Chamaesyce hooveri* (**Figure II-3**) trails along the ground, forming gray-green mats 5 to 100 centimeters (2.0 to 39.4 inches) in diameter (Broyles 1987, Stone *et al.* 1988). The stems are hairless and contain milky sap. The tiny (2 to 5 millimeter [0.08 to 0.20 inch]) leaves are opposite, rounded to kidney-shaped, with an asymmetric base and a toothed margin. In the genus *Chamaesyce*, the structures that appear to be flowers actually are groups of flowers; each group is referred to as a cyathium. The cyathium in *C. hooveri* consists of a tiny, cup-like structure 2 millimeters (0.08 inch) in diameter containing five clusters of male flowers and a single female flower. None of the flowers have petals, but instead have white appendages on the edge of the cup that resemble petals. Each appendage is divided into from three to five finger-like projections about 1 millimeter (0.04 inch) long. The appendages are attached to four reddish glands situated along the margin of the cup. The tiny, white seeds are contained in a spherical capsule 2 millimeters (0.08 inch) in

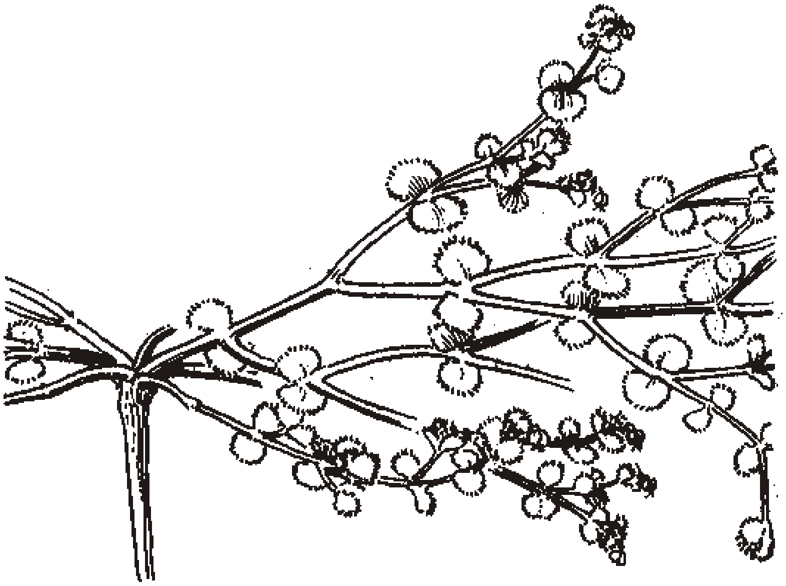

Figure II-3. Illustration of *Chamaesyce hooveri* (Hoover's spurge). Reprinted with permission from Abrams (1951), Illustrated Flora of the Pacific States: Washington, Oregon, and California, Vol. III. © Stanford University Press.

diameter on a stalk that hangs over the edge of the cup. One cyathium is located between each pair of leaves (Wheeler 1941, Munz and Keck 1959, Koutnik 1993). The chromosome number of this taxon has not been determined.

b. Historical and Current Distribution

Historical Distribution.—For decades, *Chamaesyce hooveri* was known from only three localities: near Yettem and Visalia in Tulare County, and near Vina in Tehama County. Collections were made from these three areas in the late 1930s and early 1940s (Wheeler 1941, Munz and Keck 1959, Stone *et al.* 1988). From 1974 through 1987, 21 additional occurrences of *C. hooveri* were reported. The majority of these (15) were in Tehama County. One to three occurrences were discovered during this period in each of Butte, Merced, Stanislaus, and Tulare Counties (Stone *et al.* 1988). The historical localities for this species were in the Northeastern Sacramento Valley, San Joaquin Valley, Solano-Colusa, and Southern Sierra Foothills Vernal Pool Regions (Keeler-Wolf *et al.* 1998) (**Figure II-4**).

Current Distribution.—Through August 2005, the California Natural Diversity Data Base (2005) listed 30 occurrences of *Chamaesyce hooveri*. In addition to these historical records, six occurrences were discovered in 1992 (three each in Glenn and Tulare Counties). Of the 30 California Natural Diversity Data Base (2003) occurrences, one each in Tehama and Tulare Counties are classified as extirpated; two others, in Butte and Tehama Counties, are “possibly extirpated” because this species was not observed for 2 consecutive years (Stone *et al.* 1988, California Natural Diversity Data Base 2003). Of the 26 occurrences presumed to be extant, only 3 have been observed within the past decade (California Natural Diversity Data Base 2003).

The main remaining area of concentration for *Chamaesyce hooveri* is within the Northeastern Sacramento Valley Vernal Pool Region. The Vina Plains of Tehama and Butte Counties contain 14 (53.8 percent) of the 26 known extant occurrences for *C. hooveri* (California Natural Diversity Data Base 2003) in an area of about 91 square kilometers (35 square miles; Stone *et al.* 1988). One other site in the same region is near Chico in Butte County. Seven of the extant occurrences are in the Southern Sierra Foothills Vernal Pool Region, including five in the Visalia-Yettem area of Tulare County and two in the Hickman-La Grange area of Stanislaus County. Three other occurrences are on the Sacramento National Wildlife Refuge in Glenn County, which is in the

Solano-Colusa Vernal Pool Region. The one other extant occurrence is on the Bert Crane Ranch in Merced County, which is within the San Joaquin Valley Vernal Pool Region (Keeler-Wolf *et al.* 1998, California Natural Diversity Data Base 2003).

c. Life History and Habitat

Reproduction and Demography.—*Chamaesyce hooveri* is a summer annual, but few details of its life history are known. Seeds of *C. hooveri* germinate after water evaporates from the pools; the plants cannot grow in standing water (Alexander and Schlising 1997). The indeterminate growth pattern allows the plants to continue growing as long as sufficient moisture is available. The proportion of seedlings surviving to reproduction has not been documented; in years of below-normal rainfall, seedling survival was characterized as "low" (Stone *et al.* 1988). Phenology varies among years and among sites, even for those populations in close proximity (Stone *et al.* 1988). Populations in Merced and Tulare Counties typically flower from late May through July, whereas those farther north in Stanislaus County and the Sacramento Valley flower from mid-June into October (Alexander and Schlising 1997, J. Silveira *in litt.* 2000, California Natural Diversity Data Base 2003). Seed set apparently begins soon after flowering. Seed production has not been quantified or studied in relation to environmental factors, but Stone *et al.* (1988) reported that large plants may produce several hundred seeds.

Demographic data suggest that seeds of *Chamaesyce hooveri* can remain dormant until the appropriate temperature and moisture conditions occur. This dormancy is evident from the fact that plants can be absent from a given pool for up to 4 years and then reappear in substantial numbers (Stone *et al.* 1988).

Beetles (order Coleoptera), flies (order Diptera), bees and wasps (order Hymenoptera), and butterflies and moths (order Lepidoptera) have been observed visiting the flowers of *Chamaesyce hooveri* and may potentially serve as pollinators (Stone *et al.* 1988, Alexander and Schlising 1997). Related species in the spurge family are pollinated by flies (Heywood 1978). Also, the glands on the cyathium produce nectar (Wheeler 1941), which is attractive to insects. Related species in the genus *Euphorbia* typically are cross-pollinated because the female flowers on each plant mature before the male (Heywood 1978), which may or may not be the case for *C. hooveri*.

Habitat and Community Associations*.—Chamaesyce hooveri* is restricted to vernal pools (Stone *et al.* 1988, Koutnik 1993, Skinner and Pavlik 1994). However, the plant appears to adapted to a wide variety of soils, which range in texture from clay to sandy loam. Specific soil series from which it has been reported include Anita, Laniger, Lewis, Madera, Meikle, Riz, Tuscan, Whitney, and Willows.

Natural pools in which the plant occurs are primarily classified as Northern Hardpan and Northern Claypan vernal pools (Sawyer and Keeler-Wolf 1995). In the Northeastern Sacramento Valley Vernal Pool Region, occupied pools are generally on acidic soils over iron-silica cemented hardpan. Most pools supporting *Chamaesyce hooveri* in the San Joaquin Valley, Solano-Colusa, and Southern Sierra Foothills vernal pool regions are on neutral to saline-alkaline soils over lime-silica cemented hardpan or claypan (Broyles 1987, Stone *et al.* 1988, Sawyer and Keeler-Wolf 1995, California Natural Diversity Data Base 2003).

Vernal pools supporting *Chamaesyce hooveri* typically occur on alluvial fans or terraces of ancient rivers or streams, with a few on the rim of the Central Valley basin. In addition, *C. hooveri* has been reported from several pools that were formed artificially when small ponds were created in appropriate soil types (California Natural Diversity Data Base 2003).

The pools supporting this species vary in size from 0.19 to 243 hectares (0.47 to 600 acres), with a median area of 0.58 hectare (1.43 acres) (Stone *et al.* 1988). This species may occur along the margins or in the deepest portions of the dried pool-bed (Stone *et al.* 1988, Alexander and Schlising 1997). Deeper pools apparently provide better habitat for this species because the duration of inundation is longer and the deeper portions are nearly devoid of other vegetation, thus limiting competition from other plants (J. Stebbins *in litt.* 2000*a*, Stone *et al.* 1988).

Throughout its range, two of the most frequent associates of *Chamaesyce hooveri* are the rare vernal pool grasses *Tuctoria greenei* and *Orcuttia pilosa*. However, *Chamaesyce hooveri* does tend to grow in different portions of the pools than these grasses (Stone *et al.* 1988, Alexander and Schlising 1997). Other plants addressed in this recovery plan that grow with *Chamaesyce hooveri* are *Atriplex persistens*, *Eryngium spinosepalum*, *Neostapfia colusana*, *Orcuttia inaequalis*, *Astragalus tener* var. *ferrisiae*, and *Gratiola heterosepala* (Oswald and Silveira 1995, Alexander and Schlising 1997, California Natural Diversity Data Base 2005). In the Vina Plains, other common associates of *Chamaesyce hooveri* are *Marsilea vestita* (water shamrock), *Eryngium castrense* (common coyote-thistle), *Convolvulus arvensis* (bindweed), and *Amaranthus albus* (white tumbleweed) (Alexander and Schlising 1997). In Glenn, Merced, and Tulare Counties, *Cressa truxillensis* (alkali weed), *Distichlis spicata* (saltgrass), *Frankenia salina* (frankenia), *Grindelia camporum* (Great Valley gumplant), and other plants tolerant of saline-alkali soils are typical associates of *Chamaesyce hooveri* (Stone *et al.* 1988, J. Silveira *in litt.* 2000, California Natural Diversity Data Base 2005).

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 *Chamaesyce hooveri* are described below.

Agricultural conversions (*i.e.,* from grasslands or pastures to croplands, or from one crop-type to another) are a continuing specific threat, particularly in Stanislaus County (Stone *et al.* 1988). Competition from invasive native and non-native plant species threatens nine of the extant occurrences, including eight in the Vina Plains and one on the Sacramento National Wildlife Refuge in Glenn County. Native competitors of *Chamaesyce hooveri* include *Eryngium* spp., *Malvella leprosa* (alkali mallow, a noxious weed according to Hill 1993), *Phyla nodiflora* (lippia), *Scirpus acutus* var. *occidentalis* (hard-stemmed tule), *Scirpus maritimus* (alkali bulrush), and *Xanthium strumarium* (cocklebur). Nonnative competitors include *Convolvulus arvensis* (a noxious weed according to Dempster 1993) and *Crypsis schoenoides* (swamp grass) (J. Silveira *in litt.* 2000, California Natural Diversity Data Base 2003). On the Vina Plains Preserve (in 1995), the pools with *Chamaesyce hooveri* also had the highest frequency of *Convolvulus arvensis* (Alexander and Schlising 1997). Increasing dominance by these competitors may be associated with changes in hydrology and livestock grazing practices (Stone *et al.* 1988, Alexander and Schlising 1997, California Natural Diversity Data Base 2003).

Five of the remaining occurrences of *Chamaesyce hooveri* are subject to specific hydrologic threats; four of the five are in the San Joaquin Valley and the fifth is in the Vina Plains. Hydrology has been altered by (1) construction of levees and other water barriers and (2) runoff from adjacent agricultural operations, roads, and culverts. Such impacts result in some pools receiving insufficient water, while others remain flooded for too long to allow growth of *C. hooveri*. Although no occurrences have been completely extirpated due to hydrologic changes, the species has been eliminated from one or more individual pools at several sites and a number of the remaining populations appear to be in decline (Stone *et al.* 1988, Stebbins *et al.* 1995, California Natural Diversity Data Base 2003).

Some specific threats also are continuing due to inappropriate livestock grazing practices. While livestock generally do not forage on *Chamaesyce hooveri*, because it grows very close to the ground and contains a toxic, milky sap

(Wheeler 1941, Stone *et al.* 1988), cattle trampling has nevertheless been identified as seriously reducing *C. hooveri* populations at one site each in Butte and Stanislaus Counties (Stone *et al.* 1988); relatively high livestock stocking rates such as often prevail during summer months could similarly damage this plant's populations at other locations.

The threat posed by small population size may also be a significant continuing factor. At least 5 of the known occurrences of this plant total fewer than 100 individuals in years of most-favorable conditions (California Natural Diversity Data Base 2003). Two other occurrences with populations of only a few hundred individuals also may be similarly threatened. Such small populations are subject to extirpation from random events, including extrinsic factors such as weather and intrinsic factors such as genetic drift (Shaffer 1981, Menges 1991).

Another specific threat is the potential lack of pollinators. However, because the specific insects that pollinate *Chamaesyce hooveri* have not yet been identified, assessment of their status and providing them with protection, if necessary, cannot yet be undertaken. If essential pollinators are declining through habitat loss, *C. hooveri* may be declining in response. Another very localized threat to *C. hooveri* on certain public and private lands is direct trampling, particularly in areas that receive high controlled human usage or vandalism activity (U.S. Fish and Wildlife Service 1997*a*).

e. Conservation Efforts

Chamaesyce hooveri was listed as a threatened species on March 26, 1997 (U.S. Fish and Wildlife Service 1997*a*). *Chamaesyce hooveri* is not listed under the California Endangered Species Act (California Department of Fish and Game 1999). The California Native Plant Society included *C. hooveri* on its first list of rare plants (Powell 1974); currently, *C. hooveri* is on List 1B and is considered to be "endangered in a portion of its range" (California Native Plant Society 2001). In 2005, critical habitat was designated for *C. hooveri* 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).

Ten occurrences of *Chamaesyce hooveri* are in preserves or on public land. The Vina Plains Preserve, managed by The Nature Conservancy, includes four of the extant occurrences and one presumed extirpated occurrence. The California Department of Fish and Game manages two of the extant Tulare County occurrences as part of the Stone Corral Ecological Reserve complex. Three of the extant occurrences are on the Sacramento National Wildlife Refuge (California

Natural Diversity Data Base 2003). The Sacramento National Wildlife Refuge populations have been monitored annually since 1992 (J. Silveira *in litt.* 2000). One additional occurrence of *C. hooveri* in Merced County is on private land (the Bert Crane Ranch) that is protected from development by a conservation easement (J. Silveira *in litt.* 2000).

We funded a status survey for *Chamaesyce hooveri* and other vernal pool plants in 1986 and 1987 (Stone *et al.* 1988), resulting in 10 new occurrences. We and the California Department of Fish and Game jointly funded an ecological study of the Vina Plains Preserve pools, which was conducted by faculty from California State University, Chico (Alexander and Schlising 1997). Independent surveys conducted by Joseph Silveira led to discovery of the Merced and Glenn county occurrences (J. Silveira *in litt.* 2000). Private landowners also have contributed to conservation of this species. One pool in Tehama County was fenced by the property owner in the late 1980s, to exclude livestock (Stone *et al.* 1988).

3. *ERYNGIUM CONSTANCEI* (LOCH LOMOND BUTTON-CELERY)

a. Description and Taxonomy

Taxonomy.—Loch Lomond button-celery, specifically known as *Eryngium constancei* (Sheikh 1983), is a member of the carrot family (Apiaceae). This species was only recently described and therefore has no history of name changes. The common name was derived from the type locality, Loch Lomond, which is in Lake County (Sheikh 1983). Other common names for this species are Loch Lomond coyote-thistle (Skinner and Pavlik 1994) and Constance's coyote-thistle (Smith *et al.* 1980).

Description and Identification.—Certain features are common to species of the genus *Eryngium*. Unlike most vernal pool plants, *Eryngium* species are biennial or perennial, with an overwintering rootstock. The plant parts are often spiny, hence the word "thistle" in the common names. The earliest leaves produced from the rootstock each year are long and tubular with crosswise partitions. Leaves produced later in the growing season typically have a narrow petiole and a broader blade, which is usually lobed. *Eryngium* plants also have leaves at both the base of the plant and on the stem; stem leaves are typically opposite, but the upper leaves may be alternate. The tiny flowers are clustered into spiny heads. Individual fruits are small, dry, often scaly, and composed of two one-seeded, indehiscent units which separate at maturity and function as seeds.

Eryngium constancei has slender, loosely branched stems 20 to 30 centimeters (7.9 to 11.8 inches) tall, which may be decumbent or upright. The entire plant is covered with downy hairs. The mature leaves are 11 to 16 centimeters (4.3 to 6.3 inches) long, with the petiole accounting for most of the length. The leaf blade is lance-shaped and may have a smooth, sharply toothed, or lobed margin. The bracts are narrow, spiny-margined, and shorter than the leaves. In this species, the rounded flower heads are only 3 to 5 millimeters (0.12 to 0.20 inch) in diameter; however, the stems supporting the flower heads may be as much as 8 centimeters (3.1 inches) long. Each flower head contains only five to seven tiny flowers. The petals are approximately 1 millimeter (0.04 inch) long and are white or tinged with purple. Fruits of this species are egg-shaped and approximately 2 millimeters (0.08 inch) long. The diploid chromosome number of *E. constancei* is 32 (Sheikh 1983, Constance 1993).

The downy hairs and sparsely-flowered heads of *Eryngium constancei* distinguish it from other *Eryngium* species. All other species in the genus are hairless and have more than 10 flowers per head (Sheikh 1983, Constance 1993).

b. Historical and Current Distribution

Historical Distribution.—For over 5 decades, this species was known only from Loch Lomond, where it was first collected in 1941 (Sheikh 1983). *Eryngium constancei* has always been restricted to the Lake-Napa Vernal Pool Region (Keeler-Wolf *et al.* 1998) (**Figure II-5**).

Current Distribution.—Three additional populations of *Eryngium constancei* were discovered during the late 1990s, bringing the total number of populations to four. Three of the *E. constancei* populations are in Lake County and the other is in Sonoma County; all are in the Lake-Napa Vernal Pool Region (Keeler-Wolf *et al.* 1998). In Lake County, the species grows at Loch Lomond, Dry Lake (California Natural Diversity Data Base 2003), and in an unnamed pool near Cobb (A. Howald *in litt.* 1995, J. Diaz-Haworth pers. comm. 2001). The Sonoma County occurrence is composed of two pools on Diamond Mountain (California Natural Diversity Data Base 2003).

The Sonoma County plants differ slightly from the description above in that the heads have more flowers and some individuals have stout stems, but their identity was verified by species expert Dr. Lincoln Constance (Hrusa and Buckmann 2000). The site near Cobb is not yet listed as an occurrence in the California Natural Diversity Data Base (2003), but Dr. Constance has confirmed the identity of the specimens (A. Howald *in litt.* 1995). Based on an analysis of soils, slope, elevation, and climate, only a very limited area in Lake and Napa Counties is considered to be suitable habitat for *Eryngium constancei* (Holland 2003).

c. Life History and Habitat

Reproduction and Demography.—*Eryngium constancei* flowers after the water evaporates from the pools, typically between June and August (California Department of Fish and Game 1985, 1994). Little else is known about the reproductive ecology or demography of this species. However, its life history may be quite similar to that of *E. vaseyi* (Vasey's coyote-thistle): producing a tuft of tubular leaves underwater from the perennial rootstock or from a newly-germinated seed in the late winter or early spring; developing broad terrestrial leaves later in the spring as the water evaporates; flowering in the summer; and developing fruits in July or August (Jepson 1922).

The demography of *Eryngium constancei* has not been studied. However, population size would not be expected to vary substantially among years because it is a perennial. The Dry Lake and Sonoma County populations numbered in the tens of thousands in both 1996 and 1997. However, in 1996, the Loch Lomond population was at least two orders of magnitude larger than in 1997 (California Natural Diversity Data Base 2003). The size of the fourth population has not been reported. Germination dates and conditions for *E. constancei* have not been determined, nor have pollinators or seed dispersal agents been identified.

Habitat and Community Associations.—Habitat information is available only for the three occurrences catalogued by the California Natural Diversity Data Base (2005). Loch Lomond is a small, intermittent lake with a surface area of about 3 hectares (7 acres) at maximum inundation (U.S. Fish and Wildlife Service 1985*b*). This wetland is classified as a Northern Volcanic Ashflow Vernal Pool (Sawyer and Keeler-Wolf 1995, California Natural Diversity Data Base 2003) and is on Collayomi-Aiken-Whispering complex soils. The lake is at an elevation of 853 meters (2,800 feet). The surrounding area is mountainous and supports a mixed forest dominated by *Pinus ponderosa* (ponderosa pine), *Quercus kelloggii* (black oak), *Pseudotsuga menziesii* (Douglas fir), and understory of *Arctostaphylos* spp. (manzanita) and *Ceanothus* spp. (California lilac) (California Department of Fish and Game 1994, K. Aasen *in litt.* 1995, California Natural Diversity Data Base 2003). *Eryngium constancei* occurred throughout the lakebed in 1994, but grew most densely towards the center, where it was one of the most abundant species. Other plants that were abundant in Loch Lomond that year included *Perideridia gairdneri* ssp. *gairdneri* (Gairdner's yampah), *Cuscuta howelliana* (Boggs Lake dodder), *Mentha pulegium* (pennyroyal), *Plagiobothrys stipitatus* (stalked popcornflower), *Plagiobothrys tener* (slender popcorn flower), and a species of navarretia (California Department of Fish and Game 1994) that has been identified as an intergrade between *Navarretia leucocephala* ssp. *plieantha* and *N. leucocephala* ssp. *pauciflora* (A. Day *in litt.* 1997). *Eryngium aristulatum* (Jepson's button-celery), a close relative of *E. constancei*, also co-occurred in the lakebed (California Department of Fish and Game 1994).

On Diamond Mountain, the pools where *Eryngium constancei* grows are shallow and spring-fed (California Natural Diversity Data Base 2003); they are classified as Northern Basalt Flow Vernal Pools (Sawyer and Keeler-Wolf 1995, California Natural Diversity Data Base 2003). The surface area of the occupied pools and the soil type have not yet been determined. The surrounding plant community consists of *Quercus garryana* (Oregon oak), *Q. lobata* (valley oak), and *Pseudotsuga menziesii* (Hrusa and Buckmann 2000). The elevation of the site has been variously reported as 628 meters (2,060 feet) (California Natural Diversity Data Base 2003) or 685 meters (2,247 feet) (Hrusa and Buckmann 2000). *Eryngium constancei* was dominant in both pools in 1996 (B. Hunter *in litt.* 1996). Associated plant species that year included *Pogogyne douglasii* (Douglas' pogogyne), *Perideridia kelloggii* (Kellogg's yampah), *Perideridia howellii* (Howell's yampah), *Eleocharis* spp. (spikerush), *Madia elegans* ssp. *densifolia* (leafy common madia), and *Clarkia purpurea* (winecup clarkia) (California Natural Diversity Data Base 2003).

Less information is known about the Cobb and Dry Lake occurrences. The surface area of the Cobb pool is approximately 2 hectares (5 acres) (J. Diaz-Haworth pers. comm. 2001), but its elevation and soil type are not known. The endangered plant *Navarretia leucocephala* ssp. *pauciflora* is the only associate that has been reported at the Cobb pool (A. Howald *in litt.* 1995). The Dry Lake pool is at an elevation of 463 meters (1,520 feet) and is surrounded by *Quercus douglasii* (blue oak) woodland. In 1997, *Eryngium constancei* was the dominant species and was associated with unidentified rushes (*Juncus* spp.; California Natural Diversity Data Base 2003). Soils underlying Dry Lake are in the Sobrante-Guenoc-Hambright complex.

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 *Eryngium constancei* are described below.

Specific threats to two of the four populations are that at least one of the occupied pools at Diamond Mountain may be converted to a vineyard, and the owner of

Dry Lake has proposed excavating the pool for a reservoir (California Natural Diversity Data Base 2003). Changes in hydrology threaten three of the four occurrences. In addition, runoff from adjacent roads and swimming pools creates excess water flow, whereas drainage ditches, culverts, and diversion of a natural spring are reducing the flow of water to *Eryngium constancei* habitat (Hrusa and Buckmann 2000, California Natural Diversity Data Base 2005).

Larger-scale hydrological alterations, including commercial development and timber harvesting, are also occurring in all the watersheds where *Eryngium constancei* grows, thus posing added hydrological threats (U.S. Fish and Wildlife Service 1985*b*, 1986, 1993*b*; California Department of Fish and Game 1994; K. Aasen *in litt.* 1995; B. Hunter *in litt.* 1996; California Natural Diversity Data Base 2005).

The extremely restricted distribution of *Eryngium constancei* is an additional threat to this species. Although the individual populations of *E. constancei* are sufficiently large that intrinsic problems such as genetic drift are not a concern, other random events could cause the species to go extinct. Catastrophic weather events, climate change, or other unforeseen circumstances potentially could eliminate all of the populations, due the very limited distribution of this plant.

A more subtle threat that could cause decline of *Eryngium constancei* populations would be a lack of pollinators, if they are necessary for seed-set. Pollinating insects may require habitat outside of the vernal pools, which could be lost if it is not identified and targeted for protection. However, neither the importance nor status of pollinators have been identified at this time.

e. Conservation Efforts

In 1985, we declared *Eryngium constancei* to be endangered under emergency listing provisions of the Endangered Species Act (U.S. Fish and Wildlife Service 1985*b*). Following this emergency listing, we published a final rule on December 23, 1986 determining *E. constancei* to be an endangered species (U.S. Fish and Wildlife Service 1986). However, due to conservation efforts directed at Loch Lomond (see below), we later proposed to downlist the species to threatened status (U.S. Fish and Wildlife Service 1993); action on this proposal is still pending.

The California Fish and Game Commission listed *Eryngium constancei* as endangered in 1987 (California Department of Fish and Game 1991). The California Native Plant Society has considered the plant rare and endangered since 1980 (Smith *et al.* 1980). *Eryngium constancei* currently is on the

California Native Plant Society's List 1B, with the highest endangerment rating possible (California Native Plant Society 2001).

California's Wildlife Conservation Board and Public Works Board acquired Loch Lomond and a small adjacent buffer in 1988 to prevent its conversion to a recreational lake. The site is now known as the Loch Lomond Vernal Pool Ecological Reserve. In 1989, the California Department of Fish and Game, with financial assistance from us, fenced the perimeter of the lake to exclude off-road vehicles and other detrimental recreational use (U.S. Fish and Wildlife Service 1993, California Department of Fish and Game 1994). In 1994, the California Department of Fish and Game prepared a management plan for the reserve and obtained a baseline population estimate for *Eryngium constancei*. Periodic monitoring of the population and interpretive displays about the species are planned (California Department of Fish and Game 1994).

A local citizen with an interest in conservation bought the Cobb parcel where *Eryngium constancei* grows. She intends to protect the vernal pool and its associated species (J. Diaz-Haworth pers. comm. 2001, B. Flynn pers. comm. 2001). The California Department of Fish and Game has reviewed timber harvest plans and other land uses for areas adjacent to any of the populations and has provided recommendations on how to avoid impacts to *E. constancei* (*e.g.,* K. Aasen *in litt.* 1995, B. Hunter *in litt.* 1996, A. Buckmann *in litt.* 1998). In addition, their biologists conducted surveys for this species (U.S. Fish and Wildlife Service 1985b), and the agency is investigating ways to protect the Diamond Mountain occurrence (Hrusa and Buckmann 2000).

4. *LASTHENIA CONJUGENS* (CONTRA COSTA GOLDFIELDS)

a. Description and Taxonomy

Taxonomy.**—**Greene (1888) first described Contra Costa goldfields, naming this species *Lasthenia conjugens.* The type locality is Antioch, in Contra Costa County (Greene 1888). Hall (1914) later lumped Contra Costa goldfields with the common species Fremont's goldfields, which at that time was called *Baeria fremontii*. Ferris (1958) proposed the name *Baeria fremontii* var. *conjugens* to recognize the distinctiveness of Contra Costa goldfields. Finally, Ornduff (1966) restored Greene's original name and rank, returning this species to the genus *Lasthenia*. The two closest relatives of *Lasthenia conjugens* are *L. burkei* (Burke's goldfields) and *L. fremontii* (Fremont's goldfields).

Description and Identification.—The stems of *Lasthenia conjugens* (**Figure II-6**) are 10 to 30 centimeters (4 to 12 inches) tall, somewhat fleshy, and usually branched. The leaves are opposite and narrow; the lower leaves are entire, but stem leaves have one or two pairs of narrow lobes. The daisy-like flower heads are solitary. Both the disk and ray flowers are golden-yellow, and the ligules are 5 to 10 millimeters (0.20 to 0.39 inch) long. Each head has numerous disk flowers and 6 to 13 ray flowers. The club-shaped achenes are no more than 1.5 millimeters (0.06 inch) long and are shiny, olive-green, hairless, and lack a pappus (Greene 1888, Ornduff 1993*b*). *Lasthenia conjugens* has a diploid chromosome number of 12 (Ornduff 1966, Ornduff 1993*b*).

Whereas all other species of *Lasthenia* have either completely free phyllaries or phyllaries fused more than two-thirds of their length, *L. conjugens* has phyllaries fused from one-quarter to one-half their length. The free phyllaries and presence of a pappus distinguish both *L. burkei* and *L. fremontii* from *L. conjugens* (Ornduff *1969*, Ornduff 1979, Ornduff 1993*b*). *Blennosperma* species can be differentiated from *L. conjugens* by the alternate leaves, clustered (as opposed to solitary) flower heads, and paler yellow ligules of the former (Ornduff 1993*a*,*b*).

b. Historical and Current Distribution

Historical Distribution.—*Lasthenia conjugens* occurred historically in seven vernal pool regions: Central Coast, Lake-Napa, Livermore, Mendocino, Santa Barbara, Santa Rosa, and Solano-Colusa (**Figure II-7**) (Keeler-Wolf *et.al*. 1998). In addition, several historical occurrences in Contra Costa County are outside of the defined vernal pool regions (Keeler-Wolf *et al.* 1998, California Natural Diversity Data Base 2003). Many collection sites from the late 19th and early 20th centuries are difficult to pinpoint because locality information on specimen labels often was vague. Ornduff (1966) reported collections from 13 sites in Alameda, Contra Costa, Mendocino, Napa, Santa Barbara, Santa Clara, and Solano Counties. Although he cited three specimens each from Contra Costa (including the type) and Santa Barbara Counties, Ornduff (1966, 1979) noted that the species was most common in Solano County. One additional site in Alameda County was documented in 1959 by G. Thomas Robbins, who collected a specimen (# 3963, housed at the Jepson Herbarium) on the “shore of San Francisco Bay” south of Russell.

Figure II-6. Photograph of *Lasthenia conjugens* (Contra Costa goldfields). (© John Game 1998; reprinted with permission).

Current Distribution.—Of the 32 occurrences of *Lasthenia conjugens* recorded between 1884 and 2003 that are currently (through August 2005) catalogued in the California Natural Diversity Data Base (2005), 22 are likely extant. Two additional populations exist at the former Fort Ord site that have not been reported to the California Natural Diversity Database (W. Collins, U.S. Army, pers. comm. 2005). Thus the total number of likely extant populations is 24. However, there is uncertainty due in part to the difficulty of relocating sites based on early vague site descriptions and also because this species may reappear on a site after several years, even if it is absent during a given survey. *Lasthenia conjugens* presumably remains in all of the vernal pool regions where it occurred historically, except for the Santa Barbara Vernal Pool Region. However, by far the greatest concentration of this species is in the Solano-Colusa Vernal Pool Region; the specific area east of Fairfield in Solano County contains 10 occurrences that are presumed extant, plus 1 that may be extirpated. Another extant occurrence is near Rodeo in Contra Costa County (California Natural Diversity Data Base 2005) which was captured within the Solano-Colusa Vernal Pool Region. Six occurrences are extant in the Central Coast Vernal Pool Region, including four at the former Fort Ord in Monterey County, one at San Francisco Bay National Wildlife Refuge, and one near Fremont, both in Alameda County (California Natural Diversity Data Base 2005). One occurrence is presumed to remain extant in the Mendocino Vernal Pool Region near Manchester in Mendocino County. In the Lake-Napa Vernal Pool Region, one occurrence is presumed to remain extant at Suscol Ridge in Napa County. Another Napa County site, Milliken Canyon, also in the Lake-Napa Vernal Pool Region contained only a single plant in 1987 and may or may not be extant (California Natural Diversity Data Base 2005). One recently discovered occurrence extends the range of *Lasthenia conjugens* to the northern part of Marin County near the boundary with Sonoma County (California Natural Diversity Data Base 2005). This location is not within the vernal pool regions covered by this plan.

c. Life History and Habitat

Little is known about this plant. However, germination, growth, reproduction, and demography are likely to be similar to *Lasthenia burkei*, a close relative that has been studied more intensively.

Reproduction and Demography.—As a vernal pool annual plant, seeds of *Lasthenia conjugens* would be expected to germinate in response to autumn rains, with the plants maturing in a single growing season, setting seed, and dying back during the summer. However, detailed research on the life cycle has not been conducted. Laboratory germination tests on the related species *L. burkei* (Rancho Santa Ana Botanical Garden unpublished data), indicated that germination occurs rapidly in a single flush (peak germination date the same as first germination date), with relatively high germination rates (49 to 100 percent). *Lasthenia burkei* plants that establish in autumn under natural conditions may tolerate prolonged submergence but do not begin rapid stem growth until vernal pools and swales drain down during late winter or early spring (Ornduff 1969, Patterson *et al.* 1994).

Lasthenia conjugens flowers from March through June (Ornduff 1966, Ornduff 1979, Skinner and Pavlik 1994). The flowers are self-incompatible (Crawford and Ornduff 1989). Although *L. conjugens* has not been the subject of pollinator studies, observations suggest that the same insects visit all outcrossed species of *Lasthenia*, rather than concentrating on any particular species (Thorp 1976). Insect visitors to flowers of *Lasthenia* belong to five orders: Coleoptera, Diptera, Hemiptera (true bugs), Hymenoptera, and Lepidoptera (Thorp and Leong 1998). Most of these insects are generalist pollinators. All of the specialist pollinators of *Lasthenia* are solitary bees (family Andrenidae); these pollinators include two species in the subgenus *Diandrena* (*Andrena submoesta* and *A. puthua*) and five or six species in the subgenus *Hesperandrena* (*Andrena baeriae, A. duboisi, A. lativentris*, and two or three undescribed species) (Thorp and Leong 1998). The extent to which pollination of *L. conjugens* depends on host-specific bees or more generalist pollinators is currently unknown.

Seed dispersal mechanisms in *Lasthenia conjugens* are unknown. However, the lack of a pappus or even hairs on the achenes makes wind dispersal unlikely (Ornduff 1976). Seed longevity, survival rates, fecundity, and other demographic parameters have not been investigated. However, as with other vernal pool annuals, population sizes have been observed to vary by up to four orders of magnitude from year to year (California Natural Diversity Data Base 2003). Thus, this species most likely forms a persistent soil seed bank. Seeds of the related species *L. burkei* have been stored artificially for many years with little loss of viability (C. Patterson, pers. comm.). However, the maximum duration of viable seed in the soil is not known.

Habitat and Community Associations.—*Lasthenia conjugens* typically grows in vernal pools, swales, moist flats, and depressions within a grassland matrix (California Natural Diversity Data Base 2003). However, several historical collections were from populations growing in the saline-alkaline transition zone between vernal pools and tidal marshes on the eastern margin of the San Francisco Bay (P. Baye *in litt.* 2000*a*). The herbarium sheet for one of the San Francisco Bay specimens notes that the species also grew in evaporating ponds used to concentrate salt (P. Baye *in litt.* 2000*b*). The vernal pool types from which this species has been reported are Northern Basalt Flow, Northern Claypan, and Northern Volcanic Ashflow (Sawyer and Keeler-Wolf 1995). The landforms and geologic formations for sites where *L. conjugens* occurs have not yet been determined. Most occurrences of *L. conjugens* are at elevations of 2 to 61 meters (6 to 200 feet), but the recently discovered Monterey County occurrences are at 122 meters (400 feet) and one Napa County occurrence is at 445 meters (1,460 feet) elevation (California Natural Diversity Data Base 2003).

The soil types have not yet been identified for most *Lasthenia conjugens* localities. However, soil series from which it is known are: Aiken, Antioch, Concepcion, Conejo, Crispin, Haire, Linne, Los Robles, Rincon, Solano, and San Ysidro, plus the Arnold-Santa Ynez, Hambright-rock outcrop, and Los Osos complexes. Soil textures, where known, are clays or loams. At least in Solano County and on the shores of San Francisco Bay, *L. conjugens* grows in alkaline or saline-alkaline sites (P. Baye *in litt.* 2000*a*, P. Baye *in litt.* 2000*b*, California Natural Diversity Data Base 2003).

Many plant species grow in association with *Lasthenia conjugens* in various parts of its range, but no comprehensive survey of associates has been undertaken. The two most commonly reported associates are *Lolium multiflorum* (Italian ryegrass) and *Plagiobothrys* spp. (popcorn flower). Other plant species that occur at several *Lasthenia conjugens* sites include *Cotula coronipifolia* (brass buttons), *Downingia pulchella* (valley downingia), *Eryngium aristulatum* (California eryngo), *Lasthenia glaberrima* (smooth goldfields), *Myosurus minimus* (common mousetail), and *Pleuropogon californicus* (California semaphore grass). Among the rare plants addressed in this recovery plan, those that co-occur with *Lasthenia conjugens* include *Astragalus tener* var. *tener* at two sites and *Navarretia leucocephala* ssp. *pauciflora* and *Legenere limosa* at one site each (California Natural Diversity Data Base 2003).

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 *Lasthenia conjugens* are described below.

With the exception of Travis Air Force Base, the entire concentration area in Solano County is within the City of Fairfield's sphere of influence and subject to relatively intense development pressure under the City's general plan. Numerous construction projects, including residential development, landfill expansion, and drainage channels, are proposed and pose specific threats (U.S. Fish and Wildlife Service 1997*b*). Some projects, such as proposed highways, may disturb habitat on Travis Air Force Base as well as in the Fairfield area (U.S. Fish and Wildlife

Service 2002). Threats due to conversions to vineyards are also continuing. The largest Napa County occurrence of this plant, at Suscol Ridge (California Natural Diversity Data Base 2003), is imminently threatened by vineyard conversion; the site is already under a 25-year lease to a winery (P. Baye *in litt.* 2000*a*).

Competition from nonnative plants, particularly *Lolium multiflorum* (Italian ryegrass), threatens at least eight occurrences of *Lasthenia conjugens*, several of which are also targeted for development (California Natural Diversity Data Base 2003). Nonnative grasses such as *Lolium multiflorum* not only shade out short-statured plants like *Lasthenia conjugens*, but can also negatively impact vernal pool hydrology by decreasing inundation periods in pools (Marty 2004). In addition, encroachment by nonnative plants often follows surface-disturbing activities, such as discing, grading, filling, ditch construction, and off-road vehicle use, which can alter hydrology and microhabitat conditions. Such surface disturbances are visually apparent at nine sites occupied by *L. conjugens*, four of which do not yet have reported problems with nonnative species (California Natural Diversity Data Base 2003). Management strategies including grazing, mowing, and burning are vital to controlling these weed species. The California Natural Diversity Data Base (2003) also cites inappropriate livestock grazing practices as a threat to seven occurrences of *Lasthenia conjugens*. However, the removal of livestock grazing from at least one site in Contra Costa County has caused significant population declines in this species (J. Marty, pers. comm. 2004). Therefore, the complete elimination of grazing, as well as overgrazing, may have adverse impacts to the *Lasthenia conjugens* and other species in this plan.

e. Conservation Efforts

We listed *Lasthenia conjugens* as endangered on June 18, 1997 (U.S. Fish and Wildlife Service 1997*b*). This species does not currently have any State listing status. The California Native Plant Society has considered *L. conjugens* rare and endangered since the organization's first list was published (Powell 1974); *L. conjugens* currently is on List 1B, the highest endangerment rating possible (Skinner and Pavlik 1994). In 2005, critical habitat was designated for *L. conjugens* 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).

Six occurrences of *Lasthenia conjugens* are on public lands: four at Fort Ord, and one each at San Francisco Bay National Wildlife Refuge and Travis Air Force Base. These lands are administered by the U.S. Bureau of Land Management, the

U.S. Fish and Wildlife Service, and the U.S. Air Force, respectively. All of the Fort Ord occurrences are on land within the Habitat Management Plan Habitat Reserve lands and will be conserved and managed in perpetuity (W. Collins *in litt*. 2005; U.S. Army Corps of Engineers 1997). The population at Travis Air Force Base, including over 20 acres of adjacent restored vernal pools, is protected as a special ecological preserve, with protective measures and appropriate management for the species provided in the Travis Air Force Base Land Management Plan.

Seasonal managed cattle grazing has been returned to two conservation sites supporting *Lasthenia conjugens*: 1) the Warm Springs Seasonal Wetland Unit of the Don Edwards San Francisco Bay National Wildlife Refuge in Alameda County, and 2) the State Route 4 Preserve managed by the Muir Heritage Land Trust in Contra Costa County. The *L. conjugens* population at the Warm Springs Unit has declined during the last 10 years due to many factors including competition by nonnative plant species. During this time period, grazing, which occurred intermittently at the Warm Springs Unit since the 1800s, has been excluded by the Refuge until a management plan could be developed. The decline in the *L. conjugens* population at the Warm Springs Unit cannot be attributed to a single factor, but most likely results from the complex interaction of several variables including current and historical land uses, the abiotic environment, and annual climatic variation. The increasing dominance of nonnative grasses, however, coincides with the suspension of livestock grazing, suggesting that the lack of a disturbance regime may be a primary factor in the degradation of habitat for *L. conjugens* at this site (U.S. Fish and Wildlife Service 2004). The population of *L. conjugens* at the State Route 4 Preserve, which was protected as part of compensation for the construction of the State Route 4 Gap Closure Project, has also declined in recent years. The decline may be due to a number of causes, including below normal precipitation and competition from nonnative species (Pardieck 2003). The site had been grazed heavily for many years resulting in stream channel erosion. Grazing was suspended in 2000 and the numbers of plants dropped sharply in 2001 and continued to decline the following year. Controlled grazing has been reintroduced to control the amount of seed and thatch produced by nonnative plants.

5. *LIMNANTHES FLOCCOSA* SSP. *CALIFORNICA* (BUTTE COUNTY MEADOWFOAM)

a. Description and Taxonomy

Taxonomy.—Before 1973, Butte County meadowfoam was not differentiated from the more widespread woolly meadowfoam (*Limnanthes floccosa* ssp. *floccosa*). Then, Arroyo (1973) determined that Butte County meadowfoam was a distinct taxon and gave it the scientific name *Limnanthes* *floccosa* ssp. *californica*. The type locality is in Butte County between Chico and Oroville, near the intersection of State Highway 99 and Shippee Road (Arroyo 1973). An alternative common name, Shippee meadowfoam, is derived from the type locality (California Department of Fish and Game 1987*a*, Ornduff 1993*c*). *Limnanthes floccosa* ssp. *californica* is a member of the meadowfoam or false mermaid family (Limnanthaceae), which is a small family comprising only 2 genera and 10 species (Ornduff 1993*c*).

Description and Identification.— *Limnanthes floccosa* ssp. *californica* is a small annual with erect stems less than 25 centimeters (9.8 inches) tall. The stem and leaves are densely pubescent. The alternate leaves are pinnately compound, up to 8 centimeters (3.1 inches) long, and consist of 5 to 11 leaflets on a long petiole. The individual leaflets are approximately 1 centimeter (0.4 inch) long and vary from narrow to egg-shaped; their margins may be smooth, toothed, or lobed. A single flower arises in the axil of each upper leaf. The fragrant flowers are cup- or bowl-shaped and consist of 5 petals, 5 sepals, 5 pistils, and 10 stamens on a long flower stalk. The petals are 8 to 10 millimeters (0.31 to 0.39 inch) long, white with yellow veins, and have two rows of hairs at the base. The sepals are about the same length as the petals and are densely pubescent on both their inner and outer surfaces. Although the sepals are not fused, the dense hairs hold them together, preventing the flower from opening fully. The pistils are separate at the base, but the upper parts are fused. Each pistil is capable of producing a nutlet; the nutlets are egg-shaped, 3 to 4.5 millimeters (0.12 to 0.18 inch) long, and covered with cone-shaped tubercles. As the nutlets mature, the petals turn inward, and at maturity the entire flower, including the nutlets, falls off the plant as a unit. The diploid chromosome number for all *Limnanthes* species is 10 (Mason 1952, Arroyo 1973, McNeill and Brown 1979, Ornduff 1993*c*).

Limnanthes floccosa ssp. *californica* has longer sepals, petals, anthers and filaments than *L. floccosa* ssp. *floccosa*. Moreover, *L. floccosa* ssp. *floccosa* lacks rows of hairs at the petal base; the nutlet is covered with narrow, sharp-pointed tubercles; and the flowers do not open as widely as in *L. floccosa* ssp. *californica*. Among the other species that occur in the same region as *L. floccosa* ssp. *californica* are *L. alba* (white meadowfoam) and *L. douglasii* ssp. *rosea* (pink meadowfoam). *Limnanthes alba* has petals that are longer than the sepals at flowering. *Limnanthes douglasii* ssp. *rosea* has longer petals that are veined with pink and notched at the tip, and the petals turn outward as the nutlets mature.

b. Historical and Current Distribution

Historical Distribution.— *Limnanthes floccosa* ssp. *californica* has always been confined to the Northeastern Sacramento Valley Vernal Pool Region, and in fact defines the extent of the region (Keeler-Wolf *et al.* 1998) (**Figure II-8**). This plant was first collected in 1914 at a site 13 kilometers (8 miles) north of Oroville (BioSystems Analysis, Inc. 1993), although it had not yet been recognized as a separate subspecies at that time. In her original description, Arroyo (1973) mentioned six collections, which ranged from 16 kilometers (10 miles) north of Chico south to the type locality and east to Table Mountain, which is north of Oroville. By 1988, 14 occurrences of *L. floccosa* ssp. *californica* had been reported (Arroyo 1973, McNeill and Brown 1979, Dole 1988, Jokerst 1989). Eight were within the city limits of Chico, four (including the type locality) were from the vicinity of Shippee, one was from Table Mountain, and one was from a site northeast of the town of Nord.

Current Distribution.—At least eight new occurrences of *Limnanthes floccosa* ssp. *californica* have been discovered since 1988, two occurrences have been combined in the California Natural Diversity Data Base, while one occurrence is now considered possibly extirpated, for a current total of 21 known natural occurrences (Jokerst 1989, Dole and Sun 1992, U.S. Fish and Wildlife Service 1992, California Natural Diversity Data Base 2005, C. Sellers *in litt.* 2001). The California Natural Diversity Data Base (2005) presumes that the Nord site maintains the most northerly extant occurrence of *L. floccosa* ssp. *californica*, a conclusion bolstered by the finding of 500 plants in this vicinity in 1999. The other occurrences are also presumed to be extant (California Natural Diversity Data Base 2005), although not all have been visited recently. Among the occurrences that have been revisited, many have been reduced in extent. Conversely, in several cases additional occupied habitat has been identified and expanded the boundaries of other occurrences (California Natural Diversity Data Base 2005, C. Sellers *in litt.* 2001).

Counting a recently recorded population and a formerly questionable population both in the Nord area, *Limnanthes floccosa* ssp. *californica* is thus now found in five natural centers of concentration: the Shippee Road area between Chico and Oroville; near the intersection of Highways 99 and 149, where there are five extant occurrences, five new occurrences on the Dove Ridge Conservation Bank south of Highway 149 not yet recorded in the California Natural Diversity Database, and three other centers of concentration within the City of Chico. The northern center is near the Chico Municipal Airport and consists of four occurrences, the northeastern center has a single occurrence and is known as Rancho Arroyo or Bidwell Ranch, and the southeastern center consists of two extant occurrences. In addition, a new location was found in 2005 on North Table Mountain east of the intersection of Highways 149 and 70.

In addition to the 21 naturally occurring populations, an experimental population of *Limnanthes floccosa* ssp. *californica* has been introduced on the Tuscan Preserve in northwestern Butte County (Kelley *et al.* 1994, C. Sellers *in litt.* 2001). The introduction site was just outside of the historical range of the taxon and thus marginally increased its range.

c. Life History and Habitat

Various species in the genus *Limnanthes* have been studied extensively because meadowfoam seeds produce an oil that is potentially valuable for many industrial and pharmaceutical uses. Research has been underway for at least two decades to identify the taxa with the most desirable features for commercial use and to cross-breed them (Pierce and Jain 1977, Brown and Jain 1979, Dole 1988). However, most of the research has been on taxa other than *L. floccosa* ssp. *californica*. Life history traits of related species are presented below when no information is available specifically for *L. floccosa* ssp. *californica*. However, it is recognized that only taxon-specific information should be used in making management decisions (Holland 1987).

Reproduction and Demography.—*Limnanthes floccosa* ssp. *californica* seeds germinate in the late fall after the rainy season begins. The earliest reported observation of seedlings is from November (M. Wacker *in litt*. 2005). Dole and Sun (1992) successfully germinated *L. floccosa* ssp. *californica* seeds under 12 hours of daylight at 15 degrees Celsius (59 degrees Fahrenheit), alternating with 12 hours of darkness at 10 degrees Celsius (50 degrees Fahrenheit). However, the optimum length of daylight and germination temperature under natural conditions have not been investigated.

Seed that does not germinate in the first year following its production may still be viable. In laboratory tests on the more common *Limnanthes floccosa* ssp. *floccosa,* two-thirds of the seed remained dormant even after exposure to favorable conditions, and some ungerminated seed remained in soil samples after 3 years (Ritland and Jain 1984). Seed dormancy also would explain population fluctuations of up to two orders of magnitude between years in *L. floccosa* ssp. *californica* (see below).

Limnanthes floccosa ssp. *californica* seedlings can apparently tolerate short periods of submergence (Jokerst 1989, Dole and Sun 1992). The seedlings develop into rosettes, which do not begin producing flowering stems immediately (McNeill and Brown 1979, Ritland and Jain 1984). *Limnanthes floccosa* ssp. *californica* typically begins flowering in February, reaches peak flowering in March, and may continue into April if conditions are suitable. Nutlets are produced in March and April, and the plants die back by early May (Jokerst 1989, Dole and Sun 1992).

Limnanthes floccosa ssp. *californica* has floral adaptations that allow for cross-pollination by insects, but self-pollination mechanisms take over to ensure seed set if insect pollination is unsuccessful. Insects are attracted by the large flowers and production of nectar. The stamens begin shedding pollen 1 day before the stigma is receptive. Thus, during this period a given flower could not self-pollinate. If insects visit the flower during this period, they remove the pollen (Arroyo 1975). However, if pollen remains in the anthers when the stigma matures, gravity can carry it to the stigma, which is situated below the anthers (Arroyo 1973). The rate of self-pollination may vary among years or among sites, depending on the size of insect populations (Kalin 1971 *in* Arroyo 1973, Dole and Sun 1992). Arroyo (1975) estimated that approximately 26 percent of *L. floccosa* ssp. *californica* flowers were self-pollinated in the field during her study. However, when she excluded insects in a greenhouse study, overall seed set in *L. floccosa* ssp. *californica* was the same as that observed under natural conditions (Arroyo 1975). Cross-pollination by insects would allow opportunities for genetic recombination, unlike self-pollination.

Although most populations of *Limnanthes floccosa* ssp. *californica* have bisexual flowers, the population at the type locality contains a small percentage of male-sterile plants (Dole and Sun 1992).   Pollination of male-sterile flowers can be achieved only by insects. Male sterility also has been observed in populations of two different subspecies of *L. douglasii* (Douglas' meadowfoam). In that species, male-sterile plants produced smaller flowers than were found on bisexual plants (Jain *et al.* 1978, Kesseli and Jain 1984). Moreover, in *L. douglasii* ssp. *rosea* the male-sterile flowers differed in color from the bisexual flowers, and male-sterile plants grew faster, flowered 2 to 3 days later, and produced more flowers per plant than did bisexual individuals. Seeds produced by male-sterile plants survived longer than those produced by bisexual flowers (Kesseli and Jain 1984).

The particular pollinators of *Limnanthes floccosa* ssp. *californica* have not been identified. Other meadowfoam species are pollinated by the native burrowing bees *Andrena limnanthis* and *Panurginus occidentalis* (Thorp and Leong 1998) and by honeybees (Kesseli and Jain 1984), beetles, flies, true bugs (order Hemiptera), butterflies, and moths (Mason 1952, Thorp and Leong 1998). Hybridization between *Limnanthes* taxa is limited in natural settings, due to differences in flower structure, phenology, and microhabitat (Arroyo 1973, Jain 1976*b*, Ritland and Jain 1984, Dole and Sun 1992). However, some hybrids between *L. floccosa* ssp. *californica* and *L. alba* have been produced under laboratory conditions (Dole and Sun 1992).

Nutlets of *Limnanthes floccosa* ssp. *californica* are apparently dispersed by water and can remain afloat for up to 3 days (Hauptli *et al.* 1978). The nutlets of *Limnanthes* taxa that grow in wet sites have larger tubercles than those adapted to dry sites. Hauptli *et al.* (1978) speculated that the tuberculate surface of such nutlets may aid in flotation by trapping air. However, most meadowfoam nutlets are dispersed only short distances. In an experiment where nine meadowfoam taxa were seeded into artificial vernal pools (Jain 1978), only four taxa colonized other parts of the pools where they had been introduced, and only two appeared in pools where they had not been seeded, even after 2 years. *Limnanthes floccosa* ssp. *californica* was not included in the study; however, *L. floccosa* ssp. *floccosa* was not found outside of the areas where it had been seeded. Thus, *L. floccosa* ssp. *californica* nutlets would not be expected to disperse beyond their pool or swale of origin. Birds and livestock are potential sources of long-distance seed dispersal, but specific instances of such dispersal have not been documented (Jain 1978).

Demographic data on *Limnanthes floccosa* ssp. *californica* include population sizes as well as estimates of survival and fecundity. Population highs for *L. floccosa* ssp. *californica* are not necessarily reached in the same year at all sites because the amount and timing of rainfall interacts with soil and topography to determine site-specific population size.

The average number of flowers and nutlets per plant also differ among sites and years. Overall, the largest populations of *Limnanthes floccosa* ssp. *californica* produce the greatest number of nutlets per plant (Dole 1988, Dole and Sun 1992). However, the number of flowers per plant is reduced in dense colonies of *L. floccosa* ssp. *californica* because individuals produce fewer branches and therefore fewer flowers. Competition from other plant species also reduces flower production (Crompton 1993, Kelley and Associates Environmental Sciences 1993*b*). Reproduction of *L. floccosa* ssp. *californica* may be reduced by insufficient moisture (Brown and Jain 1979) or inappropriate livestock grazing practices (Dole 1988, Dole and Sun 1992).

Several races of *Limnanthes floccosa* ssp. *californica* exist. Jokerst (1989) identified “north” and “south” races of *L. floccosa* ssp. *californica* in the Chico “sphere of influence” based on morphology. Later, in studies of enzyme systems, Dole and Sun (1992) confirmed that these races differed genetically. They also identified genetically distinct races that they called “northeast” and “southwest,” with the latter referring to the type locality. Although Arroyo (1975) had concluded that *L. floccosa* exhibited considerable genetic diversity within populations, Dole and Sun (1992) evaluated many more enzyme systems and refuted her conclusions. They found that 96 percent of genetic diversity in *L. floccosa* ssp. *californica* existed among populations and that little variability was evident within populations. Dole and Sun speculated that the low genetic diversity was due to bottlenecks and subsequent inbreeding. In other words, if populations were reduced to only a few plants at certain times in their history, only those few individuals would have passed on their genes. Self-pollination among the remaining plants would have further restricted the gene pool. Dole and Sun (1992) used mathematical formulas to estimate an average generation time of 2 years for *L. floccosa* ssp. *californica* and to predict that a seed would be transferred between populations only once every 100 to 200 years. Although considerable morphological variability has been observed within populations, it apparently is attributable to differences in environmental response by plants of similar genetic makeup (Jain 1976*a*, Jokerst 1989).

Habitat and Community Associations.—*Limnanthes floccosa* ssp. *californica* is found primarily in vernal swales and to a lesser extent on the margins of vernal pools (Arroyo 1973, Dole 1988, Jokerst 1989, BioSystems Analysis, Inc. 1993, California Natural Diversity Data Base 2003). Both the swales and vernal pools where it grows are on alluvial terraces in annual grasslands with a mima mound topography (Kelley and Associates Environmental Sciences 1992*b*, BioSystems Analysis, Inc. 1993). Swales vary in width from narrow channels to broad, pool-like areas (LSA Associates, Inc. 1994). They may connect in branching, tree-like patterns or in net-like patterns around low mounds. Occupied swales are inundated periodically by water from the surrounding uplands, causing the soil to become saturated. However, *L. floccosa* ssp. *californica* does not persist in pools or swales that are inundated for prolonged periods or remain wet during the summer months, nor does it occur in drainages where water flows swiftly (Jokerst 1989, Kelley and Associates Environmental Sciences 1993*a*). One *L. floccosa* ssp. *californica* site near the Chico Municipal Airport is unusual in that it does not contain vernal pools or recognizable swales (Dole 1988, Dole and Sun 1992), which were most likely obliterated by earlier grading (Jokerst 1989).

The swales that support *Limnanthes floccosa* ssp. *californica* are generally less than 10 centimeters (3.9 inches) deep (LSA Associates, Inc. 1994) and pools are typically less than 30 meters (100 feet) long (Jokerst 1989). In vernal pools, *L. floccosa* ssp. *californica* more often grows on the margins than in the bottom, but the pattern is reversed in swales, with the plants more often growing in the center (BioSystems Analysis, Inc. 1993). This plant typically occurs in long, narrow bands in connected swales or on pool margins but can be found in irregular clusters in isolated drainages (Crompton 1993). *Limnanthes floccosa* ssp. *californica* has also been found occasionally in disturbed areas, such as drainage ditches, firebreaks, and graded sites (McNeill and Brown 1979, Jokerst 1989, Kelley and Associates Environmental Sciences 1992*b*, BioSystems Analysis, Inc. 1993, Kelley and Associates Environmental Sciences 1993*a*).

Limnanthes floccosa ssp. *californica* occurs on soils of the Tuscan-Anita and the Redding-Igo complexes, specifically on the Anita and Igo soils, which are confined to the pools and swales. Tuscan and Redding soils are restricted to the mounds. Anita soils can be up to 50 centimeters (19.7 inches) deep, whereas Igo soils are no more than 18 centimeters (7.1 inches) deep; the two soils are underlain by iron-silica cemented and indurated hardpan, respectively (Kelley and Associates Environmental Sciences 1993*a*). Large cobbles are often present throughout pools and swales in such areas (Jokerst 1989). *Limnanthes floccosa* ssp. *californica* has been observed on Anita clay soils annually regardless of rainfall but appears on Igo soils only in years of above average rainfall (Kelley and Associates Environmental Sciences 1992*a*, 1992*b*; Crompton 1993; R. Schonholtz *in litt.* 1995), presumably because the former can hold roughly twice as much moisture (Kelley and Associates Environmental Sciences 1993*a*). Confirmed occurrences have been found at 50 to 90 meters (165 to 300 feet) in elevation (McNeill and Brown 1979, California Natural Diversity Data Base 2003).

Associated species vary somewhat through the range of *Limnanthes floccosa* ssp. *californica*. In most of the occupied habitat within the City of Chico, *Limnanthes floccosa* ssp. *californica* grows with *Layia fremontii* (Fremont’s tidy-tips), *Navarretia leucocephala* (whiteflower navarretia), *Blennosperma nanum* (yellow carpet), and *Lasthenia californica* (California goldfields) (Dole 1988, Dole and Sun 1992). In the Shippee area, *Limnanthes floccosa* ssp. *californica* is associated most frequently with *Juncus bufonius* (toad rush), *Erodium botrys* (long-beak heron’s bill), and *Eryngium vaseyi* ssp. *vallicola* (Vasey’s coyote thistle) (BioSystems Analysis, Inc. 1993). *Limnanthes floccosa* ssp. *californica* also co-occurs with *Limnanthes alba* at two occurrences and with *Limnanthes douglasii* ssp. *rosea* at five occurrences (McNeill and Brown 1979, Dole and Sun 1992, California Natural Diversity Data Base 2003). *Limnanthes floccosa* ssp. *floccosa* was observed not far from a population of *Limnanthes floccosa* ssp. *californica*, but the two subspecies were not growing together (California Natural Diversity Data Base 2003).

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 *Limnanthes floccosa* ssp. *californica* are described below.

At least seven more urbanization actions are being considered within occupied *Limnanthes floccosa* ssp. *californica* habitat in the City of Chico (Kelley and

Associates Environmental Sciences 1992*c*). These projects include various proposals for residential developments and expansion of the Chico Municipal Airport (U.S. Fish and Wildlife Service 1992, C. Sellers *in litt.* 2001, E. Warne pers. comm. 2001, California Natural Diversity Data Base 2003); these projects would affect two occurrences of the southeastern race and one of the northern race of the taxon. Outside of the City, residential developments and agricultural conversions are also continuing threats to some populations.

A proposed project to widen Highway 149 and build interchanges potentially threatens portions of California Natural Diversity Data Base Element Occurrence 1 and 40 of *Limnanthes floccosa* ssp. *californica* (Finn 2000, California Natural Diversity Data Base 2003), which represent the Shippee race. The California Department of Transportation plans to avoid altering the patterns of surface water flow along Gold Run Creek when they widen Highway 149, but individual pools and swales could be filled and the watersheds of others could be reduced (Finn 2000). Additionally, a casino is proposed to be constructed on a 50-acre site containing potential *Limnanthes floccosa* ssp. *californica* habitat approximately 10 miles south of the city of Chico and adjacent to and east of State Route 149, near its intersection with Highway 99.

Another example of ongoing degradation of *Limnanthes floccosa* ssp. *californica* habitat involves illegal trash dumping and off-highway vehicle use (U.S. Fish and Wildlife Service 1992). Also, competition from grasses and other weedy nonnative plants poses a potential problem to four occurrences of *L. floccosa* ssp. *californica* (California Natural Diversity Data Base 2003). For example, at the Doe Mill Preserve, competition from the nonnative grass *Taeniatherum caput-medusae* (medusahead) apparently has reduced population size and seed set in *L. floccosa* ssp. *californica* (Center for Natural Lands Management 1997). In addition, threats are also continuing due to inappropriate grazing practices in certain instances, such as insufficient grazing at the Doe Mill Preserve. Finally, two populations of *L. floccosa* ssp. *californica* are small enough (fewer than 500 plants even in favorable years) that random events could lead to their extirpation (C. Sellers *in litt.* 2001, California Natural Diversity Data Base 2003). Moreover, the narrow geographic range of the taxon increases the likelihood that a single catastrophic event could destroy all or most of the occurrences. A threat to the Doe Mill Preserve and other *L. floccosa* ssp. *californica* preserves in Butte County is their small size (Conservation Efforts below). A concern for these small preserves is that the risk of extirpation in the event of stochastic events increases if low population densities of the plants are coupled with restricted distribution.

Another potential threat is lack of pollinators. Although *Limnanthes floccosa* ssp. *californica* is capable of setting seed in the absence of insect pollinators, continuing adaptation to environmental changes is not possible without the genetic recombination that occurs during cross-pollination. Considering the widespread habitat destruction and degradation in the area where *L. floccosa* ssp. *californica* is endemic, breeding habitat for pollinators could well be declining. However, the identity of pollinators for this subspecies must be determined before their population and habitat status can be evaluated.

e. Conservation Efforts

We listed *Limnanthes floccosa* ssp. *californica* as an endangered species on June 8, 1992 (U.S. Fish and Wildlife Service 1992). The California Fish and Game Commission had previously listed this taxon as endangered under the California Endangered Species Act in 1982 (California Department of Fish and Game 1991). *Limnanthes floccosa* ssp. *californica* has been included on the California Native Plant Society's list of rare and endangered plants for almost two decades (Smith *et al.* 1980) and is currently on List 1B with the highest endangerment rating (California Native Plant Society 2001). In 2002, critical habitat was proposed for *L. floccosa* ssp. *californica* and several other vernal pool species in *Proposed Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon* (U.S. Fish and Wildlife Service 2002a); however, it was eliminated from the final designation (U.S. Fish and Wildlife Service 2003). In 2005, however, critical habitat was reinstated for L. *floccosa* ssp. *californica* 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).

In 1988, the City of Chico funded surveys to determine the status of *Limnanthes floccosa* ssp. *californica* (Dole 1988). Money from the California Endangered Species Tax Check-Off Fund was used to prepare a plan for conserving *L. floccosa* ssp. *californica* within the City, while allowing for continued development (Jokerst 1989). The City prepared a supplement to the conservation plan presenting a schedule for acquisition and other details of management (City of Chico 1989) and was developing a Habitat Resources Conservation Plan for *L. floccosa* ssp. *californica* and other listed species, but has abandoned the effort (J. Knight pers. comm. 1997).

Several areas have been set aside for the conservation of *Limnanthes floccosa* ssp. *californica*. These areas include the 6-hectare (15-acre) Doe Mill Preserve, a conservation easement of about 14 hectares (35 acres) on Humboldt Road, and a 2.8-hectare (7-acre) conservation easement on the publicly owned Gillick-Evans Firing Range (U.S. Fish and Wildlife Service 1992, K. Tarp pers. comm. 1997, C.

Sellers *in litt.* 2001). The City of Chico also has a conservation easement on 118 hectares (292 acres) of habitat that appears to be suitable for *L. floccosa* ssp. *californica*, although very few of the plants are present (C. Sellers *in litt.* 2001). The Dove Ridge Conservation Bank, which contains over 200 acres of vernal pool habitat, is operated as conservation bank for this and other vernal pool species. The Center for Natural Lands Management holds a conservation easement and conducts management and monitoring of the site (M. Wacker *in litt*. 2005).

Other conservation efforts for *Limnanthes floccosa* ssp. *californica* have been accomplished through mitigation programs. The Bruce-Stilson population was enhanced by spreading nutlets to unoccupied areas within a proposed preserve (Stern 1992, K. Stern *in litt.* 1994). *Limnanthes floccosa* ssp. *californica* also was introduced onto suitable, unoccupied habitat on the Tuscan Preserve (also known as Lower Wurlitzer Ranch) in 1992 and 1993 (Kelley *et al.* 1994). The population has continued to reproduce and expand, increasing to approximately 200,000 plants by the spring of 2000 (C. Sellers *in litt.* 2001).

6. *NAVARRETIA LEUCOCEPHALA* SSP. *PAUCIFLORA* (FEW-FLOWERED NAVARRETIA)

a. Description and Taxonomy

Taxonomy.—Navarretias are members of the phlox family (Polemoniaceae). Mason (1946) first gave few-flowered navarretia the Latin name *Navarretia pauciflora*. He had collected the type specimen "5 miles north of Lower Lake, Lake County" in 1945 (Mason 1946). Day (1993*a*) subsequently reduced few-flowered navarretia in rank and assigned it the name *Navarretia leucocephala* ssp. *pauciflora*.

Some plants exhibit characteristics intermediate between *Navarretia leucocephala* ssp. *pauciflora* and ssp. *plieantha*. According to Dr. Alva Day (A. Day *in litt.* 1993, *in litt.* 1997, pers. comm. 1997), such plants cannot be assigned definitively to either subspecies. She does not consider these intergrades (intermediate plants) to be hybrids because there is no evidence that they resulted from crosses between the two subspecies. Thus, the characterization of these intermediate plants as "intercrosses" in the final rule (U.S. Fish and Wildlife Service 1997*b*) was misleading. The existence of such intermediate forms was Dr. Day's primary reason for reducing several taxa previously treated as full species to subspecies within *N. leucocephala* (Day 1993*a*, A. Day pers. comm. 1997). The distribution, life history, threats, conservation efforts, and recovery strategy for intergrades are discussed in the species account for *N. leucocephala* ssp. *plieantha*.

Description and Identification.—Navarretias are annual herbs with alternate, usually lobed leaves that also may have secondary lobes. The small, funnel-shaped flowers have four or five corolla lobes and a tubular calyx with four or five sepals joined at the base by a papery membrane. *Navarretia* flowers are clustered into head-like inflorescences that are surrounded by spine-tipped bracts similar to the leaves. The small capsules are egg-shaped and contain one or more tiny seeds (Day 1993*b*). All *Navarretia* species and subspecies that occur in vernal pools apparently evolved from a single ancestor and share a suite of characteristics including short stature, simple stem anatomy, few glands, very short stigmas, a single vein leading to each corolla lobe, stamens attached near or at the top of the corolla tube, a membranous-walled capsule that does not split along predetermined lines, and few seeds (Crampton 1954, Spencer 1993).

Navarretia leucocephala ssp. *pauciflora* (**Figure II-9**) is only 1 to 4 centimeters (0.4 to 1.6 inches) tall but is twice as wide due to branches originating near the base of the stem. The stem is white with purple streaks and has few hairs. Although the majority of the stem is very slender (less than 0.5 millimeter [0.02 inch] thick), the portion at and just below ground level is two to four times as thick. The narrow leaves are 1 to 2.5 centimeters (0.4 to 1.0 inch) long and may have a few narrow lobes. Each flower head is 4 to 10 millimeters (0.16 to 0.39 inch) wide and contains between 2 and 20 pale blue or white flowers. The fruit of *Navarretia leucocephala* ssp. *pauciflora* is a papery capsule that breaks open in an irregular pattern only when it is wet. Each capsule contains one or two reddish-brown seeds that stick together until water washes them apart (Mason 1946, Day 1993*b*). The chromosome number of this taxon has not been determined.

Navarretia leucocephala ssp. *pauciflora* has fewer flowers per head and fewer lobes on the outer bracts than *N. leucocephala* ssp. *plieantha*. Also, the latter has narrower, needle-like tips on the bract lobes (A. Day *in litt.* 1993). Other navarretias that occur in vernal pools differ in growth habit or have more flowers per head, longer corollas with the tube extending beyond the calyx lobes, branching veins in the corollas, or stamens attached farther down the corolla tube. Those growing outside of vernal pools typically are covered with glandular hairs and have many corolla veins, longer stigma branches, and leathery capsules that split apart when dry; they also may differ in flower color or number of corolla and calyx lobes (Mason 1946, Crampton 1954, Day 1993*b*).

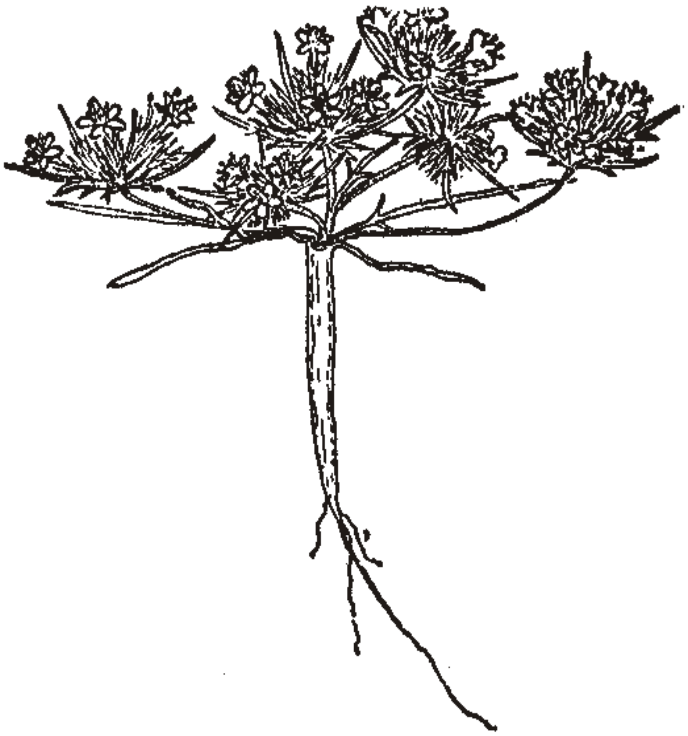

Figure II-9. Illustration of *Navarretia leucocephala* ssp. *pauciflora* (few-flowered navarretia). Reprinted with permission from Abrams (1951), Illustrated Flora of the Pacific States: Washington, Oregon, and California, Vol. III. © Stanford University Press.

b. Historical and Current Distribution

Historical Distribution.**—**Between 1923 and 1988, typical *Navarretia leucocephala* ssp. *pauciflora* specimens were collected from as many as nine sites in southern Lake County (A. Day *in litt.* 1997). The actual number of collection localities may have been fewer because some vaguely-described sites may in fact be the same as others described in greater detail. Manning Flat is presumed to be the type locality (California Natural Diversity Data Base 2003), even though it is actually west-northwest, rather than north, of Lower Lake. The specimens of typical *N. leucocephala* ssp. *pauciflora* were collected in the area between the towns of Clearlake, Kelseyville, and Middletown (Niehaus and Fruchter 1977, Bittman 1989, A. Day *in litt.* 1997). All of the historical sites were in the Lake-Napa Vernal Pool Region (Keeler-Wolf *et al.* 1998) (**Figure II-5**).

Intermediates between *Navarretia leucocephala* ssp. *pauciflora* and ssp. *plieantha* were collected historically from Loch Lomond and from the Siegler Springs Road area of Lake County. Those specimens have been cited as *N. leucocephala* ssp. *pauciflora* in some reports (*e.g.,* Niehaus and Fruchter 1977, Bittman 1989). The California Natural Diversity Data Base (2005) treats Loch Lomond as an occurrence of both *Navarretia leucocephala* ssp. *pauciflora* and ssp. *plieantha*. However, Day (*in litt.* 1993, *in litt.* 1997) does not consider collections from either Loch Lomond or Siegler Springs Road to represent *N. leucocephala* ssp. *pauciflora*.

Current Distribution.**—**Existing information is insufficient to clearly assess whether or not *Navarretia leucocephala* ssp. *pauciflora* has, in fact, significantly declined. Although two of the historical sites in Lake County are not confirmed to have extant populations, the vague original location information leaves open the possibility that these historical occurrences are actually the same as where the taxon is currently known.

Navarretia leucocephala ssp. *pauciflora* is restricted to the Lake-Napa Vernal Pool Region (Keeler-Wolf *et al.* 1998). Eight populations of typical *N. leucocephala* ssp. *pauciflora* are known or presumed to be extant (California Natural Diversity Data Base 2005), including three that were discovered during the past two decades (A. Howald *in litt.* 1995, California Natural Diversity Data Base 2005). Six of the eight extant occurrences are in Lake County and the other two are in Napa County. Among the Lake County occurrences, all six are south of Clear Lake within the area where the taxon was reported historically. One site in Lake County is farther south near the town of Cobb and was discovered in 1995 (J. Diaz-Haworth pers. comm. 2001). According to Howald (*in litt.* 1995), Dr. Alva Day verified the identity of the Cobb occurrence. The two Napa County occurrences were also discovered within the past two decades. Both are in the Foss Valley-Milliken Canyon area east of Yountville (A. Day *in litt.* 1997, California Natural Diversity Data Base 2005).

There is one occurrence that contains both true *Navarretia leucocephala* ssp. *pauciflora* and populations of plants intermediate between *N. leucocephala* ssp. *pauciflora* and ssp. *plieantha*. These populations are in the vicinity of Loch Lomond and near Siegler Springs (A. Day *in litt.* 1993, *in litt.* 1997; California Department of Fish and Game 1994; California Natural Diversity Data Base 2005).

c. Life History and Habitat

Reproduction and Demography.**—**Little is known about the life history and demography of *Navarretia leucocephala* ssp. *pauciflora*. Like many vernal pool annuals, *N. leucocephala* ssp. *pauciflora* seeds germinate underwater (Crampton 1954) and flower after the pools dry (Day 1993*a*). The plants flower in May and June (California Department of Fish and Game 1994, Skinner and Pavlik 1994). The flowers are probably insect-pollinated. Navarretias with similar flowers that occur outside of vernal pools are pollinated by a variety of bees and bee flies (family Bombyliidae), although other insects may visit to collect nectar (Grant and Grant 1965). The seeds of *N. leucocephala* ssp. *pauciflora* do not disperse far from the parent plant because they have a gelatinous coating and stick together when the fruit ruptures (Crampton 1954, Day 1993*b*). Population sizes fluctuate widely among years (California Natural Diversity Data Base 2005).

Habitat and Community Associations.**—***Navarretia leucocephala* ssp. *pauciflora* grows in vernal pools that form on substrates of volcanic origin (Bittman 1989, California Natural Diversity Data Base 2005), specifically in Northern Basalt Flow and Northern Volcanic Ashflow Vernal Pools (Sawyer and Keeler-Wolf 1995). Extant occurrences in Lake County are in “flats” of recent alluvium in mountainous areas; site-specific details are not available for Napa County sites. The vernal pools where *N. leucocephala* ssp. *pauciflora* occurs are interspersed with grassland or marsh and chaparral (Mason 1946, California Natural Diversity Data Base 2005). Pool sizes have not been well characterized, although this taxon has been reported from both small pools and large, shallow, playa-type lakes. Soils underlying the pools typically are shallow and rocky, and obsidian often is present on the surface (Mason 1946, California Natural Diversity Data Base 2003). The Manning Flat site has volcanic ash soil mapped as Oxalis variant silt loam, whereas one Milliken Canyon site has Aiken loam. Soil types are not known for the other occurrences. *Navarretia leucocephala* ssp. *pauciflora* has been reported from elevations ranging from 445 to 707 meters (1,460 to 2,320 feet).

Associated plants differ among sites. In Lake County, associates include other rare plants: *Gratiola heterosepala*, *Parvisedum leiocarpum*, *Lasthenia burkei*, and *Eryngium constancei* (A. Howald *in litt.* 1995, California Natural Diversity Data Base 2003). Napa County associates include *E. aristulatum*, *L. conjugens*, and several species of *Downingia* (California Natural Diversity Data Base 2003).

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 *Navarretia leucocephala* ssp. *pauciflora* are described below.

Continuing specific threats involving potential loss or fragmentation of habitat include: (1) various disturbances of the volcanic ash soils, which accelerates erosion, at Manning Flat (Bittman 1989, A. Buckmann pers. comm. 2001); (2) off-road vehicle use continuing to degrade certain habitat (Bittman 1989, California Natural Diversity Data Base 2005); (3) erosion problems from attempts to drain habitat (California Natural Diversity Data Base 2005); (4) land-use conversions for residential development or agriculture threatening all but two occurrences (J. Diaz-Haworth pers. comm. 2001, B. Flynn pers. comm. 2001); (5) possible inappropriate grazing practices at certain sites; and (6) possible population reductions of important insect pollinators.

e. Conservation Efforts

Navarretia leucocephala ssp. *pauciflora* was federally-listed as an endangered species on June 18, 1997 (U.S. Fish and Wildlife Service 1997*b*). The California Fish and Game Commission had previously listed *N. leucocephala* ssp. *pauciflora* as threatened in 1990 (California Department of Fish and Game 1991). The California Native Plant Society included this plant in their first listing of rare plants (Powell 1974). Currently, *N. leucocephala* ssp. *pauciflora* is on the California Native Plant Society's List 1B and has the highest endangerment rating possible (California Native Plant Society 2001).

The Mead Ranch population of *Navarretia leucocephala* ssp. *pauciflora* in Napa County is protected from development by a conservation easement (California Natural Diversity Data Base 2003). A private citizen bought the Cobb-area vernal pool that supports *N. leucocephala* ssp. *pauciflora* and *Eryngium* *constancei* specifically to protect these species from potential threats (J. Diaz-Haworth pers. comm. 2001, B. Flynn pers. comm. 2001). One of the sites near Loch Lomond is now protected by the California Department of Fish and Game as a Vernal Pool Ecological Reserve and is managed for the benefit of several rare plants (California Department of Fish and Game 1994, California Natural Diversity Data Base 2003). However, the *Navarretia* at that site is an intermediate form (A. Day *in litt.* 1997).

Surveys conducted by California Native Plant Society members and California Department of Fish and Game personnel in the 1990s led to the discovery of several new or historical populations. In 1988, the California Native Plant Society petitioned the California Fish and Game Commission to list *Navarretia leucocephala* ssp. *pauciflora* (Bittman 1989, California Department of Fish and Game 1990*a*).

7. *NAVARRETIA LEUCOCEPHALA* SSP. *PLIEANTHA* (MANY-FLOWERED NAVARRETIA)

a. Description and Taxonomy

Taxonomy.**—**Many-flowered navarretia is in the phlox family. The name first assigned to many-flowered navarretia was *Navarretia plieantha*. The type locality for the species is Boggs Lake, in Lake County (Mason 1946). Day (1993*a*) later reduced many-flowered navarretia to the rank of subspecies, under the name *Navarretia leucocephala* ssp. *plieantha*.

As explained in the species account for *Navarretia leucocephala* ssp. *pauciflora*, some populations of *Navarretia* consist of individuals intermediate in characteristics between two subspecies. According to Dr. Alva Day (*in litt.* 1997, pers. comm. 1997), these plants are not properly called hybrids nor "intercrosses," as the final listing rule (U.S. Fish and Wildlife Service 1997*b*) described them. Dr. Day (*in litt.* 1997) has distinguished two types of intermediate specimens, which others have identified as *N. leucocephala* ssp. *plieantha*. One group is intermediate between *N. leucocephala* ssp. *pauciflora* and *N. leucocephala* ssp. *plieantha*, and the other is intermediate between *N. leucocephala* ssp. *plieantha* and *N. leucocephala* ssp. *bakeri* (Baker's navarretia). For convenience, we refer to all of these as *N. leucocephala* ssp. *plieantha* throughout this plan, but the population at the type locality is referred to as "typical" *N. leucocephala* ssp. *plieantha*.

Description and Identification.**—**Characteristics common to all members of this genus were presented in the *Navarretia leucocephala* ssp. *pauciflora* account. *Navarretia leucocephala* ssp. *plieantha* (**Figure II-10**) forms mats 5 to 20 centimeters (2.0 to 7.9 inches) across and 1 to 3 centimeters (0.4 to 1.2 inches) high. The stems have a peeling, white surface and are highly branched. Stem thickness is 0.8 to 1.4 millimeters (0.03 to 0.06 inch) and is more or less uniform throughout its length. The leaves are 3 to 4 centimeters (1.2 to 1.6 inches) long and are either entire or have a few thread-like lobes. Flower heads are 1.5 to 2 centimeters (0.6 to 0.8 inch) across and contain between 10 and 60 pale blue flowers. Each flower in the head is 5 to 6 millimeters (0.20 to 0.24 inch) long. The capsule and seeds are similar to those of *N. leucocephala* ssp. *pauciflora*; each fruit may contain as many as three seeds (Mason 1946, Day 1993*b*). The chromosome number is unknown.

Navarretia leucocephala ssp. *plieantha* has up to twice as many flowers per head as *N. leucocephala* ssp. *pauciflora*, and the former also has more highly branched outer bracts with needle-like tips on the lobes (A. Day *in litt.* 1993). Moreover, *N. leucocephala* ssp. *plieantha* does not have a thicker stem below ground level and its corolla is about the same length as its calyx. *Navarretia leucocephala* ssp. *bakeri* differs from *N. leucocephala* ssp. *plieantha* in that the former has an erect habit, stems up to 15 centimeters (5.9 inches) tall, and white corollas. Other vernal pool navarretias have corolla lobes with more veins, corolla tubes longer than the calyx, calyx lobes of unequal length, or different stamen attachment (Mason 1946, Crampton 1954, Munz and Keck 1968, Day 1993*b*). Identifying features of upland navarretias were described under *N. leucocephala* ssp. *pauciflora*.

b. Historical and Current Distribution

Historical Distribution.—The California Natural Diversity Data Base (2005) includes seven occurrences of *Navarretia leucocephala* ssp. *plieantha*, (California Natural Diversity Data Base 2005) (**Figure II-5**). The final rule for *N. leucocephala* ssp. *plieantha* (U.S. Fish and Wildlife Service 1997*b*) erroneously reported eight historical locations instead of the nine that were catalogued by the California Natural Diversity Data Base at that time. The historical occurrences are from Lake and Sonoma Counties.

Typical *Navarretia leucocephala* ssp. *plieantha* was known historically only from Boggs Lake (A. Day *in litt.* 1993, 1997). The other reported occurrences include six sites with plants that are intermediate between *N. leucocephala* ssp. *plieantha* and other subspecies, and two sites where Dr. Alva Day does not have access to specimens to confirm the identity of the plants (A. Day *in litt.* 1993, 1997). Three historical occurrences in Lake County (Loch Lomond, Mount Hannah Lodge, and

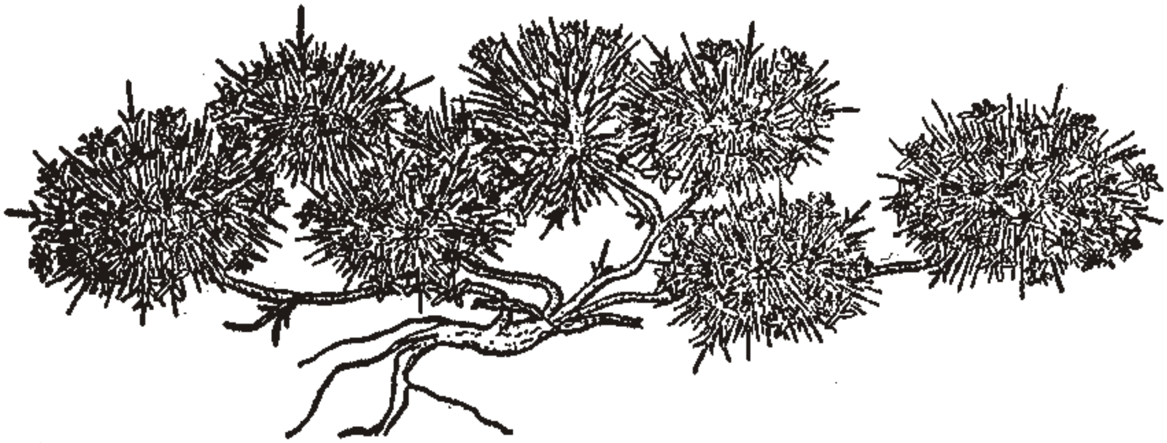

Figure II-10. Illustration of *Navarretia leucocephala* ssp. *plieantha* (many-flowered navarretia). Reprinted with permission from Abrams (1951), Illustrated Flora of the Pacific States: Washington, Oregon, and California, Vol. III. © Stanford University Press.

Siegler Springs Road) have plants intermediate between *N. leucocephala* ssp. *pauciflora* and *N. leucocephala* ssp. *plieantha*. At least three occurrences in the Santa Rosa area, in Sonoma County, consist of plants intermediate between *N. leucocephala* ssp. *plieantha* and *N. leucocephala* ssp. *bakeri* (A. Day *in litt*. 1993, 1997). Dr. Day has not seen specimens from Stienhart Lake in Lake County and thus cannot confirm that *N. leucocephala* ssp. *plieantha* occurs there (A. Day *in litt.* 1997).

Current Distribution.——Of the seven occurrences the California Natural Diversity Data Base (2005) has catalogued as *Navarretia leucocephala* ssp. *plieantha*, all are considered to be extant. Please refer to the Draft Santa Rosa Plains Recovery Plan (in development) for information regarding occurrences within the Santa Rosa vernal pool region identified by Keeler-Wolf *et. al*. (1998).

The five occurrences reported as extant in the final rule (U.S. Fish and Wildlife Service 1997*b*) were Boggs Lake, Loch Lomond, Mount Hannah Lodge, Siegler Springs Road, and Stienhart Lake, which are in the Lake-Napa Vernal Pool Region (Keeler-Wolf *et al.* 1998). These occurrences are still believed to be extant, although only three populations have been revisited since 1989 (California Natural Diversity Data Base 2005). The typical population of *Navarretia leucocephala* ssp. *plieantha* at Boggs Lake has not declined (Baldwin and Baldwin 1991, California Natural Diversity Data Base 2005).

c. Life History and Habitat

Reproduction and Demography.**—**The basic life history of *Navarretia leucocephala* ssp. *plieantha* presumably is similar to that of *N. leucocephala* ssp. *pauciflora*, although neither has been studied intensively. Three different measures of abundance collected annually from 1987 through 1991 at Boggs Lake revealed that the *N. leucocephala* ssp. *plieantha* population in the lakebed had increased in abundance while that in the adjoining meadow had decreased. *Navarretia leucocephala* ssp. *plieantha* plants rarely had more than one flower head each during the monitoring period (Baldwin and Baldwin 1991). In certain years, competition from associated plants along the lake margin apparently caused the *N. leucocephala* ssp. *plieantha* plants to develop longer, less robust stems (Baldwin and Baldwin 1990).

Habitat and Community Associations.**—**Typical *Navarretia leucocephala* ssp. *plieantha* occurs only at Boggs Lake. The lake itself is classified as a Northern Volcanic Ashflow Vernal Pool (Sawyer and Keeler-Wolf 1995), which consists of a clay layer that is impervious to water and is buried under a layer of volcanic ash (California Department of Fish and Game 1987*b*). Mason

(1946:200) noted that he collected the type specimen "In peaty soil of lake margin surrounded by a black oak, madrone [*Arbutus menziesii*], Douglas fir, and yellow pine [*Pinus ponderosa*] forest." More recent reports from Boggs Lake indicated that *N. leucocephala* ssp. *plieantha* also can grow in the center of the lake bed and in wet portions of the surrounding meadow (Baldwin and Baldwin 1989*a*, Baldwin and Baldwin 1991). The soil at Boggs Lake is in the Collayomi-Aiken-Whispering complex. Numerous plant species are associated with *N. leucocephala* ssp. *plieantha* at Boggs Lake, including *Eryngium aristulatum*, *Plagiobothrys stipitatus*, *Downingia* spp., and several other species of *Navarretia*. Rare plants that co-occur with typical *N. leucocephala* ssp. *plieantha* include *Orcuttia tenuis* and *Gratiola heterosepala* (Baldwin and Baldwin 1989*a*, California Natural Diversity Data Base 2003). The elevation of Boggs Lake is approximately 850 meters (2,800 feet) (California Natural Diversity Data Base 2005).

Elsewhere, *Navarretia leucocephala* ssp. *plieantha* occurs in vernal pools, vernal lakes, and swales (California Natural Diversity Data Base 2003). Occupied pools are classified as "Northern Vernal Pools" or Northern Volcanic Ashflow Vernal Pools (Sawyer and Keeler-Wolf 1995, California Natural Diversity Data Base 2003). *Pinus ponderosa* forest or mixed forests of *Quercus kelloggii*, *Pseudotsuga menziesii*, and *Pinus ponderosa* typically occur in the surrounding areas (California Department of Fish and Game 1987*b*, California Natural Diversity Data Base 2003).

Associates of *Navarretia leucocephala* ssp. *plieantha* throughout its range are similar to those at Boggs Lake (California Natural Diversity Data Base 2003). Other plants featured in this recovery plan that co-occur with *N. leucocephala* ssp. *plieantha* include *Eryngium constancei*, *Orcuttia tenuis*, *Gratiola heterosepala*, and *Legenere limosa*. In addition, the endangered plant *Lasthenia burkei* co-occurs with *N. leucocephala* ssp. *plieantha* in Sonoma County (California Natural Diversity Data Base 2005).

At three sites that support *Navarretia leucocephala* ssp. *plieantha*, the soils are mapped in the Collayomi-Aiken-Whispering complex, whereas the Stienhart Lake site has soils in the Konocti-Hambright complex. Soil types are not known for the other occurrences. At Loch Lomond, *N. leucocephala* ssp. *plieantha* is found in the deeper parts of the pool (California Department of Fish and Game 1994). Known sites range in elevation from 33 meters (110 feet) north of Santa Rosa to 853 meters (2,800 feet) at Loch Lomond (California Natural Diversity Data Base 2005).

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 *Navarretia leucocephala* ssp. *plieantha* are described below.

Unique to *Navarretia leucocephala* ssp. *plieantha* are three habitat impacts not generally reported as important factors in the declines of the other vernal pool species: rooting by feral pigs, horseback riding, and foot traffic related to human recreational activity. Hybridization has also been cited as a reason for the decline of *N. leucocephala* ssp. *plieantha* (Bittman 1989, California Department of Fish and Game 1990*a*), but the presence of intermediate forms is not evidence of any threat. The intermediates are not believed to be hybrids (A. Day *in litt.* 1997, pers. comm. 1997), and the fact that similar specimens were collected historically at all sites with intermediate plants indicates that the intergradation is not a recent phenomenon (A. Day *in litt.* 1993).

Other threats are also continuing. In particular, at Boggs Lake, competition from *Typha* spp. (cat-tail), *Centaurea solstitialis* (yellow star-thistle), and a native thistle (*Cirsium remotifolium*) threaten to crowd out *Navarretia leucocephala* ssp. *plieantha* (Baldwin and Baldwin 1991). Competition from nonnative plants such as *Taeniatherum caput-medusae* and *Centaurea solstitialis* threatens *N. leucocephala* ssp. *plieantha* at the site east of Mount Hannah Lodge. Random events pose a threat to two small populations, one east of Mount Hannah Lodge and another in Sonoma County, which number only a few hundred individuals in even the most favorable years (California Natural Diversity Data Base 2003). Please refer to the Draft Santa Rosa Plains Recovery Plan (in development) for information regarding threats facing *Navarretia leucocephala* ssp. *plieantha* in the Santa Rosa vernal pool region, as identified by Keeler-Wolf *et. al*. (1998).

e. Conservation Efforts

A final rule listing *Navarretia leucocephala* ssp. *plieantha* as an endangered species was published on June 18, 1997 (U.S. Fish and Wildlife Service 1997*b*). *Navarretia leucocephala* ssp. *plieantha* had previously been listed as endangered by the California Fish and Game Commission since 1979 (California Department of Fish and Game 1991). The California Native Plant Society has long recognized *N. leucocephala* ssp. *plieantha* as rare and endangered (Powell 1974); it is currently on List 1B and is ranked as “endangered in a portion of its range” (California Native Plant Society 2003).

Two localities for *Navarretia leucocephala* ssp. *plieantha* are protected as reserves. The Trust for Wildland Communities manages the Boggs Lake Preserve and the California Department of Fish and Game manages the Loch Lomond Vernal Pool Ecological Reserve. Management activities at the two reserves include annual monitoring, protective measures such as fencing, and removal of competitors, and interpretive displays (Baldwin and Baldwin 1991; California Department of Fish and Game 1991, 1994).

Additional past conservation efforts included a 1985 survey throughout the range of *Navarretia leucocephala* ssp. *plieantha* (California Department of Fish and Game 1987*b*) and a survey in the Santa Rosa area of Sonoma County in 1988 (Waaland and Vilms 1989). Please refer to the Draft Santa Rosa Plains Recovery Plan (in development) for specific information regarding *Navarretia leucocephala* ssp. *plieantha* conservation efforts.

8. *NEOSTAPFIA COLUSANA* (COLUSA GRASS)

a. Description and Taxonomy

Taxonomy.—Colusa grass is a member of the subfamily Chloridoideae in the grass family (Poaceae) and is in the Orcuttieae tribe, which also includes *Orcuttia* and *Tuctoria* (Reeder 1965, Keeley 1998). Davy (1898) first described Colusa grass, giving it the Latin name *Stapfia colusana.* He had collected the type specimen near the town of Princeton in Colusa County. Davy soon realized that the name *Stapfia* had already been assigned to a genus of green algae and therefore changed the scientific name of Colusa grass to *Neostapfia colusana* (Davy 1899). The name *Anthochloa colusana* was used for decades after Scribner (1899) published the combination in the mistaken belief that Colusa grass was closely related to a South American species of that genus. However, Hoover (1940) evaluated the many differences between *Anthochloa* and *Neostapfia* and concluded that the latter should be considered a distinct genus. Since that time, the accepted name for Colusa grass has been *Neostapfia colusana*. No other species of *Neostapfia* are known (Reeder 1982, Reeder 1993). *Neostapfia* is the most primitive member of the tribe (Keeley 1998).

Description and Identification.—All members of the Orcuttieae share several characteristics that differ from many other grasses. Most grasses have hollow stems, but the Orcuttieae have stems filled with pith. Another difference is that the Orcuttieae produce two or three different types of leaves during their life cycle, whereas most grasses have a single leaf type throughout their life span. The juvenile leaves of the Orcuttieae, which form underwater, are cylindrical and clustered into a basal rosette. After the pool dries, terrestrial leaves form in all species of the tribe; these leaves have flattened blades and are distributed along the stem (Keeley 1998). *Orcuttia* species have a third type of leaf that is not found in *Neostapfia* or *Tuctoria* (Reeder 1982, Keeley 1998). The terrestrial leaves of the Orcuttieae also differ from other grasses in other respects. Whereas grass leaves typically are differentiated into a narrow, tubular sheath that clasps the stem tightly and a broader blade that projects away from the stem, terrestrial leaves of the Orcuttieae are broad throughout and the lower portion enfolds the stem only loosely. The Orcuttieae also lack a ligule, which is a leaf appendage commonly found in other grasses (Reeder 1965, Reeder 1982, Keeley 1998). Another characteristic common to all Orcuttieae is the production of an aromatic exudate, which changes from clear to brown during the growing season (Reeder 1965, Reeder 1982). The exudate most likely helps to repel herbivores (Crampton 1976, Griggs 1981).

The Orcuttieae are, however, similar to other grasses in their flower structure. Grasses do not have petals and sepals like most other flowering plants, so their flowers are inconspicuous. Grass flowers are reduced to florets, which include several stamens (three in the Orcuttieae) and one pistil enclosed in two scales known as the lemma and palea. A spikelet consists of one or more florets and may have one or two glumes at its base. The grass inflorescence typically includes several to many spikelets, which are attached to a central stem known as the rachis. A grass fruit, which is known as a caryopsis or grain, consists of a single seed fused to the fruit wall. Each floret is capable of producing one grain.

Compared to other members of the Orcuttieae, *Neostapfia colusana* (**Figure II-11**) shows fewer adaptations to existence underwater, indicative of its relatively primitive evolutionary position and the shorter duration of underwater growth (Keeley 1998). The aquatic seedlings of *N. colusana* have only one or two juvenile leaves (Keeley 1998). The terrestrial stage consists of multiple stems arising in clumps from a common root system. The stems are decumbent and have a characteristic zigzag growth form (Crampton 1976). Overall stem length ranges from 10 to 30 centimeters (3.9 to 11.8 inches). The entire plant is pale green when young (Davy 1898), but becomes brownish as the exudate darkens (Reeder 1982, Reeder 1993). Leaf length is 5 to 10 centimeters (2.0 to 3.9 inches) (Hitchcock and Chase 1971). Each stem produces one dense, cylindrical inflorescence that is 2 to 8 centimeters (0.8 to 3.1 inches) long and 8 to 12 millimeters (0.31 to 0.47 inch) broad. Within the inflorescence, the spikelets are densely packed in a spiral arrangement; the tip of the rachis projects beyond the spikelets. *Neostapfia colusana* has a diploid chromosome number of 40 (Reeder 1982, Reeder 1993).

Figure II-11. Illustration of *Neostapfia colusana* (Colusa grass). Reprinted with permission from Abrams (1940), Illustrated Flora of the Pacific States: Washington, Oregon, and California, Vol. I. © Stanford University Press.

Unlike terrestrial grasses, *Neostapfia colusana* has pith-filled stems, lacks distinct leaf sheaths and ligules, and produces exudate. *Neostapfia colusana* differs from other members of the Orcuttieae in that it has zigzag stems, cylindrical inflorescences, and fan-shaped lemmas and lacks glumes, whereas the other genera within the tribe have fairly straight stems and possess glumes. Moreover, *Orcuttia* species have distichous spikelets and narrow, five-toothed lemmas, and *Tuctoria* species have spikelets arranged in a loose spiral, and narrow, more-or-less entire lemmas. *Neostapfia colusana* is not likely to be confused with *Anthochloa*, despite their former taxonomic affiliation. The latter does not occur in North America, is perennial, does not have glands, the inflorescence is not cylindrical, and the spikelets have glumes (Hoover 1940).

b. Historical and Current Distribution

Historical Distribution.**—**In the 50 years after its initial discovery (Davy 1898), *Neostapfia colusana* was reported from only three sites other than the type locality; these sites were in Merced and Stanislaus Counties. By 1989, 51 occurrences were known, but 11 of those had already been extirpated (Stone *et al.* 1988, California Natural Diversity Data Base 2003). Through November 2003, the California Natural Diversity Data Base (2003) included 60 reported occurrences of *N. colusana* in Colusa, Merced, Solano, Stanislaus. and Yolo Counties. Five each were reported from the San Joaquin Valley and Solano-Colusa Vernal Pool Regions, and the remainder were from the Southern Sierra Foothills Vernal Pool Region (**Figure II-12**).

Current Distribution.**—**Currently, no more than 42 occurrences of *Neostapfia colusana* remain extant (Hogle 2002, California Natural Diversity Data Base 2005). At least one population remains in each of the vernal pool regions from which *N. colusana* was known historically. The majority of extant occurrences are in the Southern Sierra Foothills Vernal Pool Region, where they are concentrated northeast of the City of Merced in Merced County and east of Hickman in Stanislaus County. One or two occurrences remain in central Merced County, which is part of the San Joaquin Valley Vernal Pool Region. Four occurrences are extant in the Solano-Colusa Vernal Pool Region, with two each in southeastern Yolo and central Solano Counties (Stone *et al.* 1988 , Keeler-Wolf *et al.* 1998, California Natural Diversity Data Base 2003). This species has apparently been extirpated from Colusa County (California Natural Diversity Data Base 2005).

c. Life History and Habitat

Many life history characteristics are common to all members of the Orcuttieae. In particular, they are all annuals (Griggs 1981). All are wind-pollinated, but pollen probably is not carried long distances between populations (Griggs 1980, Griggs and Jain 1983). Local seed (*i.e.*, caryopsis) dispersal is by water, which breaks up the inflorescences (Reeder 1965, Crampton 1976, Griggs 1980, Griggs 1981). Long-distance dispersal is unlikely (U.S. Fish and Wildlife Service 1985*a*), but seed may have been carried occasionally by waterfowl (family Anatidae), tule elk (*Cervus elaphus nannoides*), or pronghorn (*Antilocapra americana*) in historical times (Griggs 1980). The seeds can remain dormant for an undetermined length of time (but at least 3 to 4 years) and germinate underwater after they have been immersed for prolonged periods (Crampton 1976, Griggs 1980, Keeley 1998). Unlike typical terrestrial grasses that grow in the uplands surrounding vernal pools, members of the Orcuttieae flower during the summer months (Keeley 1998).

Among all members of the Orcuttieae, the soil seed bank may be 50 times or more larger than the population in any given year. In general, years of above-average rainfall promote larger populations of Orcuttieae, but population responses vary by pool and by species (Griggs 1980, Griggs and Jain 1983). Population sizes have been observed to vary by one to four orders of magnitude among successive years and to return to previous levels even after 3 to 5 consecutive years when no mature plants were present (Griggs 1980, Griggs and Jain 1983, Holland 1987). Thus, many years of observation are necessary to determine whether a population is stable, declining, or extirpated. All members of the Orcuttieae are endemic to vernal pools. Although the various species have been found in pools ranging widely in size, the vast majority occur in pools of 0.01 hectare (0.025 acre) to 10 hectares (24.7 acres) (Stone *et al.* 1988). Large pools such as these retain water until May or June, creating optimal conditions for Orcuttieae (Crampton 1959, 1976; Griggs 1981; Griggs and Jain 1983). Within such pools, Orcuttieae occurs in patches that are essentially devoid of other plant species (Crampton 1959, 1976). Typically, plants near the center of a pool grow larger and produce more spikelets than those near the margins, but patterns vary, depending on individual pool characteristics and seasonal weather conditions (Griggs 1980).

Reproduction and Demography.—In an experiment where *Neostapfia colusana* was grown along with *Tuctoria greenei* and two species of *Orcuttia* (Keeley 1998), seeds of *N. colusana* took about 3 months to germinate following inundation, longer than all other species. Hogle (2002) also provided evidence that long periods of inundation are necessary for germination of *N. colusana* seeds. Unlike *Orcuttia* species, *N. colusana* does not produce flattened, floating, juvenile leaves (Reeder 1982, Keeley 1998). Germination and seedling development have not been studied in the wild, but are assumed to be similar to those of *Tuctoria* species, which have similar seedlings. Thus, *N. colusana* seed would be expected to germinate in late spring when little standing water remains in the pool, and flowering would begin approximately 3 to 4 weeks later, as observed for *Tuctoria* (Griggs 1980). Flowering individuals of *N. colusana* have been collected as early as May throughout the range of the species (California Natural Diversity Data Base 2005). *Neostapfia colusana* spikelets break between the florets (Reeder 1993), quickly shattering as soon as the inflorescence matures (Crampton 1976).

Reproductive and survival rates have not been reported, but annual monitoring confirms that population sizes of *Neostapfia colusana* vary widely from year to year. Over a 6-year monitoring period, the population at the Bert Crane Ranch in Merced County dropped from 250 plants in 1987 to zero in 1989 and 1990, but rebounded to over 2,000 plants in 1992 (J. Silveira *in litt.* 2000). At Olcott Lake in Solano County, the lowest population of the decade was 1,000 in 1994; but this low point was followed by a high of over 1 million estimated plants the following year (California Natural Diversity Data Base 2003).

Habitat and Community Associations.—*Neostapfia colusana* has the broadest ecological range among the Orcuttieae. It occurs on the rim of alkaline basins in the Sacramento and San Joaquin Valleys, as well as on acidic soils of alluvial fans and stream terraces along the eastern margin of the San Joaquin Valley and into the adjacent foothills (Stone *et al.* 1988). Elevations range from 5 meters (18 feet) to about 105 meters (350 feet) at known sites (California Natural Diversity Data Base 2005). *Neostapfia colusana* has been found in Northern Claypan and Northern Hardpan vernal pool types (Sawyer and Keeler-Wolf 1995) within rolling grasslands (Crampton 1959). It grows in pools ranging from 0.01 to 250 hectares (0.02 to 617.5 acres), with a median size of 0.2 hectare (0.5 acre), and also occurs in the beds of intermittent streams and in artificial ponds (Stone *et al.* 1988, K. Fuller pers. comm. 1997, EIP Associates 1999). This species typically grows in the deepest portion of the pool or stream bed (Crampton 1959, Stone *et al.* 1988), but may also occur on the margins (Hoover 1937, Stone *et al.* 1988). It appears that deeper pools and stock ponds are most likely to provide the long inundation period required for germination (EIP Associates 1999).

Several soil series are represented throughout the range of *Neostapfia colusana*. In the Solano-Colusa Vernal Pool Region, *N. colusana* grows on clay, silty clay, or silty clay loam soils in the Marvin, Pescadero, and Willows series. In the San Joaquin Valley Vernal Pool Region, soils are clay or silty clay loam in the Landlow and Lewis series (J. Silveira *in litt.* 2000). *Neostapfia colusana* habitat in the Southern Sierra Foothills Vernal Pool Region includes many soil series with textures ranging from clay to gravelly loam. For sites with known soil series, Bear Creek, Corning, Greenfield, Keyes, Meikle, Pentz, Peters, Raynor, Redding, and Whitney are represented (Stone *et al.* 1988, EIP Associates 1999, California Natural Diversity Data Base 2003). The type and composition of impermeable layers underlying occupied vernal pools also varies, ranging from claypan to lime-silica or iron-silica cemented hardpan and tuffaceous alluvium (Stone *et al.* 1988).

Neostapfia colusana usually grows in single-species stands, rather than intermixed with other plants. Thus, associated species in this case are plants that occur in different zones of the same pools, but are generally present in the same season. For example, Crampton (1959) observed that *N. colusana* dominated pool beds, with *Orcuttia pilosa* forming a band around the upper edge of the stand. In saline-alkaline sites, common associates of *N. colusana* are *Frankenia salina* and *Distichlis spicata*, whereas on acidic sites associates include *Eryngium* spp., *Eremocarpus setigerus* (turkey mullein), and *Plagiobothrys stipitatus* (Stone *et al.* 1988, EIP Associates 1999). Many of the other rare plants featured in this recovery plan grow in the same pools as *N. colusana*. Among these species, the most frequent associate is *Orcuttia inaequalis*, followed by *O. pilosa*, *Tuctoria mucronata*, *Chamaesyce hooveri*, *Atriplex persistens*, and *Astragalus tener* var. *tener* (Stone *et al.* 1988, EIP Associates 1999, J. Silveira *in litt.* 2000, California Natural Diversity Data Base 2003). *Tuctoria greenei* formerly grew in one vernal pool with *N. colusana*, but the former no longer occurs there (Stone *et al.* 1988, California Natural Diversity Data Base 2003).

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 *Neostapfia colusana* are described below.

Three additional potential reasons for site-specific declines have been reported relative to this species: inundation by poultry manure and, in Yolo County, damage by herbicide applications (C. Witham *in litt.* 2000*a*) and contamination of groundwater by industrial chemicals (K. Fuller pers. comm. 1997).

The largest continuing threat to this species is agricultural conversion, especially in Stanislaus County. Urbanization is the second greatest threat, especially at the proposed University of California campus and associated community development in eastern Merced County. Four occurrences are in the area expected to be developed within the next 15 years and two others are within the general "planning area" (EIP Associates 1999, California Natural Diversity Data Base 2003). Proposed construction of a new prison and a landfill also threaten other specific populations (U.S. Fish and Wildlife Service 1997*a*). A proposed flood control project in eastern Merced County threatens four of the occurrences with inundation, and runoff alterations are a threat to the two Yolo County occurrences. Almost all of the extant occurrences of *Neostapfia colusana* are subject to livestock grazing, thus to the extent inappropriate grazing practices are still being followed at certain sites, these sites may be threatened. Competition from invasive native and nonnative plants poses a problem at several sites, especially in combination with adverse hydrology changes and adverse grazing practices (Stone *et al.* 1988, C. Witham *in litt.* 2000*a*). One or two sites have also been reported as threatened by vandalism (*i.e.*, trampling near urban areas [U.S. Fish and Wildlife Service 1997*a*]) and foraging by grasshopper outbreaks (Stone *et al.* 1988). Small population size may be a threat at 9 sites, which have never exceeded 100 plants in number. In addition, several other sites that were formerly larger than 100 plants each now appear to have declined to fewer than that number of individuals (Hogle 2002, California Natural Diversity Data Base 2003).

e. Conservation Efforts

We listed *Neostapfia colusana* as a threatened species on March 26, 1997 (U.S. Fish and Wildlife Service 1997*a*). *Neostapfia colusana* has been State-listed as endangered since 1979 (California Department of Fish and Game 1991) and has been considered to be rare and endangered by the California Native Plant Society since 1974 (Powell 1974). The California Native Plant Society now includes *N. colusana* on List 1B and considers it to be "endangered throughout its range" (California Native Plant Society 2001). In 2005, critical habitat was designated for *N. colusana* 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).

Most of the conservation efforts for *Neostapfia colusana* have been accomplished as part of the broader effort to survey and protect vernal pools in the Central Valley. Surveys conducted by Crampton (1959), Medeiros (1976), and Stone *et al.* (1988) contributed to distributional records and identification of threats. Four occurrences of *N. colusana*, comprising six occupied pools, have been protected by The Nature Conservancy. One is Olcott Lake on the Jepson Prairie Preserve in Solano County, where the *N. colusana* population has been monitored annually since 1989 (C. Witham *in litt.* 1992, California Natural Diversity Data

Base 2003). The other five pools are on the Flying M Ranch conservation easement in eastern Merced County (Stone *et al.* 1988).

Three additional occurrences of *Neostapfia colusana* are on Federal land, which offers more options for conservation, but does not in itself constitute protection. Two are on a U.S. Department of Defense facility in Yolo County (Davis Communications Annex), which is in the process of being transferred to the ownership of Yolo County Parks (K. Fuller *in litt.* 2000). This site is the subject of a nonnative invasive plant management effort, particularly for *Lepidium latifolium* (pepperweed), and vernal pool restoration under a CalFed grant to benefit *N. colusana* and *Tuctoria mucronata*, another federally-listed plant included in this plan (N. McCarten *in litt*. 2004). The third occurrence on Federal land is on the Arena Plains Unit of the Merced National Wildlife Refuge in Merced County. Our National Wildlife Refuge system acquired the Arena Plains in 1992, and refuge personnel have been monitoring the *N. colusana* population annually since 1993. Although the refuge allowed grazing to continue on the Arena Plains after it was purchased, temporary electric fencing was placed around the *N. colusana* pool to exclude cattle in one year when the plant population was deemed to be particularly vulnerable (D. Woolington pers. comm. 1997, J. Silveira *in litt.* 2000).

9. *ORCUTTIA INAEQUALIS* (SAN JOAQUIN VALLEY ORCUTT GRASS)

a. Description and Taxonomy

Taxonomy.—Hoover (1936*b*) first published the scientific name *Orcuttia inaequalis* for San Joaquin Valley Orcutt grass. A 1935 collection from "Montpellier [sic], Stanislaus County" was cited as the type specimen (Hoover 1936*b*). Hoover (1941) subsequently reduced this taxon to a variety of California Orcutt grass (*Orcuttia californica*), using the combination *Orcuttia californica* var. *inaequalis*. Based on differences in morphology, seed size, and chromosome number, Reeder (1980) restored the taxon to species status, and the scientific name *Orcuttia inaequalis* is thus currently in use (Reeder 1993). *Orcuttia inaequalis* is a member of the grass family (Poaceae), subfamily Chloridoideae, and is in the tribe Orcuttieae (Reeder 1965). The genus *Orcuttia* is the most evolutionarily advanced group within the tribe (Keeley 1998, L. Boykin *in litt.* 2000). Alternative common names for this species are San Joaquin Valley orcuttia (Smith *et al.* 1980) and San Joaquin Orcutt grass (U.S. Fish and Wildlife Service 1985*c*).

Description and Identification.—Characteristics common to all members of the Orcuttieae were described earlier in this document in the *Neostapfia* *colusana* species account. Species in the genus *Orcuttia* are characterized by an inflorescence consisting of narrow, flattened, distichous spikelets, each of which has two glumes at the base. *Orcuttia* species produce three different types of leaves during their life cycle: a submerged basal rosette of five to eight cylindrical, juvenile leaves; intermediate leaves in which the submerged portion is cylindrical but the upper portion has a flat, floating blade; and terrestrial leaves with a flattened blade and loosely sheathing base, which develop after the pools dry (Keeley 1998).

Mature plants of *Orcuttia inaequalis* grow in tufts of several erect stems, each of which ranges from 5 to 30 centimeters (2.0 to 11.8 inches) in length. The entire plant is grayish-green, due to the long hairs on the stem and leaves, and the plant produces exudate. Terrestrial leaves are 2 to 4 millimeters (0.08 to 0.16 inch) wide. The oval lemmas are 4 to 5 millimeters (0.16 to 0.20 inch) long and their tips are divided into five teeth approximately 2 millimeters (0.08 inch) long; the central tooth is longer than the others, hence the name *inaequalis* ("unequal"). Each spikelet is flattened and contains 4 to 30 florets. Both rows of spikelets grow towards one side. The spikelets are crowded near the top one-third of the stem, producing a head-like inflorescence 2 to 3.5 centimeters (0.8 to 1.4 inches) long. Each caryopsis is 1.3 to 1.5 millimeters (0.05 to 0.06 inch) long (Hoover 1941; Crampton 1976; Reeder 1982, 1993). The seeds averaged 0.28 milligram (1×10^{-5} ounce) in one population, although seed weight likely varies among sites (Griggs 1980). *Orcuttia inaequalis* has a diploid chromosome number of 24 (Reeder 1980, 1982).

The pith-filled stems, lack of both leaf sheaths and ligules, and presence of exudate distinguish *Orcuttia inaequalis* (and all members of the Orcuttieae) from grasses in other tribes. The elongate, distichous spikelets with oval lemmas and glumes differentiate *Orcuttia* species from *Neostapfia*, which has a cylindrical head with the spikelets arranged in a spiral, fan-shaped spikelets and lemmas, and no glumes. The unequal lemma teeth in *O. inaequalis* distinguish it from *O. pilosa* and *O. tenuis*. *Orcuttia californica* is similar to *O. inaequalis* but the former does not have a head-like inflorescence, has few hairs on the plant, and grows only near the California-Mexico border. *Orcuttia inaequalis* has shorter lemmas, shorter bristles, and smaller seeds than *O. viscida*. Furthermore, each species of *Orcuttia* has a unique chromosome number (Reeder 1982).

b. Historical and Current Distribution

Historical Distribution.—*Orcuttia inaequalis* has always been restricted to the Southern Sierra Foothills Vernal Pool Region (Keeler-Wolf *et al.* 1998) (**Figure II-13**). The earliest collection was made in 1927 from the

Fresno-Madera County border near Lanes Bridge (California Natural Diversity Data Base 2003). Hoover (1941) mentioned collections from eight sites in Fresno, Madera, Merced, Stanislaus, and Tulare Counties. A total of 20 occurrences had been reported by the mid-1970s, all in the same 5 counties (Crampton 1959, California Natural Diversity Data Base 2003), but none remained as of the late 1970s (Griggs 1980, Griggs and Jain 1983). However, 20 new occurrences were discovered within the following decade, including 16 in Merced County, 3 in Madera County, and 1 in Fresno County (Stone *et al.* 1988, California Natural Diversity Data Base 2003).

***Current Distribution.*—**Since 1990, 18 additional occurrences of *Orcuttia inaequalis* have been found, including 1 in Tulare County (EIP Associates 1999, C. Witham *in litt.* 2000*b*, California Natural Diversity Data Base 2005) and 5 on ranches in Merced County (California Natural Diversity Data Base 2005), with another 1 that was established artificially (Stebbins *et al.* 1995). Of the 52 occurrences of *O. inaequalis* catalogued, 32 are presumed to be extant; 17 are extirpated and 3 others are considered possibly extirpated because the habitat has been modified (California Natural Diversity Data Base 2005). However, only 3 of the occurrences presumed extant have been revisited within the past decade, so even the most recent information is outdated. This species has apparently been extirpated from Stanislaus County but remains in Fresno, Madera, Merced, and Tulare Counties (Stone *et al.* 1988, Skinner and Pavlik 1994, California Natural Diversity Data Base 2003). *Orcuttia inaequalis* does not occur outside of the Southern Sierra Foothills Vernal Pool Region (Keeler-Wolf *et al.* 1998). The primary area of concentration of presumed extant occurrences is northeast of Merced in Merced County, with 19 occurrences (59 percent) on the Flying M Ranch and adjacent lands (EIP Associates 1999, C. Witham *in litt.* 2000*b*, California Natural Diversity Data Base 2005). Eastern Merced County is considered a critical region for the conservation of this species from the perspective of being located near the historical geographic center of the range, for harboring a large majority of the extant occurrences, and for harboring one of the largest incompletely surveyed blocks of quality habitat within the species' range (Vollmar 2002).

The Lanes Bridge area of Madera and Fresno Counties has the second highest concentration, with seven occurrences (22 percent), including the introduced population. The remaining six occurrences include three in the Le Grand area of Merced County, two on the tabletops near the San Joaquin River in Madera and Fresno Counties, and one in northwestern Tulare County (Stone *et al.* 1988, Stebbins *et al.* 1995, California Natural Diversity Data Base 2003).

c. Life History and Habitat

Many life-history characteristics for *Orcuttia inaequalis* are common to the entire tribe and have been discussed earlier in this document. Certain other aspects of the life history are shared by *Orcuttia* and *Tuctoria* species, but not by *Neostapfia*. One of these aspects is the pattern of flowering. The first two flowers on a given plant open simultaneously and do not produce pollen until the ovaries are no longer receptive. Thus, if they are fertilized it must be with pollen from another plant. Flowers that open subsequently may receive pollen from the same plant or others (Griggs 1980). *Orcuttia* and *Tuctoria* species are believed to be outcrossers based on estimates of genetic diversity (Griggs 1980, Griggs and Jain 1983). Seed production in *Orcuttia* and *Tuctoria* species can vary two- to three-fold among years (Griggs 1980, Griggs and Jain 1983).

Another suite of life history characteristics is shared among all Orcutt grasses (*Orcuttia* species), but not other genera in the Orcuttieae. In particular, seeds of *Orcuttia* species germinate underwater in January and February (Griggs 1980, Griggs and Jain 1983, Keeley 1998), after being colonized by aquatic fungi (Griggs 1980, 1981). This observation was supported by Keeley's (1988) research, which indicated that fungicide inhibited germination of *O. californica* seeds, but did not affect *Tuctoria greenei* seeds. Detailed germination studies have not been conducted on all species, but cold treatment and other forms of stratification promoted germination in *O. californica* (Keeley 1988), *O. pilosa*, and *O. tenuis* (Griggs 1974, as cited in Stone *et al.* 1988) and most likely benefit other *Orcuttia* species as well. In an experimental study of *O. californica*, seeds germinated equally well in the light or the dark and could germinate whether exposed to air or anaerobic conditions; maximum germination was achieved in anaerobic conditions following cold stratification (Keeley 1988).

Orcuttia plants grow underwater for 3 months or more and have evolved specific adaptations for aquatic growth (Keeley 1998). Among these adaptations is the formation of the three different leaf types. The well-developed rosette of juvenile leaves is more specialized than those in *Neostapfia* or *Tuctoria* species, however (Keeley 1998). The floating-leaf stage is unique to *Orcuttia* species; these leaves form as water in the pool warms and remain as long as the standing water lasts (Hoover 1941; Griggs 1980, 1981; Reeder 1982; Keeley 1998). Aquatic leaves of *Orcuttia* species also lack stomates, even though they are present on the juvenile leaves of both *Neostapfia* and *Tuctoria* (Keeley 1998).

As soon as the pools dry, normally in June or July, Orcutt grasses begin producing their typical terrestrial leaves (Hoover 1941; Griggs 1980, 1981; Reeder 1982; Keeley 1998). Inflorescences appear within a few days after the water evaporates. June and July are the peak months of flower production for most species, although flowering may continue into August and September in years of above-normal precipitation (Griggs 1980, 1981). Late-spring rains may prolong the flowering season (Griggs 1981, Griggs and Jain 1983), but inundation is more likely to kill flowering individuals (J. Silveira *in litt.* 1997). Spikelets break apart and scatter their seeds when autumn rains arrive (Reeder 1965; Crampton 1976; Griggs 1980, 1981).

Reproduction and Demography.—Griggs (1980) conducted demographic and genetic studies of one Fresno County population of *Orcuttia inaequalis* during spring 1976. In that year, each plant in the population produced an average of approximately 8 stems, 1,783 florets, and 254 seeds. The floret-to-seed ratio indicated a relatively good rate of pollination. Survival rates were not determined. Annual population estimates indicated that 1976 and 1978 were favorable years for the Fresno County population. Genetic diversity was high, even among plants grown from seeds collected from the same plant; among-population diversity was not evaluated for this species. The enzyme systems of *O. inaequalis* were most similar to those of *O. tenuis* (Griggs 1980, Griggs and Jain 1983).

Habitat and Community Associations.—Typical habitat requirements for all members of the Orcuttieae were described above under *Neostapfia colusana*. *Orcuttia inaequalis* occurs on alluvial fans, high and low stream terraces (Stone *et al.* 1988), and tabletop lava flows (Stebbins *et al.* 1995, California Natural Diversity Data Base 2003). This species grows in Northern Claypan, Northern Hardpan, and Northern Basalt Flow vernal pools (Sawyer and Keeler-Wolf 1995) within rolling grassland (Crampton 1959). Occupied pools range in surface area from 0.014 to 4.9 hectares (0.05 to 12.1 acres), with a median area of 0.62 hectare (1.54 acres) (Stone *et al.* 1988). *Orcuttia inaequalis* has been reported from elevations of 30 to 755 meters (100 to 2,475 feet); the highest-elevation sites are those on the tabletops of Fresno and Madera Counties (Stebbins *et al.* 1995, California Natural Diversity Data Base 2003).

Soils underlying *Orcuttia inaequalis* pools are acidic and vary in texture from clay to sandy loam. Soil series represented include the Hideaway series on Fresno-Madera County tabletops, and Amador, Cometa, Corning, Greenfield, Los Robles, Madera, Peters, Pollasky-Montpellier complex, Raynor, Redding, and San Joaquin soil series elsewhere in the range. Underlying layers at historical or extant occurrences included iron-silica cemented hardpan, tuffaceous alluvium, and basaltic rock from ancient volcanic flows (Stone *et al.* 1988, Stebbins *et al.* 1995, EIP Associates 1999, California Natural Diversity Data Base 2003).

The plants most commonly associated with *Orcuttia inaequalis* are *Eryngium* spp., *Plagiobothrys stipitatus*, *Neostapfia colusana*, *Psilocarphus brevissimus* (dwarf woolly-heads), and *Eremocarpus setigerus*. Among the rare plants featured in this recovery plan, five currently co-occur or historically co-occurred with *O. inaequalis*. In descending order by number of co-occurrences, these are: *N. colusana* (nine), *Castilleja campestris* ssp. *succulenta* (five), *Gratiola heterosepala* (three), *O. pilosa* (two), and *Chamaesyce hooveri* (one) (EIP Associates 1999, C. Witham *in litt.* 2000*b*, California Natural Diversity Data Base 2003).

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 *Orcuttia inaequalis* are described below.

A potential reason for some site-specific declines of this species may be foraging during grasshopper outbreaks, which can decimate entire plant populations of *Orcuttia inaequalis* before they set seed (Griggs and Jain 1983, Stone *et al.* 1988).

At least ten of the extant occurrences are threatened with habitat loss due to urbanization. Four of these are in the path of the proposed extension of State Highway 41 in Madera County (R. Stone *in litt.* 1992). Three others are threatened by a proposed residential development in Madera and Fresno Counties (Stone *et al.* 1988, Stebbins *et al.* 1995, California Natural Diversity Data Base 2003), and three more could be destroyed by construction of the proposed University of California campus and associated community in Merced County (EIP Associates 1999, California Natural Diversity Data Base 2003). Most extant populations are still being grazed; thus to the extent inappropriate grazing practices are still being followed, certain sites may be threatened. At least six occurrences are threatened by small population size. Among the *Orcuttia inaequalis* occurrences for which population size has been estimated, 6 numbered fewer than 100 plants each, even in favorable years. Ten others are of unknown size (R. Stone *in litt.* 1992, Stebbins *et al.* 1995, California Natural Diversity Data Base 2003).

e. Conservation Efforts

Orcuttia inaequalis was federally-listed as a threatened species on March 26, 1997 (U.S. Fish and Wildlife Service 1997*a*). The State of California had previously listed this grass as endangered in 1979 (California Department of Fish and Game 1991). The California Native Plant Society has considered this species to be rare and endangered for even longer (Powell 1974). Currently, *O. inaequalis* is on the California Native Plant Society's List 1B and is rated as "endangered throughout its range" (California Native Plant Society 2001). In 2005, critical habitat was designated for *O. inaequalis* 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).

Currently, few occurrences of *Orcuttia inaequalis* are protected permanently. Two occurrences are on the Flying M Ranch in Merced County, which is protected under a conservation easement with The Nature Conservancy. Within those two occurrences, four pools supported *O. inaequalis* populations in excess of 5,000 individuals each in 1986 (Stone *et al.* 1988). The extant Tulare County occurrence of *O. inaequalis* is on a California Department of Fish and Game Ecological Reserve; it contained 250 plants in 1997 (California Natural Diversity Data Base 2003).

Three other occurrences are wholly or partially on public land. One occurrence in Fresno County consists of a pool that is partially on public land administered by the U.S. Bureau of Land Management. The pool supports the second-largest existing population of the species. The U.S. Bureau of Land Management and conservation groups hope to protect the entire pool through the potential acquisition of adjacent lands (California Natural Diversity Data Base 2003). Another occurrence is within an 81-hectare (200-acre) vernal pool complex in Madera County, where one pool contains a small population of *Orcuttia inaequalis* (Stebbins *et al.* 1995); the California Department of Transportation recently acquired this complex. Although the proposed Highway 41 extension would cross this property, alignment to avoid affecting the plant is possible (D. York pers. comm. 1996). The third occurrence on public land is the result of a vernal pool re-creation program coupled with seeding of various plant species. The California Department of Transportation funded the creation of artificial vernal pools in Madera County by staff and students from California State University, Fresno (D. York pers. comm. 1996). *Orcuttia inaequalis* was introduced into six of the created pools; it germinated and flowered in five pools during the 2 years following its introduction (Durgarian 1995, Stebbins *et al.* 1995) and was still present in 2000 (R. Faubion *in litt.* 2000). This site is now recorded in California Natural Diversity Data Base occurrences (California Natural Diversity Data Base (2003). The Madera Irrigation District manages this property, which is owned by the U.S. Bureau of Reclamation (Stebbins *et al.* 1995).

10. *ORCUTTIA PILOSA* (HAIRY ORCUTT GRASS)

a. Description and Taxonomy

Taxonomy.—Hairy Orcutt grass is in the tribe Orcuttieae of the grass family Poaceae (Reeder 1965). Hoover (1941) published the original scientific name *Orcuttia pilosa* for hairy Orcutt grass, which has remained unchanged since. He collected the type specimen in Stanislaus County, "12 miles east of Waterford" (Hoover 1941) in 1937. Hoover (1937) initially identified that specimen as *Orcuttia tenuis*, but later recognized that it represented a new species (Hoover 1941). This species also has been known by the common names hairy Orcuttia (Smith *et al.* 1980) and pilose Orcutt grass (U.S. Fish and Wildlife Service 1985*c*).

Description and Identification.—Characteristics shared among all members of the tribe or among species in the genus *Orcuttia* are described above in the *Neostapfia colusana* and *O. inaequalis* species accounts. *Orcuttia pilosa* grows in tufts consisting of numerous stems. The stems are decumbent or erect and branch from only the lower nodes. Stems are 5 to 20 centimeters (2.0 to 7.9 inches) long and 1 to 2 millimeters (0.04 to 0.08 inch) in diameter (Stone *et al.* 1988). Almost the entire plant is pilose (bearing long, soft, straight hairs), giving it a grayish appearance. The terrestrial leaves are 3 to 6 millimeters (0.12 to 0.24 inch) wide. The inflorescence is 5 to 10 centimeters (2.0 to 3.9 inches) long and contains between 8 and 18 flattened spikelets. The spikelets near the tip of the inflorescence are crowded together, whereas those near the base are more widely spaced. Each spikelet consists of 10 to 40 florets and two tiny (3 millimeters [0.12 inch]) glumes. The lemmas are 4 to 5 millimeters (0.16 to 0.20 inch) long, with five teeth of equal size. Each caryopsis is 1.75 to 2 millimeters (0.07 to 0.08 inch) long (Hoover 1941; Reeder 1982, 1993) and weighs 0.46 to 0.95 milligram (1.6 to 3.4×10^{-5} ounce) (Griggs 1980). *Orcuttia pilosa* has a diploid chromosome number of 30 (Reeder 1982).

Orcuttia pilosa is most likely to be confused with *O. tenuis*. However, *O. pilosa* has broader stems and leaves, branches originating from the lower nodes, smaller spikelets that are crowded near the rachis tip, smaller grains, a later flowering period, and a different chromosome number (Reeder 1982). Other *Orcuttia* species typically have unequal lemma teeth and differ in seed size and chromosome number from *O. pilosa* and *O. tenuis* (Reeder 1982).

b. Historical and Current Distribution

Historical Distribution.—Prior to the surveys by Stone *et al.* (1988), *Orcuttia pilosa* had been reported from 25 sites, primarily in the Northeastern Sacramento Valley and Southern Sierra Foothills Vernal Pool Regions (Keeler-Wolf *et al.* 1998) (**Figure II-14**). These included eight occurrences each in Tehama and Stanislaus Counties, six in Madera County, and two in Merced County (Hoover 1941, Crampton 1959, Reeder 1982, Stone *et al.* 1988, California Natural Diversity Data Base 2003). *Orcuttia pilosa* also was collected in the Solano-Colusa Vernal Pool Region, Glenn County, in 1937 (California Natural Diversity Data Base 2003); the specimen has since been lost, but may have originally been misidentified as California Orcutt grass (Oswald and Silveira 1995, J. Silveira pers. comm. 1997, J. Silveira *in litt.* 2000). During the late 1980s, Stone *et al.* (1988) determined that 12 historical occurrences had been extirpated, but they and others discovered 3 additional populations in Madera, Stanislaus, and Tehama Counties. One other occurrence from Madera County (California Natural Diversity Data Base Element Occurrence 29) was previously considered to be *O. pilosa* and is still listed as such in the California Natural Diversity Data Base (2003); however, this population has been identified as *O. inaequalis* (R. Stone *in litt.* 1992).

Current Distribution.—Within about the last decade, 10 new natural occurrences of *Orcuttia pilosa* have been discovered: 5 in Madera County, 4 in Tehama County, and 1 in Stanislaus County (California Natural Diversity Data Base 2005). *Orcuttia pilosa* also has been discovered in another pool at the Vina Plains Preserve in Tehama County (Alexander and Schlising 1997); this pool may represent a separate occurrence or it may be an extension of California Natural Diversity Data Base Element Occurrence 25. In addition, this species has been introduced into a re-created pool in Madera County (Durgarian 1995, Stebbins *et al.* 1995, California Natural Diversity Data Base 2005).

Of the 39 Element Occurrences listed by the California Natural Diversity Data Base (2003), not counting the misidentified population of *Orcuttia inaequalis* previously mentioned, 27 natural occurrences and the introduced population are presumed to be extant (California Natural Diversity Data Base 2005).

Currently, the main area of concentration for *Orcuttia pilosa* (9 extant occurrences and 1 that is possibly extirpated) is the Vina Plains in Tehama County, which is in the Northeastern Sacramento Valley Vernal Pool Region. An isolated occurrence in central Butte County is in the same region. Eleven occurrences are in the Southern Sierra Foothills Vernal Pool Region, including nine in Madera County between the City of Madera and Millerton Lake, and two in eastern Stanislaus County. All six extant occurrences in the Solano-Colusa Vernal Pool Region are on the Sacramento National Wildlife Refuge in Glenn County (Stone *et al.* 1988, Keeler-Wolf *et al.* 1998, California Natural Diversity Data Base 2005).

c. Life History and Habitat

The life history characteristics common to all members of the Orcuttieae were presented above within the *Neostapfia colusana* discussion, and others shared by all *Orcuttia* species were described under the *O. inaequalis* discussion.

Reproduction and Demography.— Griggs (1974, as cited in Stone *et al.* 1988) found that stratification followed by temperatures of 15 to 32 degrees Celsius (59 to 90 degrees Fahrenheit) was necessary for seed germination in *Orcuttia pilosa*. Flowering individuals have been observed as early as mid-April in Madera County (Durgarian 1995). Populations observed in Glenn County began flowering at the beginning of May 1993. However, heavy rains in late May and early June of that year refilled the five pools that were being monitored, causing 80 percent to 100 percent of the plants to die before they set seed (J. Silveira *in litt.* 1997). Seed production has not been studied extensively in *O. pilosa*, but Griggs and Jain (1983) did note that one individual plant produced more than 10,000 seeds. Although the predominant pollination agent for all Orcutt grasses is wind, native bees (Halictidae) have been observed visiting the inflorescences of *O. pilosa* to gather pollen (Griggs 1974, as cited in Stone *et al.* 1988).

Like other vernal pool annuals, the size of *Orcuttia pilosa* populations fluctuates dramatically from year-to-year. Population sizes have varied by as much as four orders of magnitude over time (Griggs 1980, Griggs and Jain 1983, Alexander and Schlising 1997). In fact, two populations that had no visible plants for 3 years in succession exceeded 10,000 plants in the fourth year (Griggs 1980, Griggs and Jain 1983). However, populations that number fewer than 100 plants in even the most favorable years are not likely to persist. They probably begin with chance dispersal events which never build up enough of a soil seed bank to become established. This phenomenon was noted at the Sacramento National Wildlife Refuge, the Vina Plains, and an unspecified location where the population consisted of six plants in 1973, dropped to zero the following year, and was considered to be extirpated when no plants reappeared by 1978 (Griggs 1980, Griggs and Jain 1983).

Densities of *Orcuttia pilosa* were determined at the Vina Plains Preserve in 1995. Among four pools where this species grew, densities ranged from 45 to 474 plants per square meter (4.2 to 44.0 plants per square foot) (Alexander and Schlising 1997). The high densities illustrate that although the total population size seems large, the individuals grow in close proximity and may actually occupy a relatively small area.

Habitat and Community Associations.— This species is found on high or low stream terraces and alluvial fans (Stone *et al.* 1988). *Orcuttia pilosa* occurs in Northern Basalt Flow, Northern Claypan, and Northern Hardpan vernal pools (Sawyer and Keeler-Wolf 1995) within annual grasslands (California Natural Diversity Data Base 2003). The median size of occupied pools measured in the late 1980s was 1.7 hectares (4.2 acres), with a range of 0.34 to 250 hectares (0.8 to 617.5 acres) (Stone *et al.* 1988). At the Vina Plains, *O. pilosa* was found growing only in pools that held water until May, June, or July in 1995, and not in those that had dried by April (Alexander and Schlising 1997). This species is known from elevations of 26 meters (85 feet) in Glenn County to 123 meters (405 feet) in Madera County (California Natural Diversity Data Base 2003). *Orcuttia pilosa* is found on both acidic and saline-alkaline soils, in pools with an iron-silica cemented hardpan or claypan. In the Northeastern Sacramento Valley Vernal Pool Region, pools supporting *O. pilosa* occur on the Anita and Tuscan soil series (Stone *et al.* 1988, California Natural Diversity Data Base 2003). At one pool in the Vina Plains that spans both Anita clay and Tuscan loam soils, *O. pilosa* was found growing primarily on the Anita clay type (Alexander and Schlising 1997). In the Solano-Colusa Vernal Pool Region, *O. pilosa* occurs on the Willows and Riz soil series (J. Silveira *in litt.* 2000), whereas in the Southern Sierra Foothills Vernal Pool Region, it occurs on the Cometa, Greenfield, Hanford, Meikle, and Whitney soil series (Stone *et al.* 1988).

Common associates of *Orcuttia pilosa* throughout its range include *Eryngium* spp. and *Plagiobothrys stipitatus*. *Orcuttia pilosa* also co-occurs at numerous sites with other rare plants addressed in this recovery plan, including *Neostapfia colusana* in the San Joaquin Valley and *Chamaesyce hooveri* and *Tuctoria greenei* in the Sacramento Valley (Stone *et al.* 1988, Alexander and Schlising 1997, California Natural Diversity Data Base 2003). Additional associates in the

San Joaquin Valley include *Trichostema lanceolatum* (vinegar weed) and *Anthemis cotula* (mayweed) (Stone *et al.* 1988). *Orcuttia pilosa* formerly occurred in one pool with *O. inaequalis* (Crampton 1959), a habitat that has since been converted to almond orchards (California Natural Diversity Data Base 2003). In the Vina Plains, other common associates of *O. pilosa* are *Marsilea vestita*, *Convolvulus arvensis*, and *Amaranthus albus* (Alexander and Schlising 1997). Both *O. pilosa* and *O. tenuis* grow on the Vina Plains, but do not occur in the same pools (Stone *et al.* 1988, Alexander and Schlising 1997). At least in 1995, the Vina Plains pools where *O. pilosa* grew had few spring-flowering annuals (Alexander and Schlising 1997).

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 *Orcuttia pilosa* are described below.

Some indications of decline (*i.e.*, California Natural Diversity Data Base description as "possibly extirpated") for this species may have, in fact, been only artifacts of random dispersal events in which the "extirpated" populations were never well-established to begin with. In particular, two such occurrences on the Vina Plains Preserve apparently died out because the populations were too small to be viable. These occurrences involved only 2 plants at one site and fewer than 100 at the other site, and thus may have not represented truly established populations.

Nevertheless, the primary threats are continuing. In particular, agricultural and residential developments, and planning for such, are proceeding in the vicinity of the remaining Stanislaus and Madera County occurrences and may lead to the destruction of additional populations in the foreseeable future (Stone *et al.* 1988). Construction of a landfill threatens one occurrence (U.S. Fish and Wildlife Service 1997*a*). Cattle grazing was an ongoing land use at 20 occurrences when they were last visited, including 6 where this species may already be extirpated (California Natural Diversity Data Base 2003). Also, competition from invasive plants is believed to be an increasing problem throughout the range of *Orcuttia pilosa* (Stone *et al.* 1988). Several researchers (Stone *et al.* 1988, Alexander and Schlising 1997) have suggested that cattle may have carried in seeds of nonnative plants, and disturbance from trampling may have then facilitated their establishment. *Convolvulus arvensis* has increased in frequency in the Vina Plains since 1984, and *Xanthium strumarium* is still present. In addition, small population size continues to be a threat to *O. pilosa*. Six of the presumably extant populations have had fewer than 100 plants at their peak (California Natural Diversity Data Base 2003).

e. Conservation Efforts

We listed *Orcuttia pilosa* as an endangered species on March 26, 1997 (U.S. Fish and Wildlife Service 1997*a*). *Orcuttia pilosa* had previously been State-listed as endangered in 1979 (California Department of Fish and Game 1991) and was identified as rare and endangered by the California Native Plant Society 5 years before that (Powell 1974). The California Native Plant Society still considers this species to be "endangered throughout its range" and includes it on its List 1B (California Native Plant Society 2001). In 2005, critical habitat was designated for *O. pilosa* 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).

Relatively large populations of *Orcuttia pilosa* are protected at The Nature Conservancy's Vina Plains Preserve in Tehama County (Broyles 1987, Alexander and Schlising 1997, California Natural Diversity Data Base 2003) and at our Sacramento National Wildlife Refuge in Glenn County (J. Silveira *in litt.* 1997, J. Silveira *in litt.* 2000). A small population is now protected at a California Department of Transportation mitigation site in Madera County, although that site has, at times, been degraded due to discing by the former landowner (Stebbins *et al.* 1995). The Vina Plains populations have been monitored sporadically since 1983 (Alexander and Schlising 1997) and the Sacramento National Wildlife Refuge populations since 1993 (J. Silveira *in litt.* 2000). *Xanthium strumarium,* an aggressive native plant, has been removed by hand from some of the Vina Plains pools (Alexander and Schlising 1997), an effort that began in 1991 using funds from the California Endangered Species Tax Check-Off Fund (California Department of Fish and Game 1991).

Orcuttia pilosa was one component of an interagency vernal pool re-creation program in Madera County. The experiment was funded by the California Department of Transportation, carried out on U.S. Bureau of Reclamation property, and conducted by personnel from California State University, Fresno, and the University of California, Davis (Stebbins *et al.* 1996). *Orcuttia pilosa* was seeded into nine of the re-created pools in fall 1993. Flowering individuals were found in eight of the pools the following year, six in 1995, and eight in 1996 (Durgarian 1995, Stebbins *et al.* 1996), and the species was also observed in the re-created pools in 2000 (R. Faubion *in litt.* 2000).

11. *ORCUTTIA TENUIS* (SLENDER ORCUTT GRASS)

a. Description and Taxonomy

Taxonomy.—Slender Orcutt grass is a member of the tribe Orcuttieae in the grass family Poaceae (Reeder 1965). Hitchcock (1934) first published the name *Orcuttia tenuis* for slender Orcutt grass, and this name has remained unchanged. Nonetheless, some confusion surrounds the taxonomy of the species. The type specimen of *Orcuttia tenuis* was collected in Goose Valley, Shasta County, in 1912. Before the initial collections had been recognized as a new species, they were mistakenly identified as *Orcuttia californica* and were used as the basis for illustrating the latter species in a 1920 publication (Hitchcock 1934). Another common name is slender orcuttia (Smith *et al.* 1980).

Description and Identification.—The *Neostapfia colusana* account provided above describes characteristics common to all members of the tribe, and the *Orcuttia inaequalis* account describes features shared among *Orcuttia* species. *Orcuttia tenuis* grows as single stems or in small tufts consisting of a few stems. The plants are sparsely hairy and branch only from the upper half of the stem. Although the stems typically are erect, they may become decumbent if many branches form near the stem tip (Reeder 1982). The stems range from 5 to 20 centimeters (2.0 to 7.9 inches) in height (G. Schoolcraft *in litt.* 2000) and are about 0.5 millimeter (0.02 inch) in diameter. The terrestrial leaves are 1.5 to 2 millimeters (0.06 to 0.08 inch) wide. In *O. tenuis*, the inflorescence comprises more than half of the plant’s height, and the spikelets are more or less evenly spaced throughout the inflorescence. Each spikelet contains from 5 to 20 florets. The grains are about 3 millimeters (0.12 inch) long (Hitchcock 1934, Reeder 1982, Stone *et al.* 1988, Reeder 1993). In one study, seed weight ranged from 0.32 to 0.81 milligram (1.1 to 2.8×10^{-5} ounce) (Griggs 1980). The diploid chromosome number of *O. tenuis* is 26 (Reeder 1982).

Orcuttia tenuis is most similar to *O. pilosa*, but the former has narrower stems and leaves, branches at the upper nodes, larger spikelets that are not crowded on the rachis, larger seeds, a different chromosome number, and it flowers earlier (Reeder 1982). Other *Orcuttia* species have unequal lemma teeth and also differ in seed size and chromosome number (Reeder 1982).

b. Historical and Current Distribution

Historical Distribution.—As of the mid-1980s, *Orcuttia tenuis* was known from only 18 localities in Lake, Sacramento, Shasta, and Tehama Counties (Reeder 1982, Stone *et al.* 1988) (**Figure II-15**). During the late 1980s, Stone *et al.* (1988) and others (California Natural Diversity Data Base 2003) discovered 34 additional occurrences of *O. tenuis*. Of these 52 occurrences reported prior to 1990, the majority (29 occurrences, 55.8 percent) were in the Northeastern Sacramento Valley Vernal Pool Region of Tehama County, mostly in the vicinity of Dales, except for 4 occurrences on the Vina Plains. Another 14 occurrences (26.9 percent) were in the Northwestern Sacramento Valley Vernal Pool Region, on the Stillwater and Millville Plains of Shasta County. The Modoc Plateau Vernal Pool Region accounted for another six occurrences (11.5 percent), including four in Shasta County and two in Siskiyou County. The remaining three occurrences included two in Lake County, which was in the Lake-Napa Vernal Pool Region, and one in Sacramento County, in the Southeastern Sacramento Valley Vernal Pool Region (Griggs and Jain 1983, Stone *et al.* 1988, California Natural Diversity Data Base 2003).

Current Distribution.—A total of 82 occurrences are known, of which 76 are presumed extant, 2 are possibly extirpated, and 4 are extirpated (K. Fuller *in litt*. 2004, California Natural Diversity Data Base 2005). Occurrences are presumed to be extant until the California Natural Diversity Data Base receives documentation that they have been extirpated. In addition to the counties where it was reported historically, *O. tenuis* is also known from Lassen, Modoc, Butte, and Plumas Counties. The primary area of concentration for *O. tenuis* is still in the vicinity of Dales, Tehama County, where 27 natural occurrences and the three introduced populations apparently remain extant (36 percent of occurrences). Those 30 occurrences and the four in the Vina Plains of Tehama County are all in the Northeastern Sacramento Valley Vernal Pool Region (Keeler-Wolf *et al.* 1998). A secondary area of concentration is the Modoc Plateau Vernal Pool Region in Lassen, Plumas, Shasta, and Siskiyou Counties, with 25 extant occurrences (33 percent). The portion of Shasta County that is in the Northwestern Sacramento Valley Vernal Pool Region has 12 extant occurrences (16 percent). The Lake-Napa Vernal Pool Region accounts for two extant occurrences, both in Lake County; three occurrences are in Sacramento County, in the Southeastern Sacramento Valley Vernal Pool Region; and the one remaining occurrence, in Shasta County (California Natural Diversity Data Base Element Occurrence 69), is outside of mapped vernal pool regions (Stone *et al.* 1988, Corbin and Schoolcraft 1989, B. Corbin *in litt.* 1999, California Natural Diversity Data Base 2005, K. Fuller *in litt*. 2005).

c. Life History and Habitat

The general life history of *Orcuttia tenuis* is similar to that of *O. inaequalis* and *Neostapfia colusana*, as discussed previously in this recovery plan.

Reproduction and Demography.—Optimal germination of *Orcuttia tenuis* is achieved through stratification followed by warm days and mild nights (Griggs 1974 as cited in Stone *et al.* 1988). Peak flowering of this species typically occurs in May in the Central Valley (Griggs 1981, Reeder 1982), but not until June or July on the Modoc Plateau (B. Corbin *in litt.* 2000, G. Schoolcraft *in litt.* 2000). Unlike *O. pilosa* and *Tuctoria greenei*, *O. tenuis* is not likely to die when pools are flooded by late spring or summer rains. At two sites near Dales that were inundated by rains in May 1977, *O. tenuis* plants dropped their existing inflorescences, but resprouted and flowered again within 1 month (Griggs 1980, Griggs and Jain 1983). Moreover, the population at the Vina Plains Preserve in Tehama County experienced a second pulse of germination after summer rains in 1982 (Broyles 1983, cited in Alexander and Schlising 1997). Conversely, drought has been known to cause 100 percent mortality of local populations (Griggs 1980, Griggs and Jain 1983).

Similar to other vernal pool annuals, *Orcuttia tenuis* populations can vary greatly in size from year to year. Fluctuations of up to four orders of magnitude have been documented in Lake and Shasta Counties (Griggs 1980, Griggs and Jain 1983). At the Vina Plains Preserve, the single population ranged in size from 1,000 to 147,700 estimated individuals during the 5 times it was reported over a 13-year period (Stone *et al.* 1988, Alexander and Schlising 1997). However, *O. tenuis* populations do not always fluctuate in size. Among five populations of *O. tenuis* that Griggs tracked from 1973 to 1979, two remained at the same order of magnitude for the entire period; both were in the Dales area. None of the other five species of Orcuttieae included in the study remained stable for the full 7 years (Griggs 1980, Griggs and Jain 1983).

Seeds of *Orcuttia tenuis* germinate even in dry years, but the proportion of plants surviving to maturity varies. In a 1977 demographic study of two *O. tenuis* populations near Dales and a third near Redding (Griggs 1980, Griggs and Jain 1983), survivorship ranged from 0 to 75 percent, averaging 40 percent. At the two sites near Dales, densities of *O. tenuis* were 694 and 1,530 plants per square meter (64.5 and 142.1 plants per square foot, respectively) in 1977 (Griggs 1980, Griggs and Jain 1983). At the Vina Plains Preserve, the single occupied pool had a density of 71 plants per square meter (6.6 plants per square foot) in 1995 (Alexander and Schlising 1997). *Orcuttia tenuis* produced an average of 58 seeds per plant in 1977, ranging from 11.3 to 163.9 among the populations studied. At one Dales-area site, the soil seed bank was estimated to be more than 14 times greater than the population of growing plants in 1977 (Griggs 1980, Griggs and Jain 1983).

Griggs (1980, Griggs and Jain 1983) reported that most of the genetic diversity in *Orcuttia tenuis* occurred among individuals with the same seed parent. He found nearly as much genetic diversity within a single population, but little difference between populations. However, his study included only two populations from Tehama County, which were in close proximity. One of the Sacramento County populations differs considerably from other occurrences in outward appearance, suggesting that it may differ in genetic makeup (S. Cochrane *in litt.* 1995*a*).

Habitat and Community Associations.—*Orcuttia tenuis* is found primarily on substrates of volcanic origin (Crampton 1959, Corbin and Schoolcraft 1989). Natural pools in which *O. tenuis* grows are classified as Northern Volcanic Ashflow and Northern Volcanic Mudflow vernal pools (Sawyer and Keeler-Wolf 1995). However, this species has also been reported from other natural and artificially-created seasonal wetlands such as creek floodplains, stock ponds, and borrow pits. Impervious layers range from iron-silica hardpan to bedrock (Stone *et al.* 1988, Corbin and Schoolcraft 1989, California Natural Diversity Data Base 2003). Among the populations studied by Stone *et al.* (1988), the median area of pools occupied by *O. tenuis* was 0.65 hectare (1.6 acres) and ranged from 0.08 to 45 hectares (0.2 to 111 acres). On the Modoc Plateau, occupied pools known as of 1989 ranged in size from 2 to 40 hectares (5 to 100 acres) and were typically at least 30 centimeters (11.8 inches) deep; this species was restricted to the deepest areas of these pools (Corbin and Schoolcraft 1989). *Orcuttia tenuis* occurs across a wide range of elevations corresponding to its broad geographical range. The lowest reported elevation is 27 meters (90 feet) in Sacramento County (Stone *et al.* 1988) and the highest is 1,756 meters (5,761 feet) in Plumas County (B. Corbin *in litt.* 1999).

Soil types supporting *Orcuttia tenuis* are similarly diverse, ranging from slightly to strongly acidic (Stone *et al.* 1988) and from clay to sandy, silty, or cobbly loam (Corbin and Schoolcraft 1989, California Natural Diversity Data Base 2003 and unprocessed data). The soil series has not been reported for all *O. tenuis* sites, but includes at least the following, by region: In the Lake-Napa Vernal Pool Region, this species occurs on the Collayomi-Aiken-Whispering complex and the Konocti-Hambright complex; Modoc Plateau populations occur on the Gooval, Lasvar, Lasvar-Pitvar complex, and Nosoni soil series; and those in the Northeastern Sacramento Valley are on the Anita, Guenon, Inks, Inskip, Laniger, Moda, Redding, Toomes, and Tuscan soil series. The Redding soil series also supports *O. tenuis* in the Southeastern Sacramento Valley Vernal Pool Region (Stone *et al.* 1988, California Natural Diversity Data Base 2003).

Vegetation types in which the occupied pools occur are diverse, ranging from grassland and oak woodland to mixed conifer forest, *Artemisia cana* (silver sagebrush) flats, and sedge meadows (Crampton 1959, California Natural Diversity Data Base 2003). Associated species vary throughout the range of *Orcuttia tenuis*. Among the most common associates in the Sacramento Valley are *Plagiobothrys stipitatus*, *Eleocharis macrostachya* (pale spikerush), *Eryngium* spp., *Navarretia leucocephala*, and *Marsilea vestita*. At other locations throughout northern California, *O. tenuis* occurs with a wide variety of plants, including various species of *Downingia*, *Eryngium*, and *Navarretia* (Stone *et al.* 1988, Corbin and Schoolcraft 1989, Alexander and Schlising 1997, California Natural Diversity Data Base 2003). *Orcuttia tenuis* also co-occurs with several of the other species addressed in this recovery plan, including *Navarretia leucocephala* ssp. *plieantha* and *Gratiola heterosepala* at Boggs Lake in Lake County (California Natural Diversity Data Base 2003), *G. heterosepala* and *Legenere limosa* at Dales Lake Ecological Reserve and Hog Lake in Tehama County (C. Witham *in litt.* 2000*a*), *Tuctoria greenei* at Laniger Lakes in Tehama County, and *G. heterosepala* at nine other sites in Tehama County and four sites in Shasta County (Stone *et al.* 1988, B. Corbin *in litt.* 2000, California Natural Diversity Data Base 2003). Although *O. tenuis* grows in the same vernal pool complexes as *O. pilosa* in Tehama County (including the Vina Plains Preserve) and *O. viscida* in Sacramento County, it has not been found to share any pools with either of these two species (Stone *et al.* 1988, S. Cochrane *in litt.* 1995*a*, Alexander and Schlising 1997, California Natural Diversity Data Base 2003).

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 *Orcuttia tenuis* are described below.

A number of specific threats are continuing for this species. In particular, urbanization is a continuing threat to *Orcuttia tenuis* populations in the vicinity of Redding and Sacramento. Off-road vehicle use is a particular problem near Redding and in forested areas of the Modoc Plateau. Despite the comparatively wide range of *O. tenuis*, small population size is of concern in the Lake-Napa Vernal Pool Region and the Millville Plains-Stillwater Plains area of the Northeastern and Northwestern Sacramento Valley Vernal Pool Regions.

e. Conservation Efforts

Orcuttia tenuis was federally listed as threatened on March 26, 1997 (U.S. Fish and Wildlife Service 1997*a*) and has been State listed as endangered since 1979 (California Department of Fish and Game 1991). This species was recognized as rare and endangered by the California Native Plant Society as early as 1974 (Powell 1974) and is now included on List 1B and is considered to be "endangered throughout its range" (California Native Plant Society 2001). In 2005, critical habitat was designated for *O. tenuis* 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).

Four natural occurrences of *Orcuttia tenuis* are in designated preserves. These include the Trust for Wildland Communities' Boggs Lake Preserve in Lake County, The Nature Conservancy's Vina Plains Preserve in Tehama County, and two occurrences on the California Department of Fish and Game's Dales Lake Ecological Reserve in Tehama County (Broyles 1987, Stone *et al.* 1988, California Natural Diversity Data Base 2003). All four populations are monitored annually (Baldwin and Baldwin 1989*a*, 1989*b*, 1991; D. Alexander pers. comm. 1997; California Natural Diversity Data Base 2003). Also, a conservation area containing a population of *O. tenuis* was recently established in Sacramento County to compensate for impacts to vernal pools (K. Fuller *in litt.* 2000). An unknown number of additional occurrences are protected from development by conservation easements; one is in Shasta County (California Natural Diversity Data Base 2003), and the others are in the Dales Lake area of Tehama County, where a private landowner put more than 16,188 hectares (40,000 acres) of ranch land into a conservation easement in cooperation with The Nature Conservancy (C. Witham *in litt.* 2000*a*).

Introductions of *Orcuttia tenuis* have been attempted at two privately-owned sites. In 1978, *O. tenuis* was seeded into two adjacent "ponds" in Chico, Butte County. Fewer than 100 plants grew in the 2 ponds that year or in 1979 (Griggs 1980), which was the last time the population size was reported. The other introduction was in 1982, when *O. tenuis* was seeded into an artificial pool in Shasta County. As of 1987, the population was thriving (California Natural Diversity Data Base 2003), but its current size is not known. An unintentional introduction may have taken place at the Dales Lake Ecological Reserve. In 1995, *O. tenuis* appeared in 11 of 21 artificially-created vernal pools there, possibly because its seeds were contained in plant litter from nearby natural pools that was spread on the surface of the created pool (C. Witham *in litt.* 2000*a*). The California Natural Diversity Data Base (2003) considers those 11 pools to comprise 3 Element Occurrences, but the populations may not be viable; very few plants were found in 1995 and only 1 of the pools still supported *O. tenuis* in 1999 (C. Witham *in litt.* 2000*a*).

Twenty-seven of the 76 (36 percent) extant occurrences of *Orcuttia tenuis* are wholly or partially on Federal land. Seventeen of these are managed by the U.S. Forest Service, primarily the Lassen National Forest, although one is on the Shasta-Trinity National Forest. The other 10 are on lands controlled by the U.S. Bureau of Land Management; 9 of these are in the Redding Resource Area and the other is in the Alturas Resource Area. Two of the occurrences on the Lassen National Forest, Adobe North and South Vernal Pools, are within an area that has been proposed as a Research Natural Area (B. Corbin *in litt.* 2000). The Green Place Reservoir occurrence in Shasta County is within a Wilderness Study Area and has been jointly proposed by the U.S. Bureau of Land Management and the Lassen National Forest as a Research Natural Area (G. Schoolcraft *in litt.* 2000).

The Lassen National Forest and Susanville District of the U.S. Bureau of Land Management jointly prepared a management plan for *Orcuttia tenuis* sites under their administration (including those in the Shasta-Trinity National Forest) in order to ensure the long-term survival of the species (Corbin and Schoolcraft 1989). Actions identified in that plan included avoidance of known populations, maintenance of natural hydrology, monitoring selected populations, and surveys in suitable habitats. As a result of the plan, several areas have been fenced to exclude livestock and a considerable number of additional populations have been discovered (B. Corbin *in litt.* 1999, B. Corbin *in litt.* 2000, G. Schoolcraft *in litt.* 2000, California Natural Diversity Data Base 2003).

Substantial information on the demography, ecology, and genetics of *Orcuttia tenuis* was provided by Griggs (1980) through his doctoral research. Also, a status survey funded by us led to the discovery of 18 new *O. tenuis* occurrences (Stone *et al.* 1988). In addition, U.S. Forest Service personnel subsequently discovered 16 additional occurrences on public land (California Natural Diversity Data Base 2003). In 1995, the California Department of Fish and Game sponsored a workshop focusing on recovery strategies for *Orcuttia* species in Sacramento County (S. Cochrane *in litt.* 1995*a*, *in litt.* 1995*b*). A study of vernal pools on the Vina Plains preserve that was conducted in 1995 provided additional ecological information and management recommendations; we supported this research through section 6 funding (Alexander and Schlising 1997).

12. *ORCUTTIA VISCIDA* (SACRAMENTO ORCUTT GRASS)

a. Description and Taxonomy

Taxonomy.—Sacramento Orcutt grass is in the tribe Orcuttieae of the grass family Poaceae (Reeder 1965). Hoover (1941) first published the scientific name *Orcuttia californica* var. *viscida* for Sacramento Orcutt grass. He had collected the type specimen from "7 miles south of Folsom" in Sacramento County (Hoover 1941:155). Although Hoover recognized that Sacramento Orcutt grass differed from California Orcutt grass in several respects, he did not consider the former to represent a distinct species. However, Reeder (1980) determined that the differences in morphology, seed size, and chromosome number were sufficient grounds to elevate Sacramento Orcutt grass to the species level as *Orcuttia viscida*. Reeder's taxonomy has been accepted since that time. Other common names for this species include Sacramento orcuttia (Smith *et al.* 1980) and sticky Orcutt grass (California Department of Fish and Game 1987*c*).

Description and Identification.—In basic form, *Orcuttia viscida* resembles other members of the tribe and genus. Although all members of the Orcuttieae produce exudate, *O. viscida* is particularly viscid even when young, hence the scientific name. The plants are densely tufted, bluish-green, and covered with hairs. The stems are erect or spreading, 3 to 10 centimeters (1.2 to 3.9 inches) long, and do not branch. Leaf width is 2 to 4 millimeters (0.08 to 0.16 inch). The inflorescence occupies the upper one-third to one-half of the stem and consists of between 5 and 15 spikelets. The spikelets are closely spaced, and although distichous, are oriented towards one side of the stem. Each spikelet contains 6 to 20 florets. The lemmas are 6 to 7 millimeters (0.24 to 0.28 inch) long and divided about halfway into teeth; the central tooth is longer than the others. The teeth are tipped with bristles 1 millimeter (0.04 inch) or more in length. The tips of the lemma teeth bend downward slightly, giving the inflorescence a bristly appearance. Seeds of *O. viscida* are about 2.5 millimeters (0.10 inch) long (Hoover 1941; Griggs 1977*a*; Reeder 1982, 1993; Stone *et al.* 1988) and weigh about 0.45 milligram (1.6×10^{-5} ounce) (Griggs 1980, Griggs and Jain 1983). The diploid chromosome number is 28 (Reeder 1980).

Orcuttia viscida has unequal lemma teeth, unlike *O. pilosa* and *O. tenuis*. Both *O. californica* and *O. inaequalis* have unequal lemma teeth but can be distinguished from *O. viscida* by the length of the lemma and its teeth and bristles, the size and density of the inflorescence, and the size of the seeds. Moreover, the chromosome number of *O. viscida* differs from all other *Orcuttia* species (Reeder 1982).

b. Historical and Current Distribution

Historical Distribution.—*Orcuttia viscida* is endemic to the Southeastern Sacramento Valley Vernal Pool Region (Keeler-Wolf *et al.* 1998) and always has been restricted to Sacramento County (**Figure II-16**). The earliest collection was from 1936 near Phoenix Field. Three other occurrences documented in 1941 and 1958 extended the range north to Orangevale and south to near Sloughhouse. *Orcuttia viscida* was introduced to Phoenix Park, in Sacramento County, in 1978. Three additional natural occurrences were discovered in the late 1980s, including one in extreme southeastern Sacramento County near Route 104. Thus, by 1990, this species was known from a total of seven natural occurrences and one introduction (Stone *et al.* 1988, California Natural Diversity Data Base 2003).

Current Distribution.—Within the past two decades, *Orcuttia viscida* has been discovered at one new site in Sacramento County, within the previously known range. However, one entire occurrence and a portion of another have been extirpated. Thus, eight of the nine occurrences are extant. Five occurrences, comprising more than 70 percent of the occupied habitat, are concentrated into a single area of about 6 square kilometers (2.3 square miles) in the Rancho Cordova area east of Mather Field. Two other occurrences are adjacent to each other: Phoenix Field Ecological Reserve and the introduced population at Phoenix Park. The eighth extant occurrence is near Rancho Seco Lake (Stone *et al.* 1988, S. Cochrane *in litt.*1995*a*, S. Morey *in litt.* 1996, California Natural Diversity Data Base 2003). All occurrences are in the Southeastern Sacramento Valley Vernal Pool Region (Keeler-Wolf *et al.* 1998).

c. Life History and Habitat

Basic life history and habitat requirements of this plant are likely similar to those described above in the species accounts for *Orcuttia inaequalis* and *Neostapfia colusana*.

Reproduction and Demography.—*Orcuttia viscida* flowers in May and June (Griggs 1977a, Skinner and Pavlik 1994, S. Cochrane *in litt.* 1995*a*) and sets seed in June and July (Holland 1987). The plants are adapted for wind pollination, but do provide a source of pollen for native bees (Griggs 1974 as cited in Stone *et al.* 1988). Seeds likely do not disperse far under natural conditions. In a 6-year period, an experimental population spread at most 3 meters (10 feet) from the seed source, and 95 percent of plants were within 30 centimeters (11.8 inches) of the source (R. Holland *in litt.* 1986). A demographic study conducted from 1974 to 1978 (Griggs 1980, Griggs and Jain 1983) indicated that *O. viscida* produced an average of 500 seeds per plant. At one site in 1978, 88 percent of plants survived to maturity. The size of the seed bank stored in the soil was about 44 times as great as the population of growing plants (Griggs 1980, Griggs and Jain 1983). The number of plants varies with rainfall. Large numbers of plants grow only in years when seasonal rainfall exceeds 40 centimeters (15.7 inches), particularly when heavy rains begin in November and continue through the end of April (Holland 1987). This species is apparently less likely to germinate in years of below-normal precipitation than are other members of the tribe (Griggs 1980, Griggs and Jain 1983). In studies of enzyme systems, genetic diversity between populations of *O. viscida* was low. However, plants from the primary area of concentration had alleles that did not occur in other areas. The amount of genetic variation occurring among related individuals was about equal to that within populations (Griggs 1980, Griggs and Jain 1983).

Habitat and Community Associations.—*Orcuttia viscida* has been found in Northern Hardpan and Northern Volcanic Mudflow vernal pools (Sawyer and Keeler-Wolf 1995). It occurs on high-terrace sites (Stone *et al.* 1988) at elevations of 46 to 82 meters (150 to 270 feet) (California Natural Diversity Data Base 2005). Occupied pools occur in *Quercus douglasii* woodland and annual grassland (Crampton 1959, Griggs 1977a, California Natural Diversity Data Base 2005). Among occupied pools discovered prior to 1988, the median area was 0.28 hectare (0.69 acre) and ranged from 0.1 hectare (0.25 acre) to 0.82 hectare (2.03 acres). Soils underlying pools where *O. viscida* grows are acidic with an iron-silica hardpan (Stone *et al.* 1988), and the pools contain numerous cobbles (Crampton 1959, Stone *et al.* 1988). Four of the known occurrences are on soils in the Redding series, two are on Red Bluff-Redding complex soils, two are (or were) on Xerarents-urban land-San Joaquin complex, and one is on Corning complex soils. The most common associates of *Orcuttia viscida* are *Plagiobothrys stipitatus*, *Eryngium* spp., *Eleocharis macrostachya*, and *Psilocarphus brevissimus* (Stone *et al.* 1988). *Gratiola heterosepala* co-occurs with *O. viscida* in one pool (Stone *et al.* 1988, California Natural Diversity Data Base 2005). One population of *O. tenuis* grows in the same vicinity as *O. viscida*, but the two species have not been found together (Cochrane *in litt.* 1995*a*).

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 *Orcuttia viscida* are described below.

Urbanization is a continuing threat, particularly in the Rancho Cordova area (S. Cochrane *in litt.* 1995*a*). Expansion of the Kiefer Landfill in Sacramento County may adversely affect the occurrences adjacent to the new landfill footprint (S. Cochrane *in litt.* 1995*a*, U.S. Fish and Wildlife Service 2005). At present, trash from the landfill frequently blows into the pools (S. Cochrane *in litt.* 1995*b*). An industrial park and road widening are other urban-related factors that threaten *Orcuttia viscida* (Stone *et al.* 1988, S. Cochrane *in litt.* 1995*a*). The Phoenix Field Ecological Reserve and Phoenix Park occurrences are in an urban landscape. The Ecological Reserve is completely surrounded by housing and the vernal pools are buffered by as little as 3 feet (1 meter) from adjacent residential backyards (D. Burmester, pers. comm. 2005). They are affected by excess runoff from lawns, ball fields, and roads; by herbicide and fertilizer applied in adjacent areas (Griggs and Jain 1983, R. Holland *in litt.* 1986, Stone *et al.* 1988, S. Cochrane *in litt.* 1995*a*, S. Morey *in litt.* 1996, Clark *et al.* 1998); and by dumping of landscape waste (Clark *et al.* 1998). The California Department of Fish and Game installed a drain to prevent urban and landscape runoff from entering the vernal pools (M. Showers, *in litt*. 2005). Another threat at the Phoenix Field Ecological Reserve is invasion of garden plants (Clark *et al.* 1998, California Natural Diversity Data Base 2003). Recreational activities such as rollerblading (C. Witham *in litt.* 2000*a*), biking, and horseback riding (S. Cochrane *in litt.* 1995*a,b*; Clark *et al.* 1998) also pose continuing threats of damage to the Phoenix Park occurrence of this plant. In addition, competition from other native plants, such as *Eleocharis macrostachya* and nonnative plants such as *Glyceria* spp. (mannagrass) could displace *O. viscida* (Stone *et al.* 1988, S. Cochrane *in litt.* 1995*a,b*; Clark *et al.* 1998). Mining, off-road vehicle use, and vandalism also threaten one or more specific occurrences (U.S. Fish and Wildlife Service 1997*a*). Although the individual populations of *O. viscida* are sufficiently large that they are not subject to random fluctuations such as genetic drift, the very restricted range of the species as a whole puts it in continued danger of extinction from random, catastrophic events.

e. Conservation Efforts

Orcuttia viscida was federally listed as an endangered species on March 26, 1997 (U.S. Fish and Wildlife Service 1997*a*) and had been previously State-listed as endangered in 1979 (California Department of Fish and Game 1991). The California Native Plant Society has included it on lists of very rare and endangered plants for over two decades (Powell 1974); *O. viscida* is currently on List 1B, with the highest endangerment rating possible (California Native Plant Society 2001). In 2005, critical habitat was designated for *O. viscida* 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).

Two reserves have been set aside to protect *Orcuttia viscida*. The Phoenix Field Ecological Reserve encompasses 3.2 hectares (8 acres) and is managed by the California Department of Fish and Game. The site has been fenced, and only authorized persons have access. The California Department of Fish and Game plans to install a drain to prevent urban and landscape runoff from entering the pools. Volunteers and agency personnel monitor the *O. viscida* population periodically (S. Morey *in litt.* 1996, Clark *et al.* 1998). The nearby Phoenix Park Vernal Pool Preserve encompasses 5.7 hectares (14 acres) and is managed by the Fair Oaks Recreation and Park District. A low fence excludes motorized vehicles, but allows foot traffic. Interpretive signs and a footbridge also have been installed (Clark *et al.* 1998).

Griggs (1980) studied the ecology, demography, and genetics of several species in the Orcuttieae tribe, including *Orcuttia viscida*. In the course of his research, he introduced local seeds into an unoccupied, natural pool in Phoenix Park. The introduction apparently was successful because the population has persisted and remained stable since 1978 (S. Cochrane *in litt.* 1995*a*, California Natural Diversity Data Base 2003).

We funded a status survey for members of the Orcuttieae in the 1980s, which led to the discovery of several new populations (Stone *et al.* 1988). The California Department of Fish and Game sponsored a native plant recovery workshop in 1995 to develop recovery strategies for *Orcuttia viscida* (S. Cochrane *in litt.* 1995*a*). Workshop participants have since conducted several tasks contributing to the species' recovery, including monitoring populations, assessing threats, and providing public education (S. Cochrane *in litt.* 1995*b*, S. Morey *in litt.* 1996).

13. *PARVISEDUM LEIOCARPUM* (LAKE COUNTY STONECROP)

a. Description and Taxonomy

Taxonomy.—Lake County stonecrop is in the stonecrop family (Crassulaceae) and is one of only three (Moran 1997) or four (Clausen 1946, Denton 1993) species in the genus *Parvisedum*, depending on individual interpretations by taxonomists. The original scientific name for Lake County stonecrop was *Sedella leiocarpa* (Sharsmith 1940). The type locality was cited as "6.5 miles north of Lower Lake, Lake County, California" (Sharsmith 1940:193). Clausen (1946) changed the name of this species to *Parvisedum leiocarpum* because the genus name *Sedella* already had been applied to another group of plants. However, Moran (1997) returned to using the name *Sedella leiocarpa* for Lake County stonecrop, after another taxonomist determined that the genus name *Sedella* had been used improperly for the other group of plants. We originally listed the species as endangered under the name *Parvisedum leiocarpum* (U.S. Fish and Wildlife Service 1997b) and we have not yet formally changed our nomenclature for the species, so in this recovery plan we continue to refer to it by the scientific name *Parvisedum leiocarpum*.

Description and Identification.—*Parvisedum leiocarpum* (**Figure II-17**) is a tiny, fleshy, annual herb. The reddish, hairless stems are at most 5 centimeters (2.0 inches) tall and may or may not be branched. Leaf arrangement is opposite at the base of the plant and alternate on the upper stem. The 2 to 5 millimeter-long (0.08 to 0.20 inch-long) leaves are entire, fleshy, and green with red streaks; the bracts are similar but smaller. The leaves fall off the stem before the flowers open, but the bracts persist. On each branch of the inflorescence, the flowers are crowded together in two rows, which are both on the same side of the branch. The individual flowers are 3 to 4 millimeters (0.12 to 0.16 inch) wide and about the same length. Flowers typically have five petals and other parts (sepals, pistils, and stamens), but occasionally have four of each flower part. The petals range in color from pale yellow to chartreuse, have reddish streaks on the back, and are about 2.6 to 3.8 millimeters (0.10 to 0.15 inch) long with light fusing at the base. Each petal has a flattened, reddish nectar-producing gland at its base; the glands are 0.5 to 0.8 millimeter (0.02 to 0.03 inch) in length. Each pistil develops into a dry, hairless fruit 1.5 to 2.5 millimeters (0.06 to 0.10 inch) long, which contains a single seed. The narrow seeds are light brown and 1 to 1.5 millimeters (0.04 to 0.06 inch) long (Sharsmith 1940, Clausen 1975, Denton 1993, Moran 1997). *Parvisedum leiocarpum* has a diploid chromosome number of 18 (Moran 1997), as do all other species in the genus (Clausen 1975, Denton 1993). The species most likely to be confused with *P. leiocarpum* is *P. pentandrum* (Mt. Hamilton stonecrop), which overlaps in range. However, the

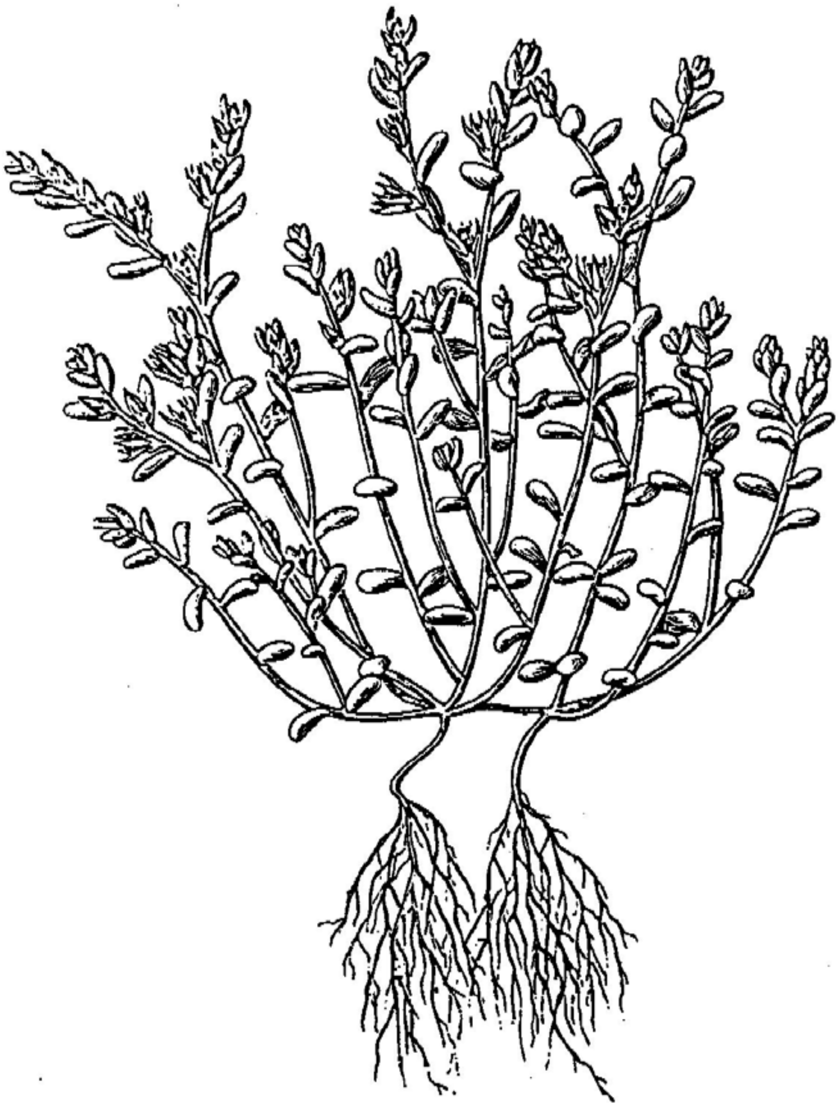

Figure II-17. Illustration of *Parvisedum leiocarpum* (Lake County stonecrop). Drawing by Elfriede Abbe, reprinted from R.T. Clausen, *Sedum of North America North of the Mexican Plateau.* Copyright © 1975 by Cornell University. Used by permission of the publisher, Cornell University Press.

latter is a taller plant with smaller flowers, nectaries, fruits, and seeds; the petals do not have red streaks on the back; and the fruits are glandular-hairy.

Other species of *Parvisedum* have 10 stamens. *Crassula connata* (pygmy stonecrop), another inconspicuous annual species in the same family, has strictly opposite leaves that are fused at the base and very tiny flowers in the leaf axils. Other genera in the family are perennial or have more seeds per pistil (Sharsmith 1940, Clausen 1975, Denton 1993).

b. Historical and Current Distribution

***Historical Distribution.*—**Current evidence indicates that this species always has been restricted to southeastern Lake County, and to the Lake-Napa Vernal Pool Region (Keeler-Wolf *et al.* 1998) (**Figure II-5**). *Parvisedum leiocarpum* was known historically from six to eight occurrences west and south of Clear Lake, where it was collected repeatedly between 1936 and 1961. The exact number of sites is uncertain because several vague location descriptions may or may not refer to the same site. All collections were from the area roughly bounded by Kelseyville, Lower Lake, and Middletown (Patterson 1986). Manning Flat, which is along Highway 29 west of Lower Lake, apparently represents the type locality (Moran 1997). Although it is west rather than north of Lower Lake, Clausen (1975:597) noted that the type specimen was collected "on Kelseyville Highway," which apparently refers to Highway 29. *Parvisedum leiocarpum* was not observed between 1963 (Clausen 1975) and the late 1980s, when it was rediscovered at three of the historical localities (Patterson 1986, 1988; California Natural Diversity Data Base 2003). A sixth population was discovered in 1995 near Snows Lake in Lake County (Moran 1997), but is not catalogued by the California Natural Diversity Data Base (2005).

***Current Distribution.*—**The four occurrences of *Parvisedum leiocarpum* last seen in the 1980s and 1990s are assumed to be extant, although they have not been revisited. Two others not seen since the 1940s also are assumed to remain extant because suitable habitat remained in the vicinity of those collections as of 1986. Three of those six occurrences, including Manning Flat, are along Highway 29. The other three occurrences include one farther south near Whispering Pines, one southeast of Lower Lake in Little High Valley (Patterson 1986, 1988; California Natural Diversity Data Base 2005), and one at Snows Lake (Moran 1997). All known occurrences are in the Boggs Lake-Clear Lake Core Area in the Lake-Napa Vernal Pool Region.

c. Life History and Habitat

Reproduction and Demography.—Relatively little is known about the life history and demography of *Parvisedum leiocarpum*. It is an annual that flowers in April and May (Clausen 1975, California Department of Fish and Game 1990*b*, Skinner and Pavlik 1994, Moran 1997). The presence of conspicuous nectaries suggests that the flowers are insect-pollinated. Seed dispersal is likely very limited in extent. The seeds normally remain inside the fruits and the fruits remain on the plants even after the growing season (Moran 1997). Water is one possible dispersal mechanism because the fruits can float if detached (Moran 1997). *Parvisedum leiocarpum* typically occurs in dense patches with few other plants (Clausen 1975), although Patterson (1988) found one colony that was very sparse. The number of individual plants in a population can be high, even when it occupies a very small area due to the high density and the small size of each plant.

Habitat and Community Associations.—*Parvisedum leiocarpum* occurs on more or less level sites in shallow depressions that retain water seasonally. Known microhabitats include Northern Basalt Flow and Northern Volcanic Ashflow vernal pools (Sawyer and Keeler-Wolf 1995), low areas in meadows and gravelly flats, and hollows in exposed rocks. A few plants were found on a man-made berm within a flat that supported a large population. The occupied habitats occur adjacent to oak woodland, chaparral, or grassland. Substrates on which *P. leiocarpum* occur frequently are of volcanic origin and often are gravelly (Patterson 1986). Soil pH at one site ranged from 6.2 to 6.4 (Clausen 1975). Soil types are not known for all historical sites, but this species grows on at least the Glenview-Bottlerock complex, the Konocti-Benridge complex, the Konocti Variant-Konocti-Hambright complex and the Speaker-Sanhedrin-Maymen association.

Extant and historical localities ranged in elevation from 518 to 792 meters (1,700 to 2,600 feet) (Moran 1997, California Natural Diversity Data Base 2003). Plants that frequently grow in the same vernal pools and meadows with *Parvisedum leiocarpum* include *Mimulus tricolor*, *Lasthenia fremontii*, and *Plagiobothrys stipitatus*. The only immediate associate in the rock pools at the Little High Valley site is an unidentified moss (class Musci). Two other plants featured in this recovery plan co-occur with *Parvisedum leiocarpum*: *Navarretia leucocephala* ssp. *pauciflora* co-occurs at three sites, and *Gratiola heterosepala* is present at one of the three. *Lasthenia burkei*, an endangered plant that is not addressed in this recovery plan, occurs at Manning Flat, but is found across the road from the *Parvisedum leiocarpum* population (Patterson 1986, California Natural Diversity Data Base 2003).

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 *Parvisedum leiocarpum* are described below.

Land conversion for housing and agriculture, highway widening, and road maintenance continue as specific threats to *Parvisedum leiocarpum* habitat at five of the historical localities (Patterson 1986, California Department of Fish and Game 1990*b*). At each of the presumed extant occurrences, *P. leiocarpum* occupies no more than 0.04 hectare (0.1 acre), so even small habitat losses to any of these factors could easily extirpate an entire population (Patterson 1986). Also, the extremely small populations are highly vulnerable to elimination from random fluctuations in environmental conditions, natural catastrophes, and genetic bottlenecks (Menges 1991); the restricted range of the species means that a regional catastrophe could drive the entire species to extinction.

e. Conservation Efforts

Parvisedum leiocarpum was federally listed as an endangered species on June 18, 1997 (U.S. Fish and Wildlife Service 1997*b*). *Parvisedum leiocarpum* was previously State listed as endangered in 1990 (California Department of Fish and Game 1991). The California Native Plant Society has recognized this species as rare and endangered since its first list was published (Powell 1974); it is still on the California Native Plant Society List 1B, assigned the highest endangerment rating possible (California Native Plant Society 2001).

The California Department of Fish and Game funded a status survey of *Parvisedum leiocarpum* in 1986 (Patterson 1986). Patterson conducted additional surveys in 1987, then petitioned the California Fish and Game Commission to list *P. leiocarpum* as an endangered species (Patterson 1988). None of the localities for this species are in public ownership, and no conservation measures have been implemented by any of the landowners.

14. *TUCTORIA GREENEI* (GREENE'S TUCTORIA)

a. Description and Taxonomy

Taxonomy.—The genus *Tuctoria* is in the grass family (Poaceae), subfamily Chloridoideae, and is a member of the Orcuttieae tribe, which also includes *Neostapfia* and *Orcuttia* (Reeder 1965, Keeley 1998). Vasey (1891:146) originally assigned the name *Orcuttia greenei* to this species, from a type specimen collected in 1890 "on moist plains of the upper Sacramento, near Chico, California," presumably in Butte County (Hoover 1941, Crampton 1958). Citing differences in lemma morphology, arrangement of the spikelets, and other differences (see "Description" below), Reeder (1982) segregated the genus *Tuctoria* from *Orcuttia* and created the new scientific name *Tuctoria greenei* for this species. Subsequent research suggests that *Tuctoria* is intermediate in evolutionary position between the primitive genus *Neostapfia* and the advanced genus *Orcuttia* (Keeley 1998, L. Boykin *in litt.* 2000). Several other common names have been used for this species, including Chico grass (Scribner 1899), awnless Orcutt grass (Abrams 1940), Greene's orcuttia (Smith *et al.* 1980), and Greene's Orcutt grass (California Department of Fish and Game 1991, U.S. Fish and Wildlife Service 1985*c).*

Description and Identification.—The basic characteristics pertaining to all members of the Orcuttieae were described above in the *Neostapfia colusana* account. The genus *Tuctoria* is characterized by flattened spikelets similar to those of *Orcuttia* species, except that the spikelets of *Tuctoria* grow in a spiral, as opposed to a distichous, arrangement. *Tuctoria* species have short-toothed, narrow lemmas. The juvenile and terrestrial leaves of *Tuctoria* are similar to those of *Orcuttia*, but *Tuctoria* does not produce the floating type of intermediate leaves (Reeder 1982, Keeley 1998). *Tuctoria* appears to be intermediate between *Neostapfia* and *Orcuttia* in its degree of aquatic specialization (Keeley 1998).

Tuctoria greenei (**Figure II-18**) grows in tufts of several stems, which are erect or decumbent and break easily at the base. The entire plant tends to be pilose, but is only slightly viscid. The stems are usually 5 to 15 centimeters (2.0 to 5.9 inches) tall and are not branched. *Tuctoria greenei* has purplish nodes and leaves no wider than 5 millimeters (0.20 inch). The inflorescence can be as much as 8 centimeters (3.1 inches) long; it may be partly hidden by the leaves when young, but is held above the leaves at maturity. The inflorescence usually consists of 7 to 15 spikelets, but may contain as many as 40. The spikelets are arranged in a spiral, with those in the upper half crowded together and those near the base more widely separated. Each spikelet consists of 5 to 15 florets and 2 glumes. The lemmas are 4 to 5 millimeters (0.16 to 0.20 inch) long and have squarish tips with 5 to 9 very short teeth; the central tooth is tipped by a very small spine. The roughened seeds are about 2 millimeters (0.08 inch) long (Vasey 1891, Hoover 1941, Griggs 1977*b*, Stone *et al.* 1988, Reeder 1982) and weigh about 0.5 milligram (1.8×10^{-5} ounce) (Griggs 1980). *Tuctoria greenei* has a diploid chromosome number of 24 (Reeder 1982).

Tuctoria greenei is differentiated from Orcutt grasses by the spiral arrangement of spikelets and lack of floating juvenile leaves, from *Neostapfia colusana* by the shape of the spikelets and the inflorescence, and from both by the shape of the lemmas. *Tuctoria greenei* can be distinguished from *T. mucronata* by the squarish lemma tip; smaller, roughened seeds; and inflorescence held above the leaves in the former. Both can be told from the remaining *Tuctoria* species by stem length, seed shape, and range. The chromosome number of *T. greenei* also differs from the other two species in the genus (Reeder 1982).

b. Historical and Current Distribution

Historical Distribution.—After its initial discovery in Butte County in 1890, *Tuctoria greenei* was not reported again for over 40 years. However, during extensive surveys in the late 1930s, Hoover (1937, 1941) found the species at 12 sites in Fresno, Madera, Merced, San Joaquin, Stanislaus, Tehama, and Tulare Counties (**Figure II-19**). In fact, he described it as the most common of all *Orcuttia* species, with which it was classified at the time.

Current Distribution.—*Tuctoria greenei* has been reported from a total of 41 occurrences in the original 8 counties listed above, plus Shasta County (Stone *et al.* 1988, Oswald and Silveira 1995, California Natural Diversity Data Base 2005). About half of the historical occurrences of *Tuctoria greenei* are presumed to be extant; 9 are certainly extirpated, and 10 others are possibly extirpated (Alexander and Schlising 1997, California Natural Diversity Data Base 2005). The majority of the 22 extant occurrences are in the Northeastern Sacramento Valley Vernal Pool Region, particularly in the Vina Plains. The next largest concentration is in the Southern Sierra Foothills Vernal Pool Region, where the only remaining occurrences are in eastern Merced County. The other two extant occurrences are in Glenn (Oswald and Silveira 1995, J. Silveira *in litt.* 2000) and Shasta Counties (California Natural Diversity Data Base 2003); the former is in the Solano-Colusa Vernal Pool Region, and the latter is in the Modoc Plateau Vernal Pool Region (Keeler-Wolf *et al.* 1998). *Tuctoria greenei* is believed extirpated from Fresno, Madera, San Joaquin, Stanislaus, and Tulare Counties (Stone *et al.* 1988, Skinner and Pavlik 1994, California Natural Diversity Data Base 2003).

Figure II-18. Illustration of *Tuctoria greenei* (Greene's tuctoria). Reprinted with permission from Abrams (1940), Illustrated Flora of the Pacific States: Washington, Oregon, and California, Vol. I. © Stanford University Press.

c. Life History and Habitat

The basic life history strategy and habitat requirements of *Tuctoria* species were described earlier in this document, under discussions for *Neostapfia colusana* and *Orcuttia inaequalis*.

Reproduction and Demography.—Optimum germination of *Tuctoria greenei* seed occurs when the seed is exposed to light and anaerobic conditions after stratification (Keeley 1988). Germination occurs about 2 months following inundation (Keeley 1998). *Tuctoria* seedlings do not develop floating juvenile leaves, as does *Orcuttia* (Griggs 1980, Keeley 1998). The plants apparently do not tolerate inundation; all five *T. greenei* plants in a Glenn County pool died when the pool refilled during late spring rains in 1996 (J. Silveira *in litt.* 1997). *Tuctoria greenei* flowers from May to July (Skinner and Pavlik 1994), with peak flowering in June and July (Griggs 1981, Broyles 1987).

As with other vernal pool annuals, population size in *Tuctoria greenei* varies widely from year to year, and populations that have no visible plants one year can reappear in large numbers in later years. Population fluctuations may be due to annual variations in weather, particularly rainfall, to changes in management, or combinations of the two. Such fluctuations were observed at scattered sites in Butte and Tehama Counties during the 1970s (Griggs 1980, Griggs and Jain 1983) and at Sacramento National Wildlife Refuge, where the population in the single occupied pool ranged from 0 to 60 plants between 1994 and 1999 (J. Silveira *in litt.* 2000). Fluctuations of as much as three orders of magnitude were documented on the Vina Plains Preserve during the 1980s and 1990s; the high 1995 population estimates followed a winter of favorable rainfall (Alexander and Schlising 1997) and a long period without livestock grazing. Cattle grazing on the Vina Plains Preserve was discontinued in the growing season of 1987 to 1988 and did not resume until the growing season of 1995 to 1996 (D. Alexander *in litt.* 1998).

Populations that decline to zero may not always be capable of rebounding from the soil seed bank, however, and the population is likely extirpated if the plants do not reappear under favorable conditions. One Stanislaus County population of *Tuctoria greenei* (Element Occurrence 39) numbered fewer than 100 plants in 1973, dropped to 2 the following year, and remained at 0 for the next 3 years (Griggs 1980, Griggs and Jain 1983). The population was not monitored for the following decade. Although the vernal pool was still intact as of 1986, *T. greenei* was not observed during surveys that year; however, the winter had been drier than average. In 1987, following a winter of favorable rainfall, *T. greenei* still was not present, even though *Neostapfia colusana* was found in large numbers.

(Stone *et al.* 1988), indicating that *T. greenei* has most likely permanently disappeared from this site. The area had been “rather heavily grazed” in 1987 (Stone *et al.* 1988), but livestock grazing intensity during the 1970s is not known

In a demographic study conducted during 1977 to 1978 on two populations from Butte and Tehama Counties, from 0 to 54 percent of seedlings survived to maturity. Plants that reached the flowering stage achieved a density of 82 to 133 individuals per square meter (7.6 to 12.4 individuals per square foot) and averaged 111 seeds per plant (Griggs 1980, Griggs and Jain 1983). In 1995, the density of *Tuctoria greenei* on the Vina Plains Preserve ranged from 7 to 133 plants per square meter (0.7 to 12.4 plants per square foot) (Alexander and Schlising 1997).

A study of genetic partitioning in five species of *Orcuttia* and *Tuctoria* (Griggs 1980, Griggs and Jain 1983) revealed that *T. greenei* had the lowest genetic diversity (50 percent) of the species studied. As with the other species, plants originating from the same seed parent accounted for about the same degree of genetic diversity (44 percent) as others within the same population (46 percent). Only 10 percent of the total genetic variability observed in the species was due to between-population differences, indicating low levels of gene flow between populations, but high levels of gene flow within populations. However, Griggs’ genetic study included only two populations from adjacent counties (Butte and Tehama) and did not consider geographically distant occurrences.

Habitat and Community Associations.—*Tuctoria greenei* has been found in three types of vernal pools: Northern Basalt Flow, Northern Claypan, and Northern Hardpan (Sawyer and Keeler-Wolf 1995) on both low and high terraces (Stone *et al.* 1988). Occupied pools are or were underlain by iron-silica cemented hardpan, tuffaceous alluvium, or claypan (Stone *et al.* 1988). Of pools where the species was known to be extant in 1987, the median size was 0.6 hectare (1.5 acres), with a range of 50 square meters (0.01 acre) to 3.4 hectares (8.4 acres) (Stone *et al.* 1988). Stone *et al.* (1988) noted that *T. greenei* grew in shallower pools than other members of the tribe or on the shallow margins of deeper pools, but they did not quantify pool depth. At the Vina Plains, *T. greenei* grew in pools of “intermediate” size, which dried in April or early May of 1995 (Alexander and Schlising 1997). The Central Valley pools containing *T. greenei* are (or were) in grasslands; the Shasta County occurrence is surrounded by pine forest (California Natural Diversity Data Base 2003). Occupied pools in the Central Valley are (or were) at elevations of 33.5 to 134 meters (110 to 440 feet) (Stone *et al.* 1988), whereas the Shasta County occurrence is at 1,067 meters (3,500 feet) (California Natural Diversity Data Base 2003).

In the Northeastern Sacramento Valley Vernal Pool Region, *Tuctoria greenei* grows mostly on Anita clay and Tuscan loam soils, with one occurrence on Tuscan stony clay loam. Soil types are not certain for several other occurrences in this region; one is on either the Rocklin or the San Joaquin series, and the others are unknown. The single occurrence in the Solano-Colusa Vernal Pool Region is on strongly saline-alkaline Willows clay (J. Silveira *in litt.* 2000). In the Southern Sierra Foothills Vernal Pool Region, *T. greenei* is known to grow on a number of different soil series including Archerdale, Bear Creek, Exeter, Meikle, Ramona, Raynor, Redding, and San Joaquin. Soil types have not been determined for occurrences in the other regions.

At the Vina Plains Preserve, frequent associates of *Tuctoria greenei* are *Eryngium castrense* and *Marsilea vestita* (Alexander and Schlising 1997). Elsewhere in the Sacramento Valley and in the San Joaquin Valley, *T. greenei* often grows in association with *E. vaseyi*, *Plagiobothrys stipitatus*, and *Alopecurus saccatus* (foxtail). The rare *Chamaesyce hooveri* co-occurs with *T. greenei* at eight sites in the Sacramento Valley. Other rare plants that grow in the same vernal pools with *T. greenei* at a few occurrences are: *Orcuttia pilosa*, *O. inaequalis*, *O. tenuis*, *Neostapfia colusana*, and *Gratiola heterosepala* (Broyles 1987, Stone *et al.* 1988, California Natural Diversity Data Base 2005).

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 *Tuctoria greenei* are described below.

One potential factor unique to this and some other vernal pool plant species may be decimation by grasshopper outbreaks. Grasshoppers have been noted consuming entire populations of *Tuctoria greenei* before they set seed (Griggs 1980, Griggs and Jain 1983, Stone *et al.* 1988). At the Vina Plains Preserve in Tehama County, the seed bank permitted some recovery after total destruction of the plants by grasshoppers. Sampling at one Vina Plains Preserve vernal pool in 1997 prior to a grasshopper event in 1998 showed that *Tuctoria greenei* had a frequency of 0.066 and a density of 26.3 plants per square meter (2.4 plants per square foot). In 1998 grasshoppers ate all of the plants and no seeds were produced. In 1999, 1 year after the grasshopper event, the same sampling showed a frequency of 0.025 and a density of 2.9 plants per square meter (0.27 plants per square foot) (R. Schlising *in litt*. 2005).

Primary threats to this species are also continuing. Agricultural conversion and inappropriate livestock grazing practices pose threats to virtually all of the occurrences remaining in the San Joaquin Valley, although one small population is on a site that has been proposed for protection as a mitigation bank (California Natural Diversity Data Base 2003). Fifteen populations of *Tuctoria greenei* throughout its range are subject to adverse effects related to cattle grazing (Stone *et al.* 1988, B. Corbin *in litt.* 2000, California Natural Diversity Data Base 2003). Small population size poses a continuing threat to seven occurrences in Butte, Glenn, and Merced Counties. Each of these populations numbered 110 or fewer *T. greenei* plants at its peak (Stone *et al.* 1988, California Natural Diversity Data Base 2005). The Shasta County population also may have declined to the point where it could be extirpated by random causes; although it consisted of 2,500 plants in 1993 and 1994, the population declined to 120 in 1996 and 35 in 1998, despite favorable hydrological conditions (B. Corbin *in litt.* 2000). Urbanization, including construction of a landfill, is a potential threat to the species.

e. Conservation Efforts

We listed *Tuctoria greenei* as endangered on March 26, 1997 (U.S. Fish and Wildlife Service 1997*a*). The State of California listed *T. greenei* as rare in 1979 (California Department of Fish and Game 1991), and the California Native Plant Society had recognized it as rare and endangered even earlier (Powell 1974). Currently, the California Native Plant Society (2001) includes *T. greenei* on List 1B, ranking it as “endangered throughout its range.” In 2005, critical habitat was designated for *T. greenei* 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).

Surveys by Hoover (1937, 1941) documented the historical range of *Tuctoria greenei*. Later surveys by Crampton (1959) and Medeiros (1976) revealed the destruction of various occurrences. The most recent, comprehensive survey (Stone *et al.* 1988) was funded by us to determine the status of *T. greenei* and related species. During the course of their surveys and related projects, Stone and others (1988) discovered four populations that were previously unknown. Research conducted by Griggs (1980) provided insights into the demography, ecology, and genetics of *T. greenei*, among other species. As part of his research, Griggs attempted to introduce *T. greenei* to two pools in Butte County, but the species never became established. Keeley (1988) conducted research on the conditions necessary for germination. We and the California Department of Fish and Game supported an ecological study of *T. greenei* and other rare species on the Vina Plains Preserve in 1995 (Alexander and Schlising 1997).

Six occurrences of *Tuctoria greenei* are on The Nature Conservancy's Vina Plains Preserve. This species has grown in as many as seven pools on the preserve in certain years (Stroud 1990, Alexander and Schlising 1997), including one pool on the Wurlitzer Unit (California Natural Diversity Data Base 2003). The Glenn County population, on the Sacramento National Wildlife Refuge, is the only occurrence known from public land.

15. *TUCTORIA MUCRONATA* (SOLANO GRASS)

a. Description and Taxonomy

Taxonomy.—Solano grass is in the Orcuttieae tribe of the grass family Poaceae (Reeder 1965). Solano grass was originally described under the name *Orcuttia mucronata*, based on specimens collected "12 miles due south of Dixon, Solano County" (Crampton 1959:108). Reeder (1982) transferred this species to a new genus, *Tuctoria*, resulting in the currently accepted name *Tuctoria mucronata*. Other common names are Crampton's Orcutt grass (Griggs 1977*b*), mucronate orcuttia (Smith *et al.* 1980), and Crampton's tuctoria (Skinner and Pavlik 1994).

Description and Identification.—Characteristics of the Orcuttieae were described earlier in this document under the *Neostapfia colusana* account and those common to the genus *Tuctoria* were presented in the *T. greenei* account. *Tuctoria mucronata* is grayish-green, pilose, and viscid. The tufted stems are decumbent, 12 centimeters (4.7 inches) or less long, and do not branch. The leaves are 1 to 4 centimeters (0.4 to 1.6 inches) long, are rolled inward, and have pointed tips. The inflorescence is 1.5 to 6 centimeters (0.6 to 2.4 inches) long, and its base is partially hidden by the uppermost leaves. As for all plants in this genus, the spikelets are arranged in a spiral; the 7 to 19 spikelets in the inflorescence of *T. mucronata* are crowded together. Spikelets range from 7 to 13 millimeters (0.28 to 0.51 inch) in length and consist of 5 to 10 florets, plus two glumes. The lemmas are 5 to 7 millimeters (0.20 to 0.28 inch) long and taper towards the tip, which is curved outward. The lemma teeth are not obvious except for the central one, which has a sharply pointed tip up to 1 millimeter (0.04 inch) long. *Tuctoria mucronata* has smooth seeds about 3 millimeters (0.12 inch) long and a diploid chromosome number of 40 (Crampton 1959; Reeder 1982, 1993).

Unlike *Tuctoria greenei*, the inflorescence of *T. mucronata* remains partly hidden by the leaves, even at maturity. In addition, *T. mucronata* stems are shorter than those of *T. greenei*, and the former has tapered lemmas and larger, smoother seeds. The spiral arrangement of the spikelets and single obvious tooth per lemma distinguish *T. mucronata* from the Orcutt grasses. Finally, the tapered lemmas of *T. mucronata* differ from the fan-shaped lemmas of *Neostapfia colusana* (Reeder 1982).

b. Historical and Current Distribution

Historical Distribution.—Prior to 1985, *Tuctoria mucronata* was known only from Olcott Lake in Solano County, which is believed to be the type locality (Crampton 1959, California Natural Diversity Data Base 2003) (**Figure II-20**). Another occurrence was discovered in 1985 about 4 kilometers (2.5 miles) southwest of Olcott Lake (California Natural Diversity Data Base 2005). A third occurrence, comprising the largest population now known, was discovered in 1993 on a Department of Defense communications facility in Yolo County (California Natural Diversity Data Base 2005). All three sites are in the Solano-Colusa Vernal Pool Region (Keeler-Wolf *et al.* 1998).

Current Distribution.— *Tuctoria mucronata* may have been extirpated from Olcott Lake; the species has not been found there since 1993, when only four individual plants were observed (California Natural Diversity Data Base 2003). Twenty-six plants were found in 2004 and 3 plants were found in 2005 at the other Solano County site (C. Witham *in. litt*. 2005). The Yolo County population is extant.

c. Life History and Habitat

Typical life history and habitat characteristics for all members of the Orcuttieae and for all *Tuctoria* species were presented earlier in this document, under the *Neostapfia colusana* and *Orcuttia inaequalis* accounts.

Reproduction and Demography.—The germination period for *Tuctoria mucronata* seeds is not known, but is presumed to be in May or June (U.S. Fish and Wildlife Service 1985*a*). *Tuctoria* seedlings do not produce floating juvenile leaves (Griggs 1980). This species typically flowers in June and sets seed during July (Holland 1987). The demography of *Tuctoria mucronata* has not been investigated in detail. Annual estimates or counts at Olcott Lake (Holland 1987, California Natural Diversity Data Base 2005) indicated that population sizes for this species fluctuate dramatically from year to year, as do other members of the Orcuttieae. *Tuctoria mucronata* was not observed at Olcott Lake from 1976 through 1980, then reappeared in 1981 (Holland 1987), indicating that viable seeds can persist in the soil for at least 5 years. Apparently both drought years and years of excessively high rainfall are unfavorable for *T. mucronata*; the largest populations were observed after seasons of 45 to 60 centimeters (17.7 to 23.6 inches) of precipitation (Holland 1987).

Habitat and Community Associations.—*Tuctoria mucronata* has been found only in the Northern Claypan type of vernal pool (Sawyer and Keeler-Wolf 1995) within annual grassland (California Natural Diversity Data Base 2005). Pools where *T. mucronata* occurs tend to be milky from suspended sediments (Holland 1987). The pools that are occupied in Solano County are more properly described as alkaline playas or intermittent lakes, due to their large surface area (Crampton 1959, U.S. Fish and Wildlife Service 1985*a*), whereas those at the Yolo County site are "relatively small" (C. Witham *in litt.* 2000*a*). Soils underlying known *T. mucronata* sites are saline-alkaline clay or silty clay in the Pescadero series (Crampton 1959, California Natural Diversity Data Base 2003). Known occurrences are at elevations of about 5 to 11 meters (15 to 35 feet) (California Natural Diversity Data Base 2005).

Tuctoria mucronata is most commonly associated with *Frankenia salina*, *Eryngium aristulatum*, and *Neostapfia colusana*; *N. colusana* occurred near *T. mucronata* at all three sites. Additional associates include *Cressa truxillensis*, *Distichlis spicata*, *Phyla nodiflora*, *Crypsis schoenoides*, *Eleocharis macrostachya*, and *Malvella leprosa* (Crampton 1959, California Natural Diversity Data Base 2003). Other than *N. colusana*, the only other rare plant featured in this recovery plan that co-occurs with *T. mucronata* is *Astragalus tener* var. *tener*; the two taxa grow in the same vernal pool complex in Yolo County, but are not found in the same pool (California Natural Diversity Data Base 2005).

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 *Tuctoria mucronata* are described below.

One additional factor potentially involved in the decline of this particular species may be overcollection (T. Griggs *in litt*. 2000, California Natural Diversity Data Base 2005). Other additional factors include the evidence that the Yolo County habitat for *Tuctoria mucronata* has been degraded by discing, excavation, herbicide runoff, application of salt, and industrial contaminants in the groundwater (K. Fuller pers. comm. 1997, C. Witham *in litt.* 2000*a*, California Natural Diversity Data Base 2005).

A number of specific threats to the species are also continuing. These include competition from aggressive plants at all three known sites where the species occurs or formerly occurred. The primary competitors are *Phyla nodiflora* at

Olcott Lake (C. Witham *in litt.* 2000*a*), *Malvella leprosa* and *Crypsis schoenoides* at the other site in Solano County (California Natural Diversity Data Base 2003), and *Lepidium latifolium* (broad-leaved pepper-weed) in Yolo County (K. Fuller *in litt.* 1999). Altered hydrology may threaten the Olcott Lake occurrence, if it is extant (T. Griggs *in litt*. 2000). Effects of inappropriate grazing continue to threaten the other Solano County population, as does trampling by hunters (California Natural Diversity Data Base 2005). Eradication of *Lepidium latifolium* is occurring at the Yolo County site, however, habitat degradation continues to be a threat (California Natural Diversity Data Base 2005, N. McCarten *in litt*. 2005). Small population size is a threat to the occurrence southwest of Olcott Lake, and to the one at Olcott Lake if it is not already extirpated. In 2005, the site southwest of Olcott Lake had declined to 3 plants and the Olcott Lake site has had no plants since 1993 (California Natural Diversity Data Base 2005).

e. Conservation Efforts

Tuctoria mucronata was listed as an endangered species on September 28, 1978 (U.S. Fish and Wildlife Service 1978*a*). A recovery plan was then prepared, which became effective 7 years following the listing (U.S. Fish and Wildlife Service 1985*a*). The California Fish and Game Commission listed *T. mucronata* as endangered in 1979 (California Department of Fish and Game 1991). *Tuctoria mucronata* is also on the California Native Plant Society's List 1B, with the highest endangerment rating possible (Skinner and Pavlik 1994). In fact, the California Native Plant Society has recognized this species as rare and endangered since it first compiled such lists (Powell 1974). In 2005, critical habitat was designated for *T. mucronata* 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).

The Nature Conservancy acquired Olcott Lake in 1980 as part of the Jepson Prairie Preserve. The preserve was transferred to the Solano County Farmlands and Open Space Foundation in 1997, which manages it jointly with the University of California, Davis (C. Witham *in litt.* 1998). Livestock grazing is now excluded from the areas of the lake formerly occupied by *Tuctoria mucronata* (U.S. Fish and Wildlife Service 1985*a*, California Natural Diversity Data Base 2005). Money from the California Endangered Species Tax Check-Off Fund has been used to repair fences and post signs in the Jepson Prairie Preserve (California Department of Fish and Game 1991). The Nature Conservancy (1991) conducted some research on the control of *Phyla nodiflora* using herbicides and mechanical removal in the early 1990s. Private individuals have partially implemented one aspect of the recovery plan, which was to survey suitable habitats for *T. mucronata*; their efforts led to the discovery of the two populations that were unknown at the time of listing (California Natural Diversity Data Base 2003).

B. State-Listed Plant Species and Other Plant Species of Concern

1. *ASTRAGALUS TENER* VAR. *FERRISIAE* (FERRIS' MILK-VETCH)

a. Description and Taxonomy

Taxonomy.—Milk-vetches are members of the pea family (Fabaceae). Ferris' milk-vetch was recognized and named as a distinct variety (*Astragalus tener* var. *ferrisiae*) only recently (Liston 1990*b*). However, Ferris had collected the type specimen in 1926, "3 miles west of Colusa," in Colusa County (Liston 1990*b*:100). Specimens now attributed to Ferris' milk-vetch formerly had been included under Jepson's milk-vetch (*Astragalus rattanii* var. *jepsonianus*), a serpentine endemic plant (Barneby 1964 as cited in Liston 1990*b*). According to Liston (1990*b*), further confusion about the taxonomy was generated when Abrams (1944) mistakenly provided a drawing of Ferris' milk-vetch labeled as Clara Hunt's milk-vetch (*Astragalus clarianus*). There is some speculation that Ferris' milk-vetch is an ecomorph of alkali milk vetch, *Astragalus tener* var. *tener*, a somewhat more common species of concern found in vernal pool habitats (C. Witham pers. comm. 2003). An alternative common name for *Astragalus tener* var. *ferrisiae* is Sacramento Valley milk-vetch.

Description and Identification.—The flower structure of *Astragalus* and related genera is complex. Although the calyx is unremarkable, the corolla consists of five petals that differ in size, shape, and sometimes in color. The outermost petal, which is called the banner, often curves upward away from the other petals. Just inside the banner is a pair of petals that are very narrow at the base; these separate but similar petals are known as the wings. The innermost pair of petals is called the keel because the two petals are fused to form a flattened structure resembling a boat. The pistil and stamens are hidden inside the keel. Although each flower has ten stamens, only one is separate; the filaments of the other nine are fused together (Smith 1977).

Astragalus tener var. *ferrisiae* is a delicate annual with one or more stems up to 26 centimeters (10.2 inches) long. The pinnately compound leaves have 7 to 15 wedge-shaped leaflets. The dense inflorescences arise from the leaf axils and contain 3 to 12 pinkish-purple flowers each. In *A. tener* var. *ferrisiae*, the banner ranges from 7.8 to 9.6 millimeters (0.31 to 0.38 inch) in length and has a white spot in the center. The keel is shorter than the wings, which are 5.8 to 7.1 millimeters (0.23 to 0.28 inch) long. Fruits of *A. tener* var. *ferrisiae* are crescent-shaped, papery pods with narrow, stalk-like bases. The pods are 2.7 to 5 centimeters (1.1 to 2.0 inches) long, about 2 millimeters (0.08 inch) wide, and have a groove running the length of the underside. The stalk-like base is at least 3 millimeters (0.12 inch) long. At maturity, the fruit stalks are deflexed at an angle of about 45 degrees. Each pod contains between 10 and 16 smooth seeds divided between two chambers (Liston 1990*b*, A. Liston *in litt.* 1993, Spellenberg 1993). The diploid chromosome number of *A. tener* var. *ferrisiae* is not known.

The other varieties of *Astragalus tener* have shorter, straighter fruits than *A. tener* var. *ferrisiae*, and their fruits do not have long, stalk-like bases (Liston 1990*b*, A. Liston *in litt.* 1993, Spellenberg 1993). All other *Astragalus* species that overlap in range have erect fruit stalks and rough seeds (Liston 1992). *Astragalus rattanii* var. *jepsonianus* is further distinguished from *A. tener* var. *ferrisiae* by its fruit shape and flower color (purple keel, white wings, and a white banner tipped with purple). Although *A. clarianus* has a pod similar in shape to that of *A. tener* var. *ferrisiae*, the former is shorter. Moreover, the flowers of *A. clarianus* differ in that the keel is longer than the wings and the banner is whitish with a purple tip (Liston 1990*b*, Liston 1992, Spellenberg 1993).

b. Historical and Current Distribution

Historical Distribution.—A total of 18 historical occurrences of *Astragalus tener* var. *ferrisiae* are reported by the California Natural Diversity Data Base (2005) (**Figure II-21**). Seven historical localities in the Solano-Colusa Vernal Pool Region included College City, Colusa, and Mountain House in Colusa County; Dunnigan and Saxon in Yolo County; Olcott Lake in Solano County; and the Sacramento National Wildlife Refuge in Glenn County. Four occurrences have been discovered in the Northeastern Sacramento Valley Vernal Pool Region (T. Keeler-Wolf *in litt*. 2000, J. Silveira *in litt*. 2000) since 1989. Three were on the Llano Seco Unit of the Sacramento River National Wildlife Refuge and one was in the Gray Lodge Waterfowl Management Area, all in Butte County (California Natural Diversity Data Base 2005). Seven other historical localities were outside of the vernal pool regions designated by Keeler-Wolf *et al.* (1998) or were not described in sufficient detail to determine the region. These sites include Biggs, Nord, Oroville Road, Sacramento River, and Upper Butte Basin Wildlife Management Area in Butte County; Yuba City in Sutter County; and an unidentified “causeway” location.

Current Distribution.— Although the California Natural Diversity Data Base (2005) lists nine occurrences as “presumed extant,” despite repeated visits only two have been confirmed extant since 1996. The extant occurrences are at Saxon Station in Yolo County, in the Solano-Colusa Vernal Pool Region, and at the Gray Lodge Waterfowl Management Area in Butte County, managed by the

California Department of Fish and Game. Morphology of the plants seems to vary depending on associated vegetation, casting doubt on the validity of this taxon (C. Witham pers. comm. 2003).

c. Life History and Habitat

Reproduction and Demography.—The life history of *Astragalus tener* var. *ferrisiae* has not been studied. Most of the information on reproductive biology and genetics in the species was gathered from *A. tener* var. *tener* and another variety of the same species, *A. tener* var. *titi* (coastal dunes milk-vetch) because the researcher (Liston 1992) was unaware of any extant populations of *A. tener* var. *ferrisiae*. Many of his observations apply to the species *A. tener* as a whole, and other information provided in the *A. tener* var. *tener* species account may also apply to *A. tener* var. *ferrisiae*.

Astragalus tener var. *ferrisiae* is an annual, but the conditions necessary for seed germination are unknown. It flowers in April and May (Skinner and Pavlik 1994). The pollinators are not known for certain. Liston (1992) predicted that butterflies would pollinate all varieties of *A. tener*, even though most other species of *Astragalus* are pollinated by bees. His rationale was that the flower structure, in which the wings are pressed tightly together with the keel shorter than the wings, would not allow bees to reach the nectar glands with their mouthparts. Butterflies are known to visit other *Astragalus* species with similar flower morphology (Liston 1990*a* cited in Liston 1992). Little is known about seed dispersal in *A. tener*, except that the pod does not split until it drops from the plant (Liston 1992). Liston (1992) speculated that this species would form a soil seed bank because seeds of related species undergo dormancy (Liston 1990*a* cited in Liston 1992).

The demography of *Astragalus tener* var. *ferrisiae* has not been monitored. Among occurrences for which the population size has been estimated, 2 numbered 200 and 400 plants when they were discovered, and 2 others numbered 10 or fewer. If the populations of *A. tener* var. *ferrisiae* follow a pattern similar to that of *A. tener* var. *tener,* plants may reappear in future years at sites where they have been absent for a number of years.

Habitat and Community Associations.—Since it was first discovered, *Astragalus tener* var. *ferrisiae* has been found in a variety of habitats including vernal meadows, “tule land” (presumably a marsh), borders of drainages, and fallow rice fields. The factors common to collection sites were that they were alkaline, moist in the springtime, and level (Liston 1992, Skinner and Pavlik 1994, California Natural Diversity Data Base 2001). This taxon does not occur in vernal pools *per se* and therefore is not referenced by vernal pool type in

A Manual of California Vegetation (Sawyer and Keeler-Wolf 1995). *Astragalus tener* var. *ferrisiae* grows on clay soils (California Natural Diversity Data Base 2001 and unprocessed data, J. Silveira *in litt.* 2000). Collection localities were at elevations ranging from 6 to 46 meters (20 to 150 feet). Plant species associated with *A. tener* var. *ferrisiae* have rarely been reported. It was growing with *Sidalcea hirsuta* (hairy checker-mallow), *Scirpus mucronatus* (bog bulrush), *Eleocharis obtusa* (blunt spikerush), and *Phalaris lemmonii* (Lemmon's canary grass) near Biggs and among "weedy grasses and forbs" at Upper Butte Basin Wildlife Management Area (California Natural Diversity Data Base 2001).

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 *Astragalus tener* var. *ferrisiae* are described below.

Much of the suitable habitat in the historical range of *Astragalus tener* var. *ferrisiae* has been converted to agriculture (Skinner and Pavlik 1994). The reasons why this variety no longer occurs at Olcott Lake, which is in a nature preserve, are unknown.

Permanent flooding is a potential threat to *Astragalus tener* var. *ferrisiae* at wildlife management areas if waterfowl production is given priority (California Natural Diversity Data Base 2001). Competition from unspecified upland plants is a problem at the Upper Butte Basin Wildlife Management Area (C. Rocco *in litt.* 1993) and probably at all sites in the Sacramento Valley (J. Silveira *in litt.* 2000). Small population size is a concern for all of the extant occurrences, which ranged in size from 10 to 400 individuals during the 1990s; growing plants have been absent from all but 1 population over the past several years (C. Witham pers. comm. 2003). An additional threat is a decline in pollinators. Pollinating insects may breed in areas outside of *A. tener* var. *ferrisiae* habitat and thus may be subject to different threats than the plants. However, until the specific pollinators of *A. tener* var. *ferrisiae* have been identified, the robustness of their populations cannot be assessed.

e. Conservation Efforts

Astragalus tener var. *ferrisiae* has no Federal or State protection. The California Native Plant Society includes this variety on List 1B, giving it the highest endangerment rating possible (Skinner and Pavlik 1994). Dr. Vernon Oswald discovered several populations during the past decade while exploring Butte and

Glenn Counties (California Natural Diversity Data Base 2001 and unprocessed data). Five occurrences are afforded some protection by virtue of their location on public land, but no particular conservation efforts have been undertaken in those areas.

2. *ASTRAGALUS TENER* VAR. *TENER* (ALKALI MILK-VETCH)

a. Description and Taxonomy

Taxonomy.—Alkali milk-vetch is in the pea family Fabaceae. Gray (1864) named *Astragalus tener*, commonly known as alkali milk-vetch. He gave the type locality only as "California ... from near Monterey or San Francisco" (Gray 1864:206). No varieties were named until Barneby (1950) reduced *Astragalus titi*, commonly known as coastal dunes milk-vetch, from a full species to the variety *Astragalus tener* var. *titi*. In so doing, the combination *Astragalus tener* var. *tener* was created automatically to represent Gray's original material (*i.e.*, alkali milk-vetch), according to accepted rules of botanical nomenclature. Another common name by which this variety is known is slender rattle-weed (Abrams 1944).

Description and Identification.—*Astragalus tener* var. *tener* (**Figure II-22**) is similar in most respects to *A. tener* var. *ferrisiae*. However, the two taxa differ in leaflet shape and fruit morphology. *Astragalus tener* var. *tener* leaflets vary, even on the same plant, from narrow and pointed to wedge-shaped with blunt or notched tips. In *A. tener* var. *tener,* the pod is only 1 to 2.5 centimeters (0.4 to 1.0 inch) long and straight or only slightly curved. The base of the pod is typically rounded; if stalk-like, the base is much less than 3 millimeters (0.12 inch) long. Also, the fruits are deflexed all the way to the stem of the inflorescence. *Astragalus tener* var. *tener* pods contain between 8 and 14 seeds (Gray 1864, Liston 1990*b,* A. Liston *in litt.* 1993, Spellenberg 1993). The plants have a diploid chromosome number of 22 (Liston 1992).

The variable leaflets and shorter, straighter pods, which are more strongly deflexed, distinguish *Astragalus tener* var. *tener* from *A. tener* var. *ferrisiae* (Liston 1990*b*, A. Liston *in litt.* 1993, Spellenberg 1993). *Astragalus tener* var. *titi* has a shorter banner (5.2 to 6 millimeters [0.20 to 0.24 inch] long) and only 5 to 11 seeds per pod (Spellenberg 1993). This species can be distinguished from all other species of *Astragalus* that occur in the same areas by its deflexed fruit stalks and smooth seeds (Liston 1992). Additional identifying features were given in the *A. tener* var. *ferrisiae* account presented earlier in this document.

Figure II-22. Illustration of *Astragalus tener* var. *tener* (alkali milk-vetch). Reprinted with permission from Abrams (1944), Illustrated Flora of the Pacific States: Washington, Oregon, and California, Vol. II. © Stanford University Press.

b. Historical and Current Distribution

Historical Distribution.—*Astragalus tener* var. *tener* formerly occurred in the Central Coast, Lake-Napa, Livermore, San Joaquin Valley, Solano-Colusa, and Santa Rosa Vernal Pool Regions (Keeler-Wolf *et al.* 1998), as well as in several locations outside of the named regions (**Figure II-23**). Between 1864 and the early 1980s, collections were made in more than 40 separate sites within 13 counties, ranging from the Salinas Valley and the San Francisco Bay area to the Central Valley (Barneby 1950, Liston 1989). Populations in the San Francisco Bay and Sacramento-San Joaquin Delta areas were being extirpated by the mid-1960s, but additional sites were discovered in the Central Valley after that time (Liston 1989, Skinner and Pavlik 1994, California Natural Diversity Data Base 2001). Alameda and Solano Counties had the largest number of historical collection sites, with 10 each, followed by Yolo County with 9 sites. Specimens were collected from two sites each in Contra Costa, Santa Clara, and San Joaquin Counties. *Astragalus tener* var. *tener* was known from one site each in Merced, Monterey, Napa, San Benito, San Francisco, Sonoma, and Stanislaus Counties prior to 1988 (A. Liston *in litt.* 1988, California Natural Diversity Data Base 2001).

Current Distribution.—Of the 66 occurrences of *Astragalus tener* var. *tener* that have been reported, 36 are presumed to be extant (A. Liston *in litt.* 1988, California Natural Diversity Data Base 2005). Twenty-three of those were discovered within the past decade. The majority of the extant occurrences are in the Solano-Colusa Vernal Pool Region (Keeler-Wolf *et al.* 1998); most are in the Dozier-Fairfield area of Solano County, but three are southeast of Woodland in Yolo County (C. Witham *in litt.* 1990, California Natural Diversity Data Base 2001). Eight other occurrences of *A. tener* var. *tener* are clustered between Merced, Newman, and Los Banos in north-central Merced County (Silveira 1996, California Natural Diversity Data Base 2005), which is in the San Joaquin Valley Vernal Pool Region (Keeler-Wolf *et al.* 1998). The single occurrence of *A. tener* var. *tener* that remains in the Lake-Napa Vernal Pool Region is located in Napa County (Keeler-Wolf *et al.* 1998, California Natural Diversity Data Base 2005). The other extant occurrence, at Albrae in the Central Coast Vernal Pool Region, was considered to be “possibly extirpated” until about 40 plants were rediscovered in a created pool there in 1999 (California Natural Diversity Data Base 2001).

c. Life History and Habitat

Reproduction and Demography.—The dates and conditions under which seeds of *Astragalus tener* var. *tener* germinate are not known. *Astragalus tener* var. *tener* flowers from March through June (Skinner and Pavlik 1994). The plants become inconspicuous within a few weeks of flowering (C. Witham *in litt.* 1993, A. Liston *in litt.* 2000). As described under the *A. tener* var. *ferrisiae* account, the probable pollinators are butterflies. However, C. Witham (*in litt.* 2000*a*) noted that butterflies are not common in the grassland habitats of *A. tener* var. *tener*. Liston's (1992) genetic studies indicated that plants within a population crossed randomly and did not suffer from excessive inbreeding, even though individual pistils can be fertilized by pollen from the same plant. *Astragalus tener* var. *tener* did not produce seeds when crossed experimentally with *A. tener* var. *titi* or with other closely-related species (Liston 1992). Seed dormancy and dispersal in *A. tener* were discussed in the *A. tener* var. *ferrisiae* account.

Based on analysis of proteins, Liston (1992) determined that *Astragalus tener* var. *tener* had more genetic variation within populations than the other six taxa in his study, although genetic diversity was low in the entire group. Genetic diversity among populations of *A. tener* var. *tener* was minimal. He also determined that *A. tener* var. *tener* and *A. tener* var. *titi* were very similar genetically. Unfortunately, *A. tener* var. *ferrisiae* was not available for inclusion in Liston's study because no populations were known to be extant at that time. Collectively, the two varieties of *A. tener* that Liston studied had two gene forms that were not found in the other five taxa (Liston 1992).

The demography of this taxon has not been investigated in detail. However, monitoring results indicated that populations could change by two orders of magnitude from one year to the next, as in one Solano County population that increased from 4 plants in 1993 to 350 in 1994 (California Natural Diversity Data Base 2001). Of the populations whose sizes have been estimated, 6 had fewer than 100 plants at maximum, 6 others numbered between 100 and 500 plants, and 1 had more than 500 (California Natural Diversity Data Base 2001).

Habitat and Community Associations.—The range of plant communities in which *Astragalus tener* var. *tener* has been found is indicative of its broad geographic range. This taxon has been reported from vernal pools and playas, edges of salt marshes, alkali meadows, and moist grassy flats (California Natural Diversity Data Base 2001). The vernal pool types in which it grows are Northern Basalt Flow, Northern Claypan, Northern Hardpan, and Northern Volcanic

Ashflow (Sawyer and Keeler-Wolf 1995). Optimum pool depth, duration, and area are unknown.

Soil types have been reported for only a few *Astragalus tener* var. *tener* occurrences in the Solano-Colusa Vernal Pool Region; those in Solano County are Solano-Pescadero and Pescadero clay, whereas one in Yolo County is Capay silty loam. The sites where this taxon grows typically are alkaline. Current and historical *A. tener* var. *tener* sites range in elevation from 1.5 to 88 meters (5 to 290 feet); one vaguely described site may have been 168 meters (550 feet) in elevation (California Natural Diversity Data Base 2001).

The species associated with *Astragalus tener* var. *tener* vary throughout its range. Plants that have been reported to occur with *Astragalus tener* var. *tener* in two or more of the vernal pool regions are *Bromus* spp. (bromes), *Castilleja densiflora* (dense-flowered owl's-clover), *Downingia pusilla* (dwarf downingia), *Lasthenia* spp. (goldfields), *Layia chrysanthemoides* (vernal pool layia), *Myosurus minimus*, and *Psilocarphus oregonus* (Oregon woolly-heads). In the Solano-Colusa Vernal Pool Region, from which multiple reports were available, the most frequent associates of *Astragalus tener* var. *tener* are *Lepidium latipes* var. *latipes* (dwarf peppergrass), *Lasthenia fremontii*, and *Distichlis spicata*, in order of frequency. Among the other plants featured in this recovery plan, those occurring in the same pools with *Astragalus tener* var. *tener* throughout its range include *Lasthenia conjugens*, *Neostapfia colusana*, *Atriplex persistens*, and *Legenere limosa*. In addition, *Chamaesyce hooveri*, *Tuctoria mucronata*, and *Gratiola heterosepala* grow in some of the same vernal pool complexes as *Astragalus tener* var. *tener*, but in different pools. The endangered *Cordylanthus palmatus* (palmate-bracted bird's-beak) occurs with *Astragalus tener* var. *tener* near Woodland (California Natural Diversity Data Base 2001), but this species is included in a different recovery plan (U.S. Fish and Wildlife Service 1998*a)*.

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 *Astragalus tener* var. *tener* are described below.

Agricultural conversion remains a threat to *Astragalus tener* var. *tener* (Skinner and Pavlik 1994). However, anecdotal evidence suggests that *A. tener* var. *tener* may benefit from some types of temporary surface disturbance. It was observed growing above a recently buried pipeline at two different sites, probably because the disturbance temporarily reduced the cover of competing plants (C. Witham *in* *litt.* 1998). *Astragalus tener* var. *tener* also appeared in a created vernal pool near Albrae, where it had not been observed since 1923 (California Natural Diversity Data Base 2001).

Grazing by cattle, sheep, or horses has been mentioned as a possible threat at 10 occurrences. However, all of the grazed populations were rated as being in "good" to "excellent" condition, including two used as permanent cattle pastures (California Natural Diversity Data Base 2001). Moreover, grazing may be necessary to reduce competition, for example from invasives such as filaree (*Erodium* species) at the Arena Plains Unit of the Merced National Wildlife Refuge in Merced County (J. Silveira *in litt.* 2000). Competitors that threaten *A. tener* var. *tener* include *Lepidium latifolium* and *Salsola* spp. (Russian thistle) in Yolo County, and *Melilotus indica* (sweet clover) and *Lolium multiflorum* in Alameda County (California Natural Diversity Data Base 2001). Extirpation from random processes is also a threat to virtually all of the populations due to their small numbers of plants, which make them vulnerable to chance events. Loss of pollinators due to destruction or degradation of their habitat also is a threat to *A. tener* var. *tener* because it would not be able to set seed if pollinators were absent. Threats specific to the Yolo County site where *A. tener* var. *tener* grows near *Tuctoria mucronata* were described under the description of the latter species. A fire burned through one of these occurrences in 2003 and construction of large stormwater retention basins for the Springlake development project impacted another. Soil that supported *A. tener* var. *tener* was salvaged from the basin footprint and translocated to a nearby site. *Astragalus tener* var. *tener* was not observed at the burn site in 2003 or 2004. The status of the seedbank at the translocation site is not known (M. Showers *in litt.* 2005).

e. Conservation Efforts

Astragalus tener var. *tener* currently is neither federally- nor State-listed. The California Native Plant Society did not consider it to be a rare taxon until 1994; it is now on List 1B and is regarded as endangered in a portion of its range (Skinner and Pavlik 1994). Dr. Aaron Liston visited historical sites and conducted research on the breeding systems and genetics of *A. tener* var. *tener* and related taxa (A. Liston *in litt.* 1988, Liston 1989, Liston 1990*a*, Liston 1992). Carol Witham undertook surveys for *A. tener* var. *tener* in Solano and Yolo Counties beginning in 1990 and discovered many of the populations now known (C. Witham *in litt.* 1990, C. Witham *in litt.* 1993, California Natural Diversity Data Base 2001). Additional populations were found during surveys for other vernal pool plants (California Natural Diversity Data Base 2001) and during pre-construction surveys for a gas pipeline (BioSystems Analysis 1994).

Twelve occurrences of *Astragalus tener* var. *tener* occur on sites protected by conservation organizations or on public land. Three are within the Jepson Prairie Preserve in Solano County (C. Witham *in litt.* 1990, California Natural Diversity Data Base 2001). Two occurrences are on the Wilcox Ranch in Solano County, part of which is owned and managed by The Nature Conservancy and the other part of which is owned and managed by Solano County (J. Marty, pers. comm. 2004). Four occurrences are on Federal or State wildlife areas in Merced County: the Arena Plains Unit of the Merced National Wildlife Refuge, Kesterson National Wildlife Refuge, the Los Banos Wildlife Management Area, and the North Grasslands Wildlife Management Area (Silveira 1996, California Natural Diversity Data Base 2001). *Astragalus tener* var. *tener* grows on land administered by the U.S. Department of Defense at Travis Air Force Base in Solano County and the U.S. Air Force Communications Facility in Yolo County (California Natural Diversity Data Base 2001). Also, one Yolo County occurrence is on property protected by a conservation easement with the City of Woodland (C. Witham *in litt.* 1990, California Natural Diversity Data Base 2001). However, this taxon is not necessarily protected simply by virtue of existing on public lands. No particular management activities have been undertaken for *A. tener* var. *tener*, and monitoring is sporadic.

3. *ATRIPLEX PERSISTENS* (VERNAL POOL SMALLSCALE)

a. Description and Taxonomy

Taxonomy.—This species is in the goosefoot family (Chenopodiaceae). Vernal pool smallscale was recognized as a unique species only recently. Stutz and Chu (1993) gave it the scientific name *Atriplex persistens*. Specimens of vernal pool smallscale collected prior to publication of the name had been incorrectly assigned to Parish's brittlescale (*Atriplex parishii*), a southern California species. The type locality of vernal pool smallscale is "Glenn Co., 5 miles S of Willows, 1/4 mi SW of Sacramento Wildlife Refuge Headquarters" (Stutz and Chu 1993:211). Other common names by which it is known are vernal pool saltbush (Silveira 1996, Keeler-Wolf *et al.* 1998) and persistent-fruited saltscale (California Department of Fish and Game 1999, California Natural Diversity Data Base 2001).

Description and Identification.—*Atriplex persistens* (**Figure II-24**) is an annual. The plants appear silvery-green (Silveira 1996) because the leaves and branches are covered with whitish, mealy scales. The 10- to 20-centimeter (4- to 8-inch) long stems may be upright or curved outward, and the branches originate from the base. *Atriplex persistens* has alternate, stalkless leaves 2 to 4 millimeters (0.08 to 0.16 inch) long. The leaves are basically egg-shaped with smooth margins, although their bases range from heart-shaped to triangular. Male and female reproductive parts are borne in separate, inconspicuous flowers. The male flowers occur in clusters in the upper leaf axils or at the branch tips, whereas the female flowers occur singly in the lower leaf axils. Each fruit consists of a single, reddish-brown seed enclosed by two bracts. The bracts are 3 to 4 millimeters (0.12 to 0.16 inch) long, wider at the tip than at the base, coarsely toothed on the upper margins, and have a few tubercles on their surfaces. At maturity, the center and base of each bract become hardened. The fruits remain on the branches even after the plants have died, a characteristic reflected in the scientific name of the species. The diploid chromosome number of *A. persistens* is 18 (Stutz and Chu 1993).

The annual species most easily confused with *Atriplex persistens* is *A. parishii*. However, *A. parishii* is restricted to southern California; male and female flowers occur together in axillary clusters; the fruiting scales remain soft, are not toothed, and are widest below the middle; and the fruits detach easily from the stem. *Atriplex fruticulosa* (ball saltbush) has hardened fruiting bracts, but they are widest at the middle, the fruits are not persistent, the leaves are longer than in *A. persistens*, and the plants are perennial (Stutz and Chu 1993, Taylor and Wilken 1993).

b. Historical and Current Distribution

Historical Distribution.—*Atriplex persistens* was collected from only five localities prior to 1990, all in the San Joaquin Valley Vernal Pool Region (Keeler-Wolf *et al.* 1998) (**Figure II-25**). The earliest record is from 1926, when Howell collected the species southwest of Merced, Merced County. Another site was discovered southwest of Merced during the late 1980s (Stone *et al.* 1988, California Natural Diversity Data Base 2001). In the 1960s, *A. persistens* was collected south of Modesto in Stanislaus County and west of Pixley in Tulare County (Stutz and Chu 1993, California Natural Diversity Data Base 2001). Another occurrence was discovered near Pixley in 1985 (California Natural Diversity Data Base 2001).

Current Distribution.—Since 1990, 27 additional populations of *Atriplex persistens* have been found in Glenn, Madera, Merced, and Solano Counties. However, three occurrences apparently have been extirpated, one each in Merced, Stanislaus, and Tulare Counties. Thus, of 32 known occurrences, 29 are believed to remain extant (California Natural Diversity Data Base 2005). Eleven of these are in the Solano-Colusa Vernal Pool Region, and the other 18 are in the San Joaquin Valley Vernal Pool Region (Keeler-Wolf *et al.* 1998). The largest concentration, comprising 11 occurrences, is on the Sacramento National Wildlife Refuge in Glenn County. The second-largest concentration is in central Merced

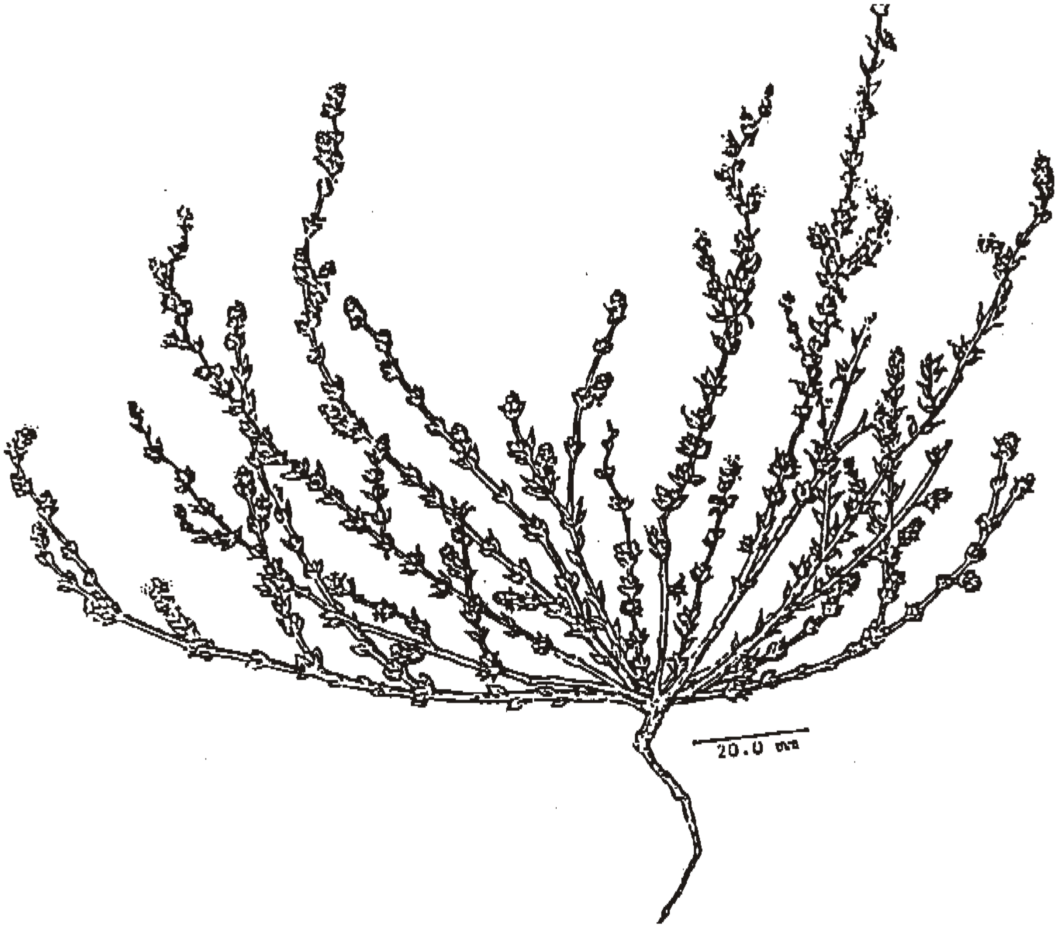

Figure II-24. Illustration of *Atriplex persistens* (vernal pool smallscale). (Reprinted with permission from the California Botanical Society)

County between Los Banos and Merced, where 11 occurrences remain extant. The other seven extant occurrences are in Solano, Madera, and Tulare Counties (California Natural Diversity Data Base 2005).

c. Life History and Habitat

Reproduction and Demography.—*Atriplex persistens* was described so recently that little information has been collected on its life history. However, it is a summer annual that flowers from July through September (Stutz and Chu 1993). Germination dates and conditions have not been reported, nor have demographic parameters or pollination agents. Population size has been reported only for the Arena Plains Unit of the Merced National Wildlife Refuge, where about 10,000 plants were observed in 1995 (California Natural Diversity Data Base unprocessed data).

Habitat and Community Associations.—*Atriplex persistens* has been observed only in large, alkaline vernal pools, where it occurs in the bottoms of the basins as opposed to the edges (D. Taylor pers. comm. 1997). These pools are considered the Northern Claypan type (Keeler-Wolf *et al.* 1998). The Glenn County pools contained water about 15 to 30 centimeters (6 to 12 inches) deep in the spring seasons of 1991 and 1993 (Stutz and Chu 1993). In Merced County, this species occurs on sandy, silty clay soils (California Natural Diversity Data Base 2001); soil types have not been noted elsewhere. Reported populations were at elevations ranging from 8 to 105 meters (25 to 345 feet) (California Natural Diversity Data Base 2001).

Atriplex persistens co-occurs with many of the other plant species featured in this recovery plan, including *Chamaesyce hooveri*; *Orcuttia pilosa*, *Neostapfia colusana*, *Astragalus tener* var. *ferrisiae*, *Astragalus tener* var. *tener*; *Tuctoria greenei*, and *Legenere limosa* (Stone *et al.* 1988, Oswald and Silveira 1995, Silveira 1996, J. Silveira *in litt.* 2000, California Natural Diversity Data Base 2001). Other plants with which it is commonly associated are *Cressa truxillensis*, *Bassia hyssopifolia* (hyssop-leaved bassia), *Frankenia salina*, *Grindelia camporum* , *Hemizonia pungens* (common spikeweed), and *Distichlis spicata* (J. Silveira *in litt.* 2000).

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 *Atriplex persistens* are described below.

The comparison of recent versus historical accounts of this species fails to document a decline. Although Stutz and Chu (1993) indicated that they could not find the species at any of the historical sites, it has since been rediscovered in Merced and Tulare Counties. Nevertheless, much suitable habitat of this species throughout the Central Valley has no doubt been lost or degraded, due to the same primary factors that have reduced populations of various other vernal pool-related species addressed earlier in this document.

One specific continuing threat is altered hydrology, which threatens the survival of *Atriplex persistens* in the East Grasslands of Merced County, where vernal pools have been flooded illegally for use as duck ponds (J. Silveira *in litt.* 2000).

e. Conservation Efforts

Atriplex persistens has no official Federal or State status. However, the California Native Plant Society has added it to List 1B of the sixth edition of their *Inventory of Rare and Endangered Vascular Plants of California* (California Native Plant Society 2001), indicating that they view the species as endangered throughout its range.

Although *Atriplex persistens* has not been the subject of focused survey efforts, it has been discovered during general surveys for vernal pool plants (Stutz and Chu 1993, Silveira 1996, D. Taylor *in litt.* 1997). Of the 29 *A. persistens* populations currently known to be extant, 19 (66 percent) are on public land or in nature preserves. However, no specific measures have been undertaken to conserve or manage for this species on these or other sites. The occurrences in public ownership include 11 on the Sacramento National Wildlife Refuge and 4 in Merced County: 2 in San Joaquin Grasslands State Park, and 1 each on the Arena Plains Unit of the Merced National Wildlife Refuge and the North Grasslands Wildlife Management Area. The two nature preserves where *A. persistens* occurs are the Jepson Prairie in Solano County and the Pixley Vernal Pool Preserve in Tulare County (Stutz and Chu 1993, D. Taylor *in litt.* 1997, California Natural Diversity Data Base 2001).

4. *ERYNGIUM SPINOSEPALUM* (SPINY-SEPALED BUTTON-CELERY)

a. Description and Taxonomy

Taxonomy.—Spiny-sepaled button-celery is a member of the carrot family Apiaceae. The scientific name first used for spiny-sepaled button-celery was *Eryngium globosum* (Jepson 1922). However, the name *Eryngium globosum* had already been used to represent an entirely different species, so Mathias (1936) changed the name of spiny-sepaled button-celery to *Eryngium spinosepalum*.

Hoover (1937) decided that this taxon was more appropriate at the rank of variety than species and thus suggested the name *Eryngium vaseyi* var. *globosum* in his thesis. Hoover's thesis did not meet the requirements for official publication of a scientific name; Mathias and Constance (1941) later properly published Hoover's combination *Eryngium vaseyi* var. *globosum*. That name remained in use until Sheik (1978) decided that spiny-sepaled button-celery deserved the rank of species and returned to the scientific name *Eryngium spinosepalum*, which remains in use (Constance 1993). However, some vernal pool experts (J. Stebbins *in litt.* 2000*a*) question whether spiny-sepaled button-celery should be considered a species due to the presence of intermediate forms. Other common names for this plant are spiny-sepaled coyote-thistle (Smith *et al.* 1980) and spiny coyote-thistle (EIP Associates 1994). The type locality of spiny-sepaled button-celery is Exeter, in Tulare County (Jepson 1922).

Description and Identification.—*Eryngium spinosepalum* has stout, branching, hairless stems 30 to 75 centimeters (11.8 to 29.5 inches) tall. The terrestrial leaves consist of a short petiole (less than 2 centimeters [0.8 inch] long) and a spiny-toothed or deeply-lobed blade 9 to 35 centimeters (3.5 to 13.8 inches) long. The flower heads of *E. spinosepalum* are spherical or egg-shaped, 0.8 to 2 centimeters (0.3 to 0.8 inch) in diameter, and contain more than 10 flowers each. Each flower head is on a stalk 2 centimeters (0.8 inch) long or less. The narrow bracts are spiny on the margin and on the underside, and typically protrude beyond the flower heads. Conversely, most bractlets are shorter than the flower head; each has a broad, papery margin at the base and only a few spines. The individual flowers of *E. spinosepalum* are tiny, with white petals and distinctive sepals. The sepals are 3.5 to 4.5 millimeters (0.14 to 0.18 inch) long, egg- or lance-shaped, and deeply divided into 3 to 8 spiny lobes or teeth. The fruits of *E. spinosepalum* are oblong to egg-shaped and 2.5 to 3 millimeters (0.10 to 0.12 inch) long (Jepson 1922, Abrams 1951, Mason 1957, Constance 1993). The diploid chromosome number of *E. spinosepalum* is 32 (Constance 1993).

Unlike *Eryngium constancei*, *E. spinosepalum* lacks hairs, has more than 10 flowers per head, the main stems are stout, and the stems supporting the flower heads are short. *Eryngium spinosepalum* is similar to both *E. castrense* and *E. vaseyi*, but both have narrower flower heads (no more than 15 millimeters [0.59 inch] in diameter) than *E. spinosepalum*. *Eryngium castrense* also has more deeply lobed leaves than *E. spinosepalum*, bracts and bractlets that are similar to each other and densely covered with spines, and bractlets that protrude well beyond the flower heads. *Eryngium vaseyi* also has deeply lobed leaves; the bracts and bractlets are similar to those of *E. spinosepalum*, but the sepals of the former are entire and shorter (2 to 3 millimeters [0.08 to 0.12 inch]) than those of *E. spinosepalum*.

Many plants found in nature are intermediate between *Eryngium spinosepalum* and either *E. castrense* or *E. vaseyi* in the size of the heads, length of the bractlets, and shape of the sepal margin. Moreover, individual plants and even single heads of *E. spinosepalum* may have both entire and toothed sepals (Hoover 1937, R. Stone *in litt.* 1992). The intermediate forms are thus difficult to classify, leading to uncertainties about the range of each taxon.

b. Historical and Current Distribution

Historical Distribution.—Typical *Eryngium spinosepalum* was known historically from the Southern Sierra Foothills Vernal Pool Region (Keeler-Wolf *et al.* 1998) in Fresno and Tulare Counties (**Figure II-26**). Hoover and others collected typical *E. spinosepalum* specimens from Orange Cove (Hoover 1937), east of Minkler, Sand Creek Basin, north of Sanger, and Squaw Valley, all in Fresno County (California Natural Diversity Data Base 2001). Specimens were collected from the following Tulare County sites between 1902 and 1954: Exeter, "Kaweah," Lemon Cove, Redstone Park near Visalia, west of Springville, and Woodlake (Jepson 1922, Hoover 1937, California Natural Diversity Data Base 2001). The exact location of Redstone Park (Hoover 1937) is not certain because it is not shown on maps, but it could possibly be in the San Joaquin Valley Vernal Pool Region rather than the Southern Sierra Foothills Vernal Pool Region. Plants intermediate between *E. spinosepalum* and *E. castrense* or *E. vaseyi* were found in the Central Coast, Livermore, and San Joaquin Valley vernal pool regions. The five westernmost locations were in Contra Costa, Merced, San Joaquin, and Stanislaus Counties (Hoover 1937). Additional sites farther east included at least three in Kern County (Hoover 1937, Twisselmann 1967) and one in Fresno County, where specimens were collected in 1971 (California Natural Diversity Data Base 2001).

Current Distribution.—The California Natural Diversity Data Base (2005) currently includes 59 extant occurrences of *Eryngium spinosepalum* and 4 that are known or presumed extirpated; it does not include intermediate populations. In addition, three of the typical populations reported historically are not included in the California Natural Diversity Data Base (2005), but could still be extant. Thus, 66 typical populations have been reported, of which 62 may remain extant. Thirty-three populations presumed to be extant are in Merced County, 14 are in Tulare County, 6 are in Fresno County, 3 are in Madera County 2 in Tuolumne County, and 1 in Calaveras County (Jepson 1922, Hoover 1937, California Natural Diversity Data Base 2005). Thirty of the Merced County occurrences were reported in 2001 (Vollmar 2001) from eastern Merced County in the Owens Reservoir/Planada area, south of Le Grand, and in the Snelling area (California Natural Diversity Data Base 2005). Many populations of this species are isolated, but minor areas of concentration are in the vicinity of Lake Kaweah in Tulare County and in the Orange Cove-Kaktus Korner area spanning the Tulare-Fresno County line. Two sites are known near Seville in Tulare County, and two others are in the Four Corners area of Madera County. According to Keeler-Wolf *et al.* (1998), *E. spinosepalum* is restricted to the Southern Sierra Foothills Vernal Pool Region.

Intermediate forms of *Eryngium* and other populations whose identity has not been confirmed have been reported from a total of 15 sites. Seven of these populations are extant: three in Fresno County (S. Snover *in litt.* 1994), three in Madera County (R. Stone *in litt.* 1992), and one in Merced County (Stebbins *et al.* 1993). The eight historical localities of intermediates (Hoover 1937, Twisselmann 1967, California Natural Diversity Data Base 2001) have not been revisited in 30 to 60 years and may or may not be extant.

c. Life History and Habitat

Reproduction and Demography.**—**Unlike most of the vernal pool plants included in this recovery plan, *Eryngium spinosepalum* is a perennial. *Eryngium spinosepalum* flowers in April and May (Skinner and Pavlik 1994). Its pollinators, seed dispersal agents, and population demographics are unknown. As a perennial, population sizes probably do not fluctuate drastically between years, except in response to major disturbances.

Habitat and Community Associations.**—***Eryngium spinosepalum* grows in both Northern Hardpan and Northern Claypan vernal pools (Sawyer and Keeler-Wolf 1995), as well as in roadside ditches (Mason 1957), depressions, and swales in annual grassland and oak woodlands (Twisselmann 1967, California Natural Diversity Data Base 2001). Characteristics of pools supporting *E. spinosepalum* have been described only from the Stone Corral Ecological Reserve in Tulare County. There, the species grew in two “swale-like” Northern Claypan Vernal Pools about 0.5 and 2.4 hectares (1.2 and 6.0 acres) in area, respectively. The smaller pool was about 41 centimeters (16 inches) deep, and the larger was more than 46 centimeters (18 inches) deep. Soil pH ranged from 6.1 to 7.1 at various points below the smaller pool and from 7.0 to 7.5 below the larger pool. Population size was in the thousands in the larger pool and in the hundreds in the smaller one (Stebbins *et al.* 1995). Both pools occur on Lewis clay loam over lime-silica hardpan at the rim of the saline-alkali basin (Stone *et al.* 1988).

Sites from which typical *Eryngium spinosepalum* has been reported range in elevation from 107 meters (350 feet) at Stone Corral Ecological Reserve to about 567 meters (1,860 feet) north of Marshall Hill in Fresno County (California Natural Diversity Data Base 2005). Intermediate forms of *Eryngium* have been reported from elevations of 67 meters (220 feet) in Merced County (Stebbins *et al.* 1993) to about 1,000 meters (3,281 feet) at Lynns Valley in Kern County (Twisselmann 1967).

Species most frequently associated with *Eryngium spinosepalum* include *Psilocarphus brevissimus*; upland grasses such as *Bromus* spp., *Hordeum marinum* ssp. *gussoneanum* (Mediterranean barley), and *Lolium multiflorum* ; unidentified species of *Plagiobothrys*; and other species of *Eryngium* (California Natural Diversity Data Base 2001). Listed vernal pool plants with which *E. spinosepalum* grows are *Chamaesyce hooveri* and *Orcuttia inaequalis*, both at the Stone Corral Ecological Reserve complex (Stone *et al.* 1988, California Natural Diversity Data Base 2005). An intermediate form of *Eryngium* also grows with *O. inaequalis* in Madera County (R. Stone *in litt.* 1992, J. Stebbins *in litt.* 2000*a*). *Brodiaea insignis* (Kaweah brodiaea), a State-listed endangered species that does not occur in vernal pools, grows with typical *E. spinosepalum* at three sites near Lake Kaweah (California Natural Diversity Data Base 2001).

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 *Eryngium spinosepalum* are described below.

One former population of *Eryngium spinosepalum* in Fresno County was extirpated by conversion to an orange grove. Another in Tulare County was in an area that has been developed for urban and agricultural uses (California Natural Diversity Data Base 2001).

Specific continuing threats include proposed construction of a new dam at Lake Kaweah, which would inundate one occurrence of *Eryngium spinosepalum* at the east end of the lake (U.S. Army Corps of Engineers 1996, California Natural Diversity Data Base 2005). Road construction and maintenance threaten one Fresno County occurrence and the two in Madera County. A development has been proposed for the single Tuolumne County site (California Natural Diversity Data Base 2005). In addition, many of the other occurrences representing typical *E. spinosepalum* face potential threats. Fourteen of the extant occurrences are threatened by conversion to intensive agriculture, particularly to citrus groves, or by development for residential or urban uses. Although the pollinating agents for *E. spinosepalum* have not yet been determined, if insects are the pollinators a decline in their populations due to habitat loss is a potential problem.

e. Conservation Efforts

Eryngium spinosepalum has no formal protection at either the Federal or State level. This species was a Federal Category 2 candidate for listing (U.S. Fish and Wildlife Service 1985*c*) until we eliminated that classification (U.S. Fish and Wildlife Service 1996*a*). The California Native Plant Society has considered *E. spinosepalum* to be rare for many years (Smith *et al.* 1980) and currently includes this species on its List 1B, noting that it is endangered in a portion of its range (California Native Plant Society 2001). This species has not been targeted for any particular conservation efforts. The only protected occurrence of *E. spinosepalum* is at the California Department of Fish and Game's Stone Corral Ecological Reserve (Stebbins *et al.* 1995). Three other occurrences are on public land owned by the U.S. Army Corps of Engineers or the California Department of Transportation, but they are not free from threats (California Natural Diversity Data Base 2005).

5. *GRATIOLA HETEROSEPALA* (BOGGS LAKE HEDGE-HYSSOP)

a. Description and Taxonomy

Taxonomy.—Boggs Lake hedge-hyssop has been known by only one scientific name, *Gratiola heterosepala*, since it was first named by Mason and Bacigalupi (1954). The type locality is Boggs Lake, in Lake County (Mason and Bacigalupi 1954). This species is a member of the figwort family (Scrophulariaeceae).

Description and Identification.—*Gratiola heterosepala* is an erect annual with hollow stems 2 to 10 centimeters (0.8 to 3.9 inches) tall. The stems are mostly hairless, except for a few glandular hairs in the inflorescence. The leaves are opposite and have entire margins. Leaves near the base of the stem are 1 to 2 centimeters (0.4 to 0.8 inch) long and lance-shaped, but the leaves become shorter, wider, and blunt-tipped farther up on the stem. The 6 to 8 millimeters (0.23 to 0.31 inch) long flowers are borne singly in the upper leaf axils. Each corolla has two lips; the tube and upper lip are yellow, whereas the lower lip is white. However, the flowers appear yellow from a distance. The calyx is 4 to 6 millimeters (0.16 to 0.24 inch) long and has five sepals of differing lengths and shapes, giving rise to the specific epithet, *heterosepala* (meaning different sepals). The upper three sepals are united for about one-third of their length; the center sepal is longer than the others. The two lower sepals are separate and have notched tips, in contrast to the blunt tips of the upper sepals. The fruit of *G. heterosepala* is a small, dry, pear-shaped capsule that is about the same length as the calyx. The tiny seeds are oblong and have narrow lengthwise ridges (Mason and Bacigalupi 1954, Mason 1957, Wetherwax 1993). *Gratiola heterosepala* is most similar to *G. ebracteata* (bractless hedge-hyssop). However, in *G. ebracteata* the sepals are longer, pointed, and are separate almost all the way to their bases; all five corolla lobes are white; and the seeds have both lengthwise and crosswise ridges. The other California species, *G. neglecta* (common American hedge-hyssop), has bracts below the calyx, purplish corolla lobes, and a corolla at least twice as long as the calyx (Mason 1957, Wetherwax 1993).

b. Historical and Current Distribution

Historical Distribution.—This species was first collected in Lake County, California, in 1923. The exact collection site is uncertain, but probably was Boggs Lake, where the species also was collected in 1929 and 1953 (Mason and Bacigalupi 1954) (**Figure II-27**). An additional site was found in Madera County in 1961, then another in Sacramento County in 1977 (California Natural Diversity Data Base 2001). During the 1980s, 20 additional occurrences were discovered in California, plus one in Lake County, Oregon (California Department of Fish and Game 1987*d*). These additional California occurrences included nine in Shasta County; three each in Fresno, Placer, and Sacramento Counties; and one each in Lake and Modoc Counties (California Natural Diversity Data Base 2001). Thus, the historical range included the Lake-Napa, Modoc Plateau, Southeastern Sacramento Valley, and Southern Sierra Foothills Vernal Pool Regions (Keeler-Wolf *et al.* 1998).

Current Distribution.—Currently, *Gratiola heterosepala* is known from 85 extant occurrences in California plus 1 in Oregon. Only one of the historical occurrences is believed to have been extirpated, in Sacramento County. In addition to the four vernal pool regions where it was known historically, *G. heterosepala* is now known from the Northeastern and Northwestern Sacramento Valley and the Solano-Colusa vernal pool regions (Keeler-Wolf *et al.* 1998). Additional counties of occurrence are Lassen, Madera, Merced, San Joaquin, Siskiyou, Solano, and Tehama (C. Witham *in litt.* 2000*b*, California Natural Diversity Data Base 2005).

The primary area of concentration for *Gratiola heterosepala*, with 32 occurrences (37 percent), is the Modoc Plateau, where occurrences are known from Lassen, Modoc, and Shasta Counties in California and Lake County in Oregon (Kaye *et al.* 1990, B. Corbin *in litt.* 2000, California Natural Diversity Data Base 2005). Two secondary areas of occurrence are the southeastern Sacramento Valley and the northeastern Sacramento Valley, with 17 extant occurrences (20 percent) each. The southeastern Sacramento Valley concentration is in Placer, Sacramento, and San Joaquin Counties, primarily between the cities of Roseville and Elk Grove. The northeastern Sacramento Valley concentration is in the vicinity of Dales, in Tehama County. The Southern Sierra Foothills Vernal Pool Region has six occurrences (7 percent), including four in Fresno County and one each in Madera (California Natural Diversity Data Base 2005) and Merced (C. Witham *in litt.* 2000*b*) Counties. Five (6 percent) occurrences in Solano County are within the Solano-Colusa Vernal Pool Region. The remaining occurrences include three (4 percent) in Lake County, California, and one in Siskiyou County, representing the Lake-Napa and Northwestern Sacramento Valley Vernal Pool Regions, respectively (California Natural Diversity Data Base 2005).

c. Life History and Habitat

Reproduction and Demography.— Most of the life history information regarding *Gratiola heterosepala* comes from an intensive study of the Oregon population by Kaye *et al.* (1990). California plants are morphologically similar to those in Oregon and grow in similar habitats; therefore, the life history of *G. heterosepala* is presumed to be similar in the two states.

The seeds of *Gratiola heterosepala* most likely germinate in response to autumn or winter rains (Kaye *et al.* 1990, Corbin *et al.* 1994). By the time the water recedes the plants already are in bud or in flower; flowering can begin when as much as 5 centimeters (2.0 inches) of water remains (Kaye *et al.* 1990, Corbin *et al.* 1994). Throughout the range of the species, flowers are open between April and August, with those at the highest elevations flowering later (Corbin *et al.* 1994). Each plant typically produces only one or two flowers (Kaye *et al.* 1990, Corbin *et al.* 1994), which mature into fruits within 1 to 2 weeks after flowering begins. The plants disappear quickly after seed-set (Corbin *et al.* 1994).

Kaye *et al.* (1990) determined that *Gratiola heterosepala* is self-compatible and does not require insects for pollination. During their one-season study in Oregon, plants set equal amounts of seed whether or not insects were excluded. Moreover, insects were not observed visiting the flowers in natural settings (Kaye *et al.* 1990). The Oregon population averaged about 150 seeds per fruit, but the number of fruits per plant was not reported. The fruits showed no insect damage (Kaye *et al.* 1990). Seed dispersal agents are not known, and seed longevity in the soil has not been tested. However, seeds in one population on the Lassen National Forest (Shasta County) apparently remained dormant for 3 years, which was the interval between observations of growing plants (Corbin *et al.* 1994).

California populations of *G. heterosepala* range in size from only a few individuals to over 1 million (California Natural Diversity Data Base 2001). As observed with other vernal pool annuals, population numbers fluctuate greatly from year to year (Corbin *et al.* 1994). The Boggs Lake population declined from 1,000 individuals in 1981 to 0 in 1989 and remained at 0 until 1997, when 5 plants were found (Serpa 1993, California Natural Diversity Data Base 2001). The plants were widely scattered at Boggs Lake historically, with individuals growing isolated from each other (Mason and Bacigalupi 1954). At the one Vina Plains occurrence, the density of *G. heterosepala* was 67.4 plants per square meter (6.3 plants per square foot) in 1995 (Alexander and Schlising 1997).

Habitat and Community Associations.—*Gratiola heterosepala* occurs in vernal pools and in marshy areas on the margins of reservoirs and lakes, as well as in man-made habitats such as borrow pits and cattle ponds (Kaye *et al.* 1990, Corbin *et al.* 1994, California Natural Diversity Data Base 2001). It has been found in several types of vernal pools, including Northern Basalt Flow, Northern Claypan, Northern Hardpan, Northern Volcanic Ashflow, and Northern Volcanic Mudflow (Sawyer and Keeler-Wolf 1995). Occupied wetlands are amongst annual grassland, *Quercus* (oak) woodland, *Juniperus* (juniper) woodland, or coniferous forest (California Department of Fish and Game 1987*d*, Kaye *et al.* 1990, Corbin *et al.* 1994, California Natural Diversity Data Base 2001).

Although *Gratiola heterosepala* most often occurs on the margins of lakes and pools where water does not become too deep (Corbin *et al.* 1994), it also has been found in the beds of deeper vernal pools (California Natural Diversity Data Base 2001). Clay is the most frequently encountered soil underlying occupied habitats, although loam and loamy sand have also been noted. Most sites are underlain by an impermeable layer (Corbin *et al.* 1994, California Natural Diversity Data Base 2001). Kaye and others (1990) noted that in juniper woodlands, *G. heterosepala* occurred on acidic soils with a pH of about 5. Some northern California sites are on slightly acidic soils, but soil pH has not been tested in other areas (Corbin *et al.* 1994).

Known *Gratiola heterosepala* sites in California range in elevation from 8 meters (25 feet) in Solano County to at least 1,576 meters (5,170 feet) in Modoc County (B. Corbin *in litt.* 2000, California Natural Diversity Data Base 2001). A reported occurrence of *G. heterosepala* at North Emerson Lake in Modoc County is at 2,400 meters (7,900 feet) in elevation (California Natural Diversity Data Base 2001), but several species experts have revisited the site and found only

G. ebracteata (B. Corbin *in litt.* 2000, G. Schoolcraft *in litt.* 2000). The elevation of the Lake County, Oregon, occurrence is 1,634 meters (5,340 feet) (Kaye *et al.* 1990).

The most frequent associate of *Gratiola heterosepala* is *G. ebracteata* (California Natural Diversity Data Base 2001); the latter may form dense colonies containing only a few individuals of *G. heterosepala* (Mason and Bacigalupi 1954). Other typical associates, in order of frequency, are *Plagiobothrys stipitatus*, *Downingia bicornuta* (two-horned downingia), *Orcuttia tenuis*, and *Eleocharis macrostachya*. Several of the rare, threatened, and endangered plants in this recovery plan co-occur with *G. heterosepala*; these taxa include *O. tenuis* at 20 sites, *Tuctoria greenei* at 2 sites, and *Castilleja campestris* ssp. *succulenta*, *O. pilosa*, *Chamaesyce hooveri*, *Legenere limosa*, *Myosurus minimus* ssp. *apus*, *Navarretia leucocephala* ssp. *plieantha*, *O. viscida*, and *O. inaequalis* at 1 site each (B. Corbin *in litt.* 2000, California Natural Diversity Data Base 2001).

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 *Gratiola heterosepala* are described below.

Habitat conversion for housing was responsible for the extirpation of one *Gratiola heterosepala* population in Sacramento County (California Natural Diversity Data Base 2001). Cattle trampling destroyed many immature plants at the Oregon occurrence (Kaye *et al.* 1990). Four occurrences have been disturbed but not extirpated by hydrological alterations such as excavation and damming, and another three by surface disturbances such as discing and grading (California Natural Diversity Data Base 2001). Urban growth through residential development, shopping center construction, and landfill expansion threatens seven of the populations in Placer and Sacramento Counties (California Natural Diversity Data Base 2001). Competition from *Taeniatherum caput-medusae* potentially threatens *G. heterosepala* at five sites of occurrence on the Modoc Plateau (Corbin *et al.* 1994). Nine of the extant occurrences contain fewer than 100 individuals at their maximum, and several are undergoing rapid declines (California Natural Diversity Data Base 2001). These populations are sufficiently small that they are in danger of extirpation from chance events (Menges 1991).

Livestock grazing may or may not pose a threat to the survival of *Gratiola heterosepala*. Although 48 California occurrences are subject to grazing by cattle, sheep, horses, or feral pigs (Corbin *et al.* 1994, B. Corbin *in litt.* 2000, California Natural Diversity Data Base 2001), only 6 of those were reported to have heavy grazing or severe trampling (California Natural Diversity Data Base 2001). Trampling and herbivory can be detrimental if they occur before seed set or if use is concentrated in a small area. Moderate grazing is believed to be a compatible use if it occurs after *G. heterosepala* sets seed (Mason and Bacigalupi 1954, California Department of Fish and Game 1987*d*). Directed research is necessary to establish appropriate use levels and seasons. The 47 occurrences administered by the U.S. Forest Service and the U.S. Bureau of Land Management potentially are subject to disturbance or destruction from livestock grazing and trampling, activities associated with logging, assorted recreational uses, hydrological alterations, road construction, fire suppression, weed competition, and herbicide drift (Corbin *et al.* 1994, California Natural Diversity Data Base 2001). However, management guidelines proposed by the agencies (Corbin *et al.* 1994) (see also "Conservation Efforts" below) would mitigate such disturbances.

e. Conservation Efforts

Gratiola heterosepala has no Federal listing status. It was listed as endangered by California in 1978 (California Department of Fish and Game 1991) and is listed as threatened in Oregon (Tibor 2001). It was included in the California Native Plant Society's first list of rare and endangered plants (Powell 1974). In the most recently published listing by this group (Tibor 2001), *G. heterosepala* was placed on List 1B. The U.S. Forest Service formerly considered *G. heterosepala* to be "sensitive" but has reclassified it as a "special interest plant" because it is more abundant than previously thought (B. Corbin *in litt.* 2000). The U.S. Bureau of Land Management classifies *G. heterosepala* as a "special status" species (Corbin *et al.* 1994).

Twelve (14 percent) of the known occurrences of *Gratiola heterosepala* are in nature reserves. Seven of those are on ecological reserves or preserves operated by the California Department of Fish and Game, including four at Dales Lake in Tehama County, two at Thomes Creek in Tehama County, and one at Big Table Mountain in Fresno County. Nature reserves owned by private conservation organizations support another five occurrences, including two at Big Table Mountain Preserve in Fresno County (one of which is partially on Federal land) and one each at Boggs Lake Preserve in Lake County, Vina Plains Preserve in Tehama County, and Jepson Prairie Preserve in Solano County. When The Nature Conservancy managed the Boggs Lake Preserve, they erected fences around colonies of *G. heterosepala* to exclude horses and deer (Serpa 1993). Volunteers conduct periodic monitoring and searches for *G. heterosepala* and other rare plants at the Boggs Lake, Jepson Prairie, and Vina Plains preserves (Baldwin and Baldwin 1991, California Natural Diversity Data Base 2001).

Forty-seven (57 percent) of *Gratiola heterosepala* occurrences are on Federal land, which does not necessarily mean that they are protected from future disturbance. Among the occurrences on Federal land, 32 are on the Lassen and Modoc National Forests in Lassen, Modoc, and Shasta Counties. Two of these occurrences are in areas with special designations, the Murken Botanical Special Interest Area and the South Warner Wilderness, where many uses are restricted (Corbin *et al.* 1994). Another 15 occurrences are at least partially on lands administered by the U.S. Bureau of Land Management in five different resource areas. These occurrences include six in Tehama County, five in Shasta County, two in Fresno County (one of which is partially on a private nature reserve), and one each in Lassen County, California, and Lake County, Oregon (Kaye *et al.* 1990, Corbin *et al.* 1994, B. Corbin *in litt.* 2000, California Natural Diversity Data Base 2001). Four of the occurrences on U.S. Bureau of Land Management property are in wilderness study areas (Corbin *et al.* 1994) and may be afforded additional protection if Congress designates those areas as official wilderness. The U.S. Forest Service and the U.S. Bureau of Land Management developed a formal conservation strategy for *G. heterosepala* (Corbin *et al.* 1994) on lands they administer in northeastern California. Their goal was to protect 90 percent of the plants and sites from direct disturbance and hydrological alterations over a 10-year period. Additional conservation measures identified in the plan were comparisons of grazed and control areas, monitoring, surveys, and acquisition through land exchanges. However, due to funding priorities and the reclassification from "sensitive" status, intensive monitoring has been discontinued (B. Corbin *in litt.* 2000). The agencies have fenced several sites in northeastern California (Corbin *et al.* 1994, B. Corbin *in litt.* 2000) and in Fresno County (California Department of Fish and Game 1991, A. Franklin *in litt.* 1993) to prevent cattle from trampling *G. heterosepala*. *Gratiola heterosepala* also may benefit from a grazing-management experiment being conducted at Big Table Mountain in Fresno County (see discussion under *Castilleja campestris* ssp. *succulenta*).

Numerous groups and individuals, including the U.S. Forest Service, and U.S. Bureau of Land Management, participated in surveys for this species over the past decade, resulting in the identification of many new populations (Kaye *et al.* 1990, Corbin *et al.* 1994, B. Corbin *in litt.* 2000, California Natural Diversity Data Base 2001). Some of the surveys were in Oregon, where the Oregon Department of Agriculture and the U.S. Bureau of Land Management also funded studies to determine the breeding system of *Gratiola heterosepala* (Kaye *et al.* 1990).

6. *JUNCUS LEIOSPERMUS* VAR. *AHARTII* (AHART'S DWARF RUSH)

a. Description and Taxonomy

Taxonomy.—This taxon was first described in 1986 as *Juncus leiospermus* var. *ahartii* (Ertter 1986), although it had been recognized as unique more than 10 years earlier (L. Ahart *in litt.* 1986). The type locality is on the Ahart Ranch in Butte County, northeast of Honcut (Ertter 1986). Ahart's dwarf rush is a member of the rush family (Juncaceae) and is also known by the common name Ahart's rush (U.S. Fish and Wildlife Service 1996*b*).

Description and Identification.—*Juncus leiospermus* var. *ahartii* is a small, reddish, grass-like plant from 2 to 6 centimeters (0.8 to 2.4 inches) tall. Each plant may produce as many as 100 slender stems from its base, but the individual stems do not branch. The grass-like leaves arise from the base and are about half as long as the stems. Each stem produces only a single, tiny flower at its tip. The 6 to 10 petal-like parts per flower are not differentiated into sepals and petals but instead are all similar in appearance. They are lance-shaped, 2.4 to 3.6 millimeters (0.09 to 0.14 inch) long, and are maroon with a green or reddish stripe down the center. The flowers have two to five stamens with anthers greater than 0.7 millimeter (0.03 inch) long and a style 0.9 to 4 millimeters (0.04 to 0.16 inch) long. The fruit is a spherical or egg-shaped capsule 2.5 to 4.5 millimeters (0.10 to 0.18 inch) long, which contains many tiny, smooth seeds. The diploid chromosome number of *J. leiospermus* var. *ahartii* is 32 (Ertter 1986, Swab 1993).

The most closely related species, *Juncus leiospermus* var. *leiospermus* (Red Bluff dwarf rush), has several flowers clustered together. *J. uncialis* (inch-high dwarf rush) is similar to *J. leiospermus* var. *ahartii* in that it has only one flower per stem, but the former is less than 3.5 centimeters (1.4 inches) tall and has a shorter style and anthers. Other annual rushes have one or more of the following characteristics: thread-like stems, flowers in heads, shorter styles and anthers, or conspicuous ridges on the seeds (Ertter 1986, Swab 1993).

b. Historical and Current Distribution

Historical Distribution.—When it was named, *Juncus leiospermus* var. *ahartii* was known from four occurrences in two areas. Three of the four historical occurrences were on the Ahart Ranch in Butte County, where this species occurred in about 10 separate pools (**Figure II-28**). The fourth occurrence was near the town of Jenny Lind in Calaveras County (Ertter 1986). The Ahart Ranch is in the Northeastern Sacramento Valley Vernal Pool Region, and Jenny Lind is in the Southeastern Sacramento Valley Vernal Pool Region (Keeler-Wolf *et al.* 1998).

Current Distribution.—*Juncus leiospermus* var. *ahartii* is currently known to be extant from nine occurrences in Butte, Calaveras, Placer, Sacramento, Tehama, and Yuba Counties (California Natural Diversity Data Base 2005). This taxon is believed to remain extant on the Ahart Ranch and near Jenny Lind, although these sites have not been revisited since 1991. In addition, *Juncus leiospermus* var. *ahartii* has been found at the Oroville Municipal Airport in Butte County, near the Lincoln Airport in Placer County and in the Buffalo Creek area of Sacramento County (California Natural Diversity Data Base 2005). Thus, a total of nine occurrences are presumed to be extant and one is presumed to be extirpated in Sacramento County. All are in either the Northeastern Sacramento Valley or the Southeastern Sacramento Valley Vernal Pool Regions (Keeler-Wolf *et al.* 1998).

c. Life History and Habitat

Reproduction and Demography.—Very little information concerning *Juncus leiospermus* var. *ahartii* has been reported. It is an annual that flowers in April and May (L. Ahart *in litt.* 1986, California Natural Diversity Data Base 2001). Germination dates and conditions are unknown. *Juncus leiospermus* var. *ahartii* is wind-pollinated (Ertter 1986). In years of low rainfall, each plant typically has only a single stem. Moreover, larger populations have been observed in wet than in dry years (L. Ahart *in litt.* 1986).

Habitat and Community Associations.—*Juncus leiospermus* var. *ahartii* occurs in the Northern Basalt Flow, Northern Claypan, Northern Hardpan, and Northern Volcanic Mudflow vernal pool types (Sawyer and Keeler-Wolf 1995). The surrounding plant communities were not mentioned, except that the vernal pools at the type locality were in a grain field. Microhabitats from which the plants have been reported are the edges of vernal pools, bottoms of intermittent drainages, and on pocket gopher (*Thomomys* species) and ground squirrel (*Spermophilus* species) mounds (L. Ahart *in litt.* 1986, Ertter 1986, California Natural Diversity Data Base 2001). Soils underlying the pools typically are acidic clays (Ertter 1986). Known occurrences are at about 30 to 90 meters (100 to 300 feet) in elevation (California Natural Diversity Data Base 2001). The most frequent associate is *J. uncialis* (L. Ahart *in litt.* 1986, Ertter 1986, California Natural Diversity Data Base 2005).

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 *Juncus leiospermus* var. *ahartii* are described below.

Expansion of the runway at Oroville Municipal Airport destroyed part of the *Juncus leiospermus* var. *ahartii* population there (California Natural Diversity Data Base 2001). The type locality for *J. leiospermus* var. *ahartii* was dry-farmed in the 1970s. However, the disturbance created by plowing and the associated reduction in competing species apparently were beneficial to this taxon. Farming has since ceased in the area (L. Ahart *in litt.* 1986, Ertter 1986), but the response of *J. leiospermus* var. *ahartii* has not been determined. The Lincoln site has been degraded by off-road vehicle use, road construction, livestock grazing, and unspecified “disturbance” from adjacent developments (California Natural Diversity Data Base 2001). Other populations may have been destroyed before their discovery because much of the suitable habitat for *J. leiospermus* var. *ahartii* has been converted to agriculture and housing (Ertter 1986).

The Lincoln occurrence is on the site of a proposed housing development, which would destroy all of the occupied pools there (California Natural Diversity Data Base 2001). Random events coupled with small population size (Menges 1991) are a potential threat to 3 of the occurrences, which range in size from 45 to about 120 individuals (L. Ahart *in litt.* 1986, California Natural Diversity Data Base 2001).

e. Conservation Efforts

Juncus leiospermus var. *ahartii* was a Category 1 candidate for Federal listing even before it was officially named (U.S. Fish and Wildlife Service 1983b). However, in 1996 candidate status was withdrawn because insufficient information was available to propose the taxon for listing, and existing data suggested that it was not in danger of extinction throughout a significant portion of its range (U.S. Fish and Wildlife Service 1996*b*). *Juncus leiospermus* var. *ahartii* has no State status. The California Native Plant Society includes it on List 1B and considers it to be rare and of limited distribution, but not in danger of extinction (California Native Plant Society 2001). The only conservation measure implemented for this taxon to date was the establishment of a preserve near the Oroville Municipal Airport (California Natural Diversity Data Base 2005).

7. *LEGENERE LIMOSA* (LEGENERE)

a. Description and Taxonomy

Taxonomy.—Greene (1890) originally published the scientific name *Howellia limosa* for legenere. He gave the type locality only as "the lower Sacramento" (Greene 1890:81). Based on label information from Greene's collections, the type locality has been further described as "Fields of the lower Sacramento Valley near Elmira, Solano County, California" (McVaugh 1943:14). McVaugh (1943) determined that this species differed sufficiently from *Howellia* to be transferred to a new genus, *Legenere*. Thus, the currently accepted name for this species is *Legenere limosa*. Legenere is the only species in its genus (Morin 1993), which is in the bellflower family (Campanulaceae). Another common name for this species is Greene's legenere (Morin and Niehaus 1977, Holland 1984).

Description and Identification.—*Legenere limosa* is an inconspicuous annual. The entire plant is hairless. The main stems are 10 to 30 centimeters (3.9 to 11.8 inches) long and decumbent, although any branches are erect. Extra roots often arise from the lower nodes. The leaves, which are produced underwater, are 1 to 3 centimeters (0.4 to 1.2 inches) long and narrowly triangular; they fall off the plant before flowers appear. The egg-shaped or oval bracts are 6 to 12 millimeters (0.24 to 0.47 inch) long and remain throughout the flowering period. A single flower arises above each bract. *Legenere limosa* flowers may or may not have corollas, and a single plant can produce both types of flowers. When present, the corollas are white or yellowish, 3.5 to 4 millimeters (0.14 to 0.16 inch) long, and two-lipped. The upper two corolla lobes are narrower than the lower three, and the corolla tube is slit on the upper side. The stamens are joined to form a tubular structure. The flower stalks are very slender and elongate as the fruit matures, reaching a final length of as much as 3 centimeters (1.2 inches). *Legenere limosa* has a cylindrical capsule 6 to 10 millimeters (0.24 to 0.39 inch) long, which splits open only at the tip. Each capsule contains up to 20 seeds, which are about 1 millimeter (0.04 inch) long, brown, smooth, and shiny (McVaugh 1943, Mason 1957, Abrams and Ferris 1960, Holland 1984, Morin 1993). The chromosome number of *L. limosa* has not been determined.

The genera most likely to be confused with *Legenere limosa* are *Howellia, Downingia*, *Lobelia,* and *Porterella*. Both *Howellia* and *Downingia* have capsules that split along the sides, whereas the capsule of *L. limosa* opens at the tip. Moreover, *Downingia* flowers are not stalked. The *Lobelia* species in California have either red or blue flowers and spherical fruits, as opposed to the whitish flowers and cylindrical fruits of *L. limosa*. *Porterella* has showy blue flowers with yellow or white marks at the base of the corolla lobes, and it occurs at higher elevations than *L. limosa* (Morin and Niehaus 1977, Holland 1984, Morin 1993).

b. Historical and Current Distribution

Historical Distribution.—Between 1890 and 1984, *Legenere limosa* had been reported from 12 sites in 8 counties encompassing 6 vernal pool regions. The historical counties of occurrence were Solano (three sites, including the type locality), Lake and Sacramento (two sites each), and Napa, Placer, San Mateo, Sonoma, and Stanislaus Counties (one site each) (Hoover 1937, Mason 1957, Rubtzoff and Heckard 1975, Holland 1984) (**Figure II-29**). These sites were located in the Central Coast, Lake-Napa, Santa Rosa, Solano-Colusa, Southeastern Sacramento Valley, and Southern Sierra Foothills vernal pool regions (Keeler-Wolf *et al.* 1998). As of 1984 the only three populations believed to remain extant were in Napa, Placer, and Sacramento Counties (Holland 1984).

Current Distribution.—Since 1984, *Legenere limosa* has been rediscovered at several historical sites and has been found at numerous new locations. During that same time period, the type locality and six other occurrences were extirpated. Among the 52 occurrences presumed to be extant, 20 are in Sacramento County, including 9 in the vicinity of Elk Grove and 6 in the vicinity of the former Mather Air Force Base. Another area of concentration, with 11 extant occurrences, is near Dozier in Solano County. Other counties where this species is presumed to remain are Alameda, Santa Clara, Sonoma, Lake, Napa, Placer, San Joaquin, San Mateo, Shasta, Tehama, and Yuba (Skinner and Pavlik 1994, W. Legard *in litt*. 2005, Platenkamp *in litt*. 2005, California Natural Diversity Data Base 2005). The vernal pool regions (Keeler-Wolf *et al.* 1998) where *Legenere limosa* remains extant are Lake-Napa, Northeastern Sacramento Valley, Northwestern Sacramento Valley, Santa Rosa, Solano-Colusa, and Southeastern Sacramento Valley. It has been extirpated from the Southern Sierra Foothills Vernal Pool Region. Please refer to the Draft Santa Rosa Plains Recovery Plan (in development) for information regarding occurrences within the Santa Rosa Vernal Pool Region, as identified by Keeler-Wolf *et. al*. (1998). The Central Coast Vernal Pool Region occurrence, in San Mateo County, has not been rediscovered since 1906 but is presumed to be extant because suitable habitat remains in the area (California Natural Diversity Data Base 2001).

c. Life History and Habitat

Reproduction and Demography.—*Legenere limosa* seeds germinate between late February and April. The specific conditions necessary for seed germination are unknown. The plants grow through the standing water; as the water evaporates or recedes, *L. limosa* stems may collapse onto the lake bottom or become caught on taller, stronger plants (Holland 1984). *L. limosa* flowers during April, May, or June (Morin and Niehaus 1977, Holland 1984, Skinner and Pavlik 1994). Pollination in *L. limosa* has not been studied, but the small, inconspicuous flowers suggest that it may be self-pollinated (Holland 1984). By late June, each plant typically produces 6 to 10 capsules containing several hundred seeds each. Seed dispersal agents are unknown but may include gravity, water, and waterfowl. Most populations contain densities of less than one plant per square meter (10.8 square feet) (Holland 1984). The presence of *Legenere limosa* is even more variable than other vernal pool annuals; entire populations have disappeared for decades, then reappeared (Holland 1984, California Natural Diversity Data Base 2001). Thus, a persistent soil seed bank most likely exists. Survival rates and other aspects of demography have not been investigated.

Habitat and Community Associations.—*Legenere limosa* grows in a variety of habitats including vernal pools, vernal marshes, artificial ponds, and floodplains of intermittent streams. Occupied vernal pool types include Northern Basalt Flow, Northern Claypan, Northern Hardpan, Northern Volcanic Ashflow, and Northern Volcanic Mudflow (Sawyer and Keeler-Wolf 1995). The surrounding plant community may be grassland, open woodland, or hardwood forest containing *Quercus* species (oaks) or *Aesculus californica* (California buckeye). At one site, *L. limosa* grows in both a vernal pool and the adjacent grassland (California Natural Diversity Data Base 2001). The vernal pools and lakes supporting *L. limosa* vary in size from about 4 square meters (43 square feet) to 41 hectares (100 acres) (Holland 1984, California Natural Diversity Data Base 2001). When it occurs in large pools and vernal lakes, *L. limosa* grows only in the shallower areas (less than 20 centimeters [8 inches] deep) (Holland 1984). Substrates in occupied areas may have been deposited by streams or volcanic flows. Soils underlying the pools themselves typically are shallow, acidic clays with few stones (Holland 1984). *Legenere limosa* has been reported from elevations ranging from 3 meters (10 feet) in Solano County to 1,024 meters (3,360 feet) in Alameda County (California Natural Diversity Data Base 2005).

Legenere limosa occurs most often with *Lasthenia glaberrima* and *Eleocharis macrostachya*, and to a lesser extent with *Gratiola heterosepala* and *Downingia pusilla*. In addition to *Gratiola heterosepala*, other plants in this recovery plan that co-occur with *Legenere limosa* are *Navarretia leucocephala* ssp. *plieantha*, and *Orcuttia tenuis* (California Natural Diversity Data Base 2005).

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 *Legenere limosa* are described below.

Of the six occurrences of *Legenere limosa* known to be extirpated, two were destroyed by conversion to agriculture, one by changes in hydrology, two by urban development, and one by unknown causes (Holland 1984, California Natural Diversity Data Base 2005). Several sites where the species still occurs have been degraded by discing or other agricultural practices, inappropriate livestock grazing, dirt biking, and trash dumping (California Natural Diversity Data Base 2005). The San Mateo County site has been subjected to logging and hydrological changes; *L. limosa* has not been observed there in over 90 years (Holland 1984). *Legenere limosa* occurred at Boggs Lake in the 1950's but has not been seen there since (Rubtzoff and Heckard 1975, Holland 1984, California Natural Diversity Data Base 2005), even though suitable habitat remains.

About one-third of the extant occurrences of *Legenere limosa* are in areas slated for commercial or residential development (Holland 1984, California Natural Diversity Data Base 2005). In fact, some of the populations extant in 1983 already may have been destroyed by development, but they have not been visited since that time. More than one-third of populations are subject to livestock grazing (California Natural Diversity Data Base 2005), but few appear to be declining. Holland (1984) indicated that “light” grazing during the winter and early spring did not seem to be detrimental to *L. limosa*. Competition from *Phyla nodiflora* is a threat at one Solano County site (California Natural Diversity Data Base 2005). If insects are involved in pollinating *L. limosa*, a decline in insect populations poses a potential threat.

e. Conservation Efforts

Legenere limosa has no Federal or State status. It has been included on California Native Plant Society lists of rare and endangered species for 25 years (Powell 1974) and is currently on List 1B because it is “endangered throughout its range” (Tibor 2001).

Holland (1984) conducted a status survey of *Legenere limosa* in 1983 with funding from the County of Sacramento, R.C. Fuller Associates, and The Nature Conservancy. He confirmed that several historical populations no longer persisted. New populations of this species were discovered during pre-project surveys and during searches by Nature Conservancy volunteers (Holland 1984, California Natural Diversity Data Base 2005).

Eighteen occurrences of *Legenere limosa* are (or were) on nature preserves or publicly-owned lands. Five occurrences are known currently from the Jepson Prairie Preserve in Solano County, two from the nearby Calhoun Cut Ecological Reserve, and two from the Dales Lake Ecological Reserve. *Legenere limosa* was known from Boggs Lake before the preserve was established, but it has not been rediscovered in that area for over 40 years (Holland 1984). *Legenere limosa* occurs in abundance in several vernal pools on the Valensin Ranch Property in Sacramento County owned and managed by The Nature Conservancy (J. Marty, unpub.data). A population of *L. limosa* was also discovered in a restored pool on Beale Air Force Base in Yuba County, California (J. Marty, unpub. data.). Two occurrences, at Hog Lake and on the Stillwater Plains, are on property administered by the U.S. Bureau of Land Management. Sacramento County owns land supporting three occurrences of *L. limosa*; one is at a wastewater treatment plant, and the other two are in county parks. Finally, one occurrence is on land owned by the Sacramento Municipal Utility District (California Natural Diversity Data Base 2001). However, mere occurrence on public land is not a guarantee of protection. Only the preserves and the U.S. Bureau of Land Management occurrences are managed to promote the continued existence of *L. limosa* and other rare species. As of 1991, one Sacramento County developer had plans to preserve several pools containing *L. limosa* when he developed the property (California Natural Diversity Data Base 2001).

8. *MYOSURUS MINIMUS* SSP. *APUS* (LITTLE MOUSETAIL)

a. Description and Taxonomy

Taxonomy.—Little mousetail was first named by Greene (1885) as *Myosurus minimus* var. *apus*. The type specimen of little mousetail was collected "from the table-lands back of San Diego" (Greene 1885:277). Campbell (1952) changed the rank of little mousetail from a variety to a subspecies, resulting in the new combination *Myosurus minimus* ssp. *apus*, which is in use today. This subspecies is believed to have originated as a hybrid between *Myosurus minimus* ssp. *filiformis* (thread-like mousetail) and *Myosurus sessilis* (sessile mousetail); *Myosurus minimus* var. *apus* is now self-perpetuating and therefore worthy of recognition as a separate taxon (Mason 1957, Stone 1959). However, *Myosurus minimus* var. *apus* may cross with *Myosurus sessilis* or with other mousetails and the hybrids then may interbreed again, resulting in a series of intermediates that are difficult to identify (Campbell 1952, Stone 1959) and that may not warrant taxonomic recognition (A. Whittemore *in litt.* 1993). Mousetails are members of the buttercup family (Ranunculaceae).

Description and Identification.—*Myosurus minimus* ssp. *apus* (**Figure II-30**) is a tiny, tufted annual lacking showy flowers. Both the leaves and the scapes originate from the base of the plant. The very narrow leaves are only 2 to 9 centimeters (0.8 to 3.5 inches) long, and the cylindrical scapes are shorter (at most 7 centimeters [2.8 inches] long). Each scape bears a single, inconspicuous flower consisting of 5 to 10 greenish-white petal-like sepals, 3 to 5 greenish-white petals, about 10 stamens, and 70 or more separate pistils. The sepals have a flattened, erect portion 2.5 to 3.5 millimeters (0.10 to 0.14 inch) long and a shorter spur pointing downward. The petals are shorter than the sepals and do not have spurs. *Myosurus minimus* ssp. *apus* has achenes (single-seeded fruits) that are more or less rectangular, 0.75 to 2 millimeters (0.03 to 0.08 inch) long, and have a beak no more than 0.5 millimeter (0.02 inch) long protruding upward from one side. The pistils cover almost the entire length of the scape or receptacle that elongates as the achenes reach maturity, and the beaks are closely appressed to this elongate receptacle, often referred to as a "spike" in this genus (Campbell 1952, Mason 1957, Wilken 1993). The diploid chromosome number of *M. minimus* ssp. *apus* is 16 (Stone 1957 as cited in Stone 1959).

Myosurus minimus ssp. *minimus* (common mousetail) and *M. minimus* ssp. *filiformis* have scapes taller than their leaves, and the achenes are only in the upper part of the scape. *Myosurus sessilis* has shorter spurs on the sepals than does *M. minimus* ssp. *apus*, only five stamens per flower, and the achene beaks project outward from the scape (Campbell 1952). *Myosurus minimus* ssp. *alopecuroides* (foxtail mousetail) also has outward-projecting beaks (Stone 1959). Other taxa of *Myosurus* are differentiated by their scape length in relation to leaf length, achene shape, outcurved beaks, or tendency to drop their flower parts and achenes when they are mature, which *M. minimus* ssp. *apus* does not (Campbell 1952, Mason 1957, Wilken 1993).

b. Historical and Current Distribution

Historical Distribution.—*Myosurus minimus* ssp. *apus* was first collected in 1882. The typical form was known historically from southern California (Campbell 1952), occurring only in the San Diego and Western Riverside County Vernal Pool Regions (Keeler-Wolf *et al.* 1998) (**Figure II-31**). Campbell (1952) also mentioned collections of plants that differed somewhat from those in southern California but were more similar to *M. minimus* ssp. *apus* than to other taxa. These collections were from Alameda, Fresno, Merced, San Benito, San Luis Obispo, and Stanislaus Counties, plus one site that was along the border of Colusa and Glenn Counties. Stone (1959) collected specimens that he attributed to this taxon in Colusa, Contra Costa, Kern, and Stanislaus Counties. Whittemore (*in litt.* 1993) does not believe that the atypical plants mentioned by Campbell and Stone actually represent *M. minimus* ssp. *apus*. If the questionable populations are truly *M. minimus* ssp. *apus*, it also occurred historically in the Carrizo, Central Coast, Livermore, San Joaquin Valley, and Solano-Colusa Vernal Pool Regions,

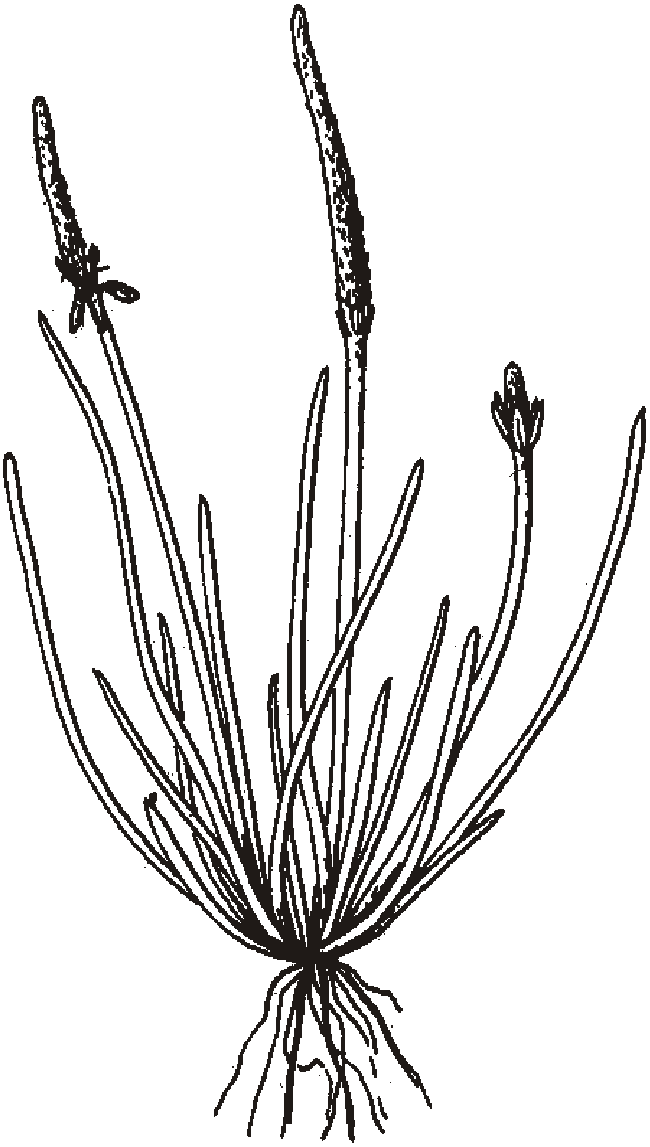

Figure II-30. Illustration of *Myosurus minimus* var. *apus* (little mousetail) Reprinted with permission from Abrams (1944), Illustrated Flora of the Pacific States: Washington, Oregon, and California, Vol. II. © Stanford University Press.

as well as in areas of Fresno and Kern Counties that are outside of the vernal pool regions designated by Keeler-Wolf *et al.* (1998).

Current Distribution.—The current distribution of *Myosurus minimus* ssp. *apus* is uncertain. Few sites have been revisited since they were first discovered, and contemporary botanists often are reluctant to assign a name to intermediate plants. The California Natural Diversity Data Base tracks only the Riverside and San Diego county occurrences; this taxon is presumed to remain extant at 24 occurrences in those two counties (California Natural Diversity Data Base 2005).

Atypical plants identified as *Myosurus minimus* ssp. *apus* have been reported recently from Alameda, Colusa, Contra Costa, and Kern Counties (Kuenster *et al.* 1994, J. Marr *in litt.* 1996, California Natural Diversity Data Base unprocessed data). An unknown subspecies of *M. minimus* still occurs in Merced County (Silveira 1996). In addition to the counties mentioned above, Tibor (2001) reported that *M. minimus* ssp. *apus* was extant in Butte, San Bernardino, and Stanislaus Counties, as well as Oregon and Baja California, Mexico. If all of the recent reports are correct, *M. minimus* ssp. *apus* is currently known from 10 California counties and from at least 6 vernal pool regions as defined by Keeler-Wolf *et al.* (1998). The vernal pool regions encompassing the recent reports are Livermore, Northeastern Sacramento Valley, San Diego, San Joaquin Valley, Solano-Colusa, and Western Riverside County; depending on the exact location of the Stanislaus County report, it could be in the Southern Sierra Foothills Vernal Pool Region or in the San Joaquin Valley Vernal Pool Region. The San Bernardino County report would be outside of any named vernal pool regions.

c. Life History and Habitat

Reproduction and Demography.—The timing of seed germination in nature has not been reported. However, two greenhouse germination experiments have been conducted with related taxa. Bliss and Zedler (1998) studied an unspecified subspecies of *Myosurus minimus* from San Diego. They compared initial wetting on 30 January, 1 March, and 31 March as well as various durations of inundation. Only the earliest wetting date was effective in triggering germination; out of 178 seeds that germinated during their study, 177 (99.4 percent) germinated following the January wetting. Fifty percent of those seeds germinated by 23 February. Also, Bliss and Zedler (1998) found that moist soil was more conducive to germination and growth of *M. minimus* than was inundated soil. Stone (1959) studied the related taxa *M. minimus* ssp. *filiformis* and *M. sessilis*. Under unspecified “standardized” conditions, both taxa reached median seed germination in 13 days. Flower buds formed about 2 months later, averaging 69 days for *M. minimus* ssp. *filiformis* and 69 days for *M. sessilis* (Stone 1959).

Myosurus minimus ssp. *apus* flowers between March and June (Tibor 2001). The seeds mature in late March and April in the Central Valley, whereas plants in southern California begin producing seed in May (Campbell 1952). Dispersal mechanisms have not been reported. The soil seed bank of *M. minimus* ssp. *apus* has not been studied, but Campbell (1952) reported that seeds of other *M. minimus* subspecies are viable for only 2 to 3 years following their production.

Although tiny flies (order Diptera) have been observed visiting *Myosurus minimus* ssp. *minimus*, insects apparently are not necessary to transfer pollen (Knuth 1908). Reproduction in *Myosurus* has been studied in depth by Stone (1959). He noted that the reproductive strategy of *Myosurus minimus* ssp. *apus* was similar to that of *M. sessilis*, which he reported in greater detail. Both are predominantly self-pollinating. Pollen is shed before the flower opens, when the pistils and stamens are covered by the sepals; although fertilization does not take place until 3 to 10 days later, this mechanism ensures that pollen will reach all the pistils that have developed. After the pollen is shed, the flower opens. If growing conditions are favorable, the scape will continue to elongate and produce additional pistils at its tip. Only pollen produced by other flowers would be available for fertilization of the newly-formed pistils. In mixed populations, the pollen could even come from different species or subspecies of *Myosurus*. However, Stone found that only 2 percent of plants collected from the field exhibited any evidence of hybridization. He noted that hybridization would be more likely in years with long growing seasons because the plants would have a greater opportunity to develop exposed pistils.

Myosurus species may produce between 10 and 400 pistils per flower, with at most one seed each, and most plants produce only one or two flowers. However, both the number of flowers and the number of pistils may vary depending on the growing conditions (Stone 1959). Other aspects of *M. minimus* ssp. *apus* demography are unknown.

Habitat and Community Associations.—*Myosurus minimus* ssp. *apus* occurs in Northern Claypan, Northern Hardpan, San Diego Mesa, San Jacinto Valley, and Santa Rosa Plateau vernal pool types (Sawyer and Keeler-Wolf 1995). It also grows occasionally in other types of depressions that hold water seasonally (Stone 1959, California Natural Diversity Data Base 2001) and in alkaline marshes (Mason 1957). Most of the occupied vernal pools occur within coastal sage scrub, *Adenostoma fasciculatum* (chamise) chaparral, or annual and perennial grasslands (California Natural Diversity Data Base 2001). In one case this taxon was found in a depression in a fallow field (Stone 1959). In the few instances where the sizes of occupied pools were reported, they ranged from 25 square meters (269 square feet) to 0.12 hectare (0.3 acre) in area (Stone 1959, California Natural Diversity Data Base 2001). Similarly, the microhabitats for *M. minimus* ssp. *apus* are not well documented; several southern California populations occurred on both the margins and beds of vernal pools (California Natural Diversity Data Base 2001).

Soils at the Central Valley sites studied by Stone (1959) were all alkaline and ranged in texture from clay to sandy loam. Information on characteristics of soils elsewhere in the range are not available. According to the California Natural Diversity Data Base (2001), elevations of occurrences in San Diego and Riverside Counties range from 4 to 640 meters (20 to 2,100 feet), but sites in other parts of the State would likely extend the elevation range.

Myosurus minimus ssp. *apus* is frequently associated with other *Myosurus* taxa, including *M. minimus* ssp. *minimus*, *M. minimus* ssp. *alopecuroides*, *M. minimus* ssp. *filiformis*, and *M. sessilis* (Stone 1959, California Natural Diversity Data Base 2001). Other genera with which it occurs in the Central Valley are *Downingia*, *Plantago* (plantain), and *Lepidium* (Stone 1959). At one site, it co-occurs with *Gratiola heterosepala* (California Natural Diversity Data Base 2005, under *G. heterosepala*). The most frequent associate of *M. minimus* ssp. *apus* in southern California is the federally- and State-listed endangered *Eryngium aristulatum* var. *parishii* (San Diego button-celery). Other federally- and State-listed endangered plants that co-occur with *M. minimus* ssp. *apus* are *Pogogyne nudiuscula* (Otay Mesa mint), *Pogogyne abramsii* (San Diego mesa mint), and *Orcuttia californica*; the federally-listed threatened species *Navarretia fossalis* (spreading navarretia) also co-occurs with *M. minimus* ssp. *apus* (California Natural Diversity Data Base 2005).

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 *Myosurus minimus* ssp. *apus* are described below.

The lack of site-specific historical information and the lack of recent surveys preclude quantification of habitat loss for this taxon. However, *Myosurus minimus* ssp. *apus* probably has declined because much vernal pool habitat throughout California has been lost through agricultural conversion and development, as described in other species accounts. At one San Diego site where *M. minimus* ssp. *apus* occurs, several vernal pools were destroyed by conversion to agriculture, but it is not known whether or not this taxon had been present in those pools. Several other southern California sites where *M. minimus* ssp. *apus* occurs were disturbed by off-road vehicle use, road and powerline construction, livestock grazing, brush removal, and trash dumping (California Natural Diversity Data Base 2001).

Urban development is mentioned as a threat to one San Diego occurrence of *Myosurus minimus* ssp. *apus*. The same occurrence also is threatened by agriculture, trash dumping, livestock grazing, construction of a border crossing, and competition from weedy species. In addition, three southern California occurrences are threatened by damage from off-highway vehicles (California Natural Diversity Data Base 2005). However, other occurrences in that region also may be threatened, particularly by urban development, judging by the magnitude of threats to the listed species of southern California vernal pools (U.S. Fish and Wildlife Service 1998b). Threats have not been assessed at northern and central California occurrences of *M. minimus* ssp. *apus*. If insects do play a role in pollination of *M. minimus* ssp. *apus*, habitat loss for the pollinators could contribute to the decline of this plant.

e. Conservation Efforts

Myosurus minimus ssp. *apus* has no official Federal status. It is not protected in California but is listed as endangered in Oregon (Tibor 2001). *Myosurus minimus* ssp. *apus* formerly was considered to be rare and endangered by the California Native Plant Society (Smith *et al.* 1980). Although it is still considered to be "endangered throughout its range," *M. minimus* ssp. *apus* now is on the California Native Plant Society "Review List" (List 3) of taxa for which insufficient information is available (Tibor 2001).

Ten of the extant occurrences are on public land or in the ownership of a conservation organization. Only three of these occurrences, all on The Nature Conservancy's Santa Rosa Plateau Preserve in Riverside County, are being managed for the benefit of rare species (California Natural Diversity Data Base 2001). Three occurrences are on Federal land in San Diego County: one is on a Navy base and the other two are on the Camp Pendleton Marine Corps installation. Two other sites are administered by State agencies; one is on California Department of Water Resources property in Contra Costa County (Kuenster *et al.* 1994) and the other, in San Diego County, is partially owned by the California Department of Transportation (California Natural Diversity Data Base 2001). County agencies are responsible for one *Myosurus minimus* ssp. *apus* site each in Kern (J. Marr *in litt.* 1996), Riverside, and San Diego Counties (California Natural Diversity Data Base 2001). No conservation actions are known to have been taken specifically for the benefit of this taxon.

9. *NAVARRETIA MYERSII* SSP. *DEMINUTA* (SMALL PINCUSHION NAVARRETIA)

a. Description and Taxonomy

Taxonomy.—Small pincushion navarretia was named only recently. The scientific name, *Navarretia myersii* ssp. *deminuta* (Day 1995), has not undergone any changes. The type locality for this subspecies is about 3 kilometers (2 miles) southeast of Middletown, in Lake County (Day 1995). *Navarretia myersii* ssp. *deminuta* is a member of the phlox family (Polemoniaceae).

Description and Identification.—Basic morphology of the genus was described under *Navarretia leucocephala* ssp. *pauciflora*. The overall appearance of *N. myersii* ssp. *deminuta* is that of a compact head of flowers growing directly out of the ground. *Navarretia myersii* ssp. *deminuta* (**Figure II-32**) has a very short stem that is thickened below ground level and bears one or two closely-spaced pairs of leaves above ground. The narrow, usually entire leaves are 1 to 5 centimeters (0.4 to 2.0 inches) long and extend far beyond the flower head, which is only 0.8 to 2 centimeters (0.3 to 0.8 inch) wide. Typically each plant has only a single flower head, although one or two secondary heads occur occasionally. Individual flowers are stalkless, with a short-hairy calyx 5 to 6 millimeters (0.20 to 0.24 inch) long and a blue corolla 12 to 13 millimeters (0.47 to 0.51 inch) long. The corolla tube is about the same length as the calyx, and the stamens and stigma protrude from the corolla tube. Inner bracts (those closest to the flowers) are about equal to the calyx in length; they have a broad, papery base and a few lobes near the tip. Three to five outer bracts, which are 1 to 2 centimeters (0.4 to 0.8 inch) long, occur on the periphery of the head. The outer bracts are broad and papery at the base, have toothed or forked lobes between the base and the middle, and are unbranched near the tip. The capsules contain four to six seeds each (Day 1995). The chromosome number of *N. myersii* ssp. *deminuta* is not known.

Navarretia myersii ssp. *myersii* (pincushion navarretia) is the closest relative of *N. myersii* ssp. *deminuta*. The former has a white flower, the corolla is longer (17 to 21 millimeters [0.67 to 0.83 inch]) than in *N. myersii* ssp. *deminuta,* the corolla tube is two to four times as long as the calyx, and the outer bracts are lobed only above the middle. Another similar species, *N. prostrata* (prostrate navarretia), has multiple (up to 20) flower heads per plant, shorter corollas (6 to 9 millimeters

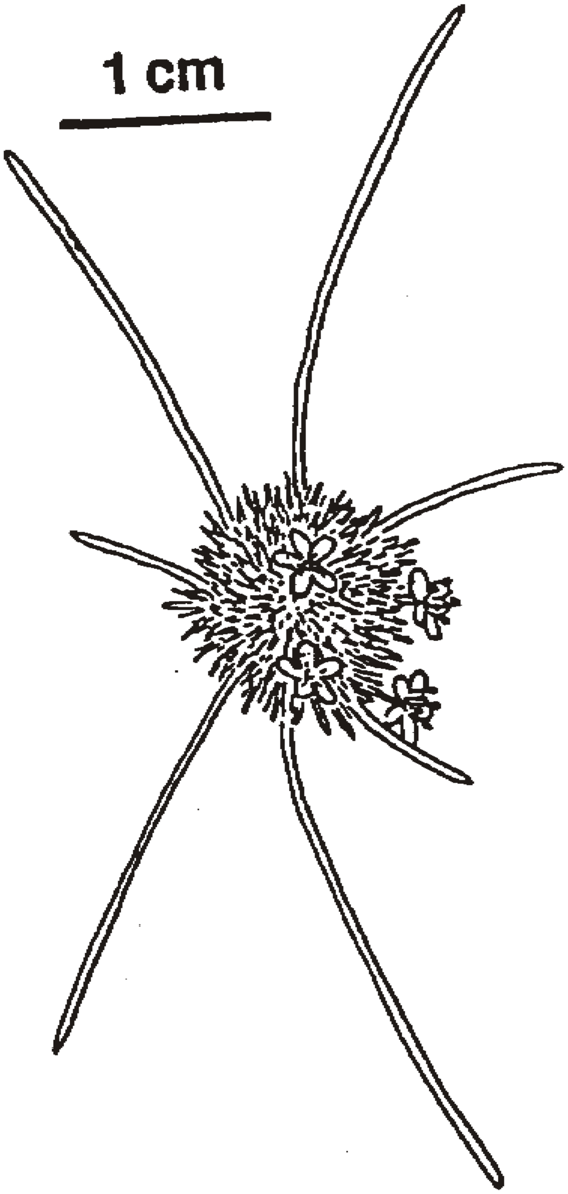

Figure II-32. Illustration of *Navarretia myersii* ssp. *deminuta* (small pincushion navarretia). (Reprinted with permission from the California Botanical Society)

[0.24 to 0.35 inch]), white or blue flowers, lobed leaves, outer bracts that are lobed throughout their length, and contains between 5 and 25 seeds per capsule (Day 1995). Other vernal pool navarretias, including *N. leucocephala* ssp. *pauciflora* and *N. leucocephala* ssp. *plieantha*, differ from *N. myersii* ssp. *deminuta* in that they have conspicuous branches and their corollas are comparatively short (Day 1993*b*).

b. Historical and Current Distribution

Historical Distribution.—*Navarretia myersii* ssp. *deminuta* was just discovered in 1992 and no earlier collections are known. Thus, the historical distribution is identical with the current distribution (**Figure II-5**).

Current Distribution.—*Navarretia myersii* ssp. *deminuta* is known only from the type locality in Lake County (Day 1995, A. Day pers. comm. 1997, L. Esposito pers. comm. 1997, California Natural Diversity Data Base 2005). Thus, the taxon is restricted to the Lake-Napa Vernal Pool Region (Keeler-Wolf *et al.* 1998).

c. Life History and Habitat

Reproduction and Demography.—The reproductive biology of *Navarretia myersii* ssp. *deminuta* has not been investigated but probably is similar to that of *N. leucocephala* ssp. *pauciflora* because they are closely-related vernal pool annuals (Day 1993*a*). *Navarretia myersii* ssp. *deminuta* flowers in April and May (Day 1995). The single population contained about 25,000 plants in 1992 (California Natural Diversity Data Base 2001). In 1993, following a season of above-average rainfall, *N. myersii* ssp. *deminuta* plants had longer leaves and more flowers than in the previous or the following years, which were drier (Day 1995).

Habitat and Community Associations.—At the single known site, *Navarretia myersii* ssp. *deminuta* occurs in vernal pools, at the edges of vernal swales, and in low areas adjacent to a road. The pools and other depressions occur within a matrix of annual grassland on clay loam soil (Day 1995, California Natural Diversity Data Base 2001). Specific types of vernal pools in which it occurs have not been reported. The type locality is at 331 meters (1,087 feet) in elevation (California Natural Diversity Data Base 2001). Plants associated with *N. myersii* ssp. *deminuta* at the site include *Eryngium aristulatum, Downingia concolor* (fringed downingia), *Juncus bufonius*, *Isoetes howelli* (Howell's quillwort), and *Psilocarphus brevissimus* (California Natural Diversity Data Base 2001).

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 *Navarretia myersii* ssp. *deminuta* are described below. *Navarretia myersii* ssp. *deminuta* is not known to have declined; the subspecies was unknown prior to 1992.

The single locality for *Navarretia myersii* ssp. *deminuta* was threatened by a subdivision (Day 1995, California Natural Diversity Data Base 2001), which was never developed. However, the parcel is zoned rural residential, and the landowner could build a residence, drain the wetland, or make other alterations without being required to obtain permits or conduct an environmental review (L. Esposito *in litt.* 2000). No imminent threats to the population have been noted but two more remote threats are possible. The single population makes *N. myersii* ssp. *deminuta* extremely susceptible to extinction by random events, including both natural and human-caused catastrophes.

e. Conservation Efforts

Navarretia myersii ssp. *deminuta* does not have any formal protection under Federal or State law. However, the California Native Plant Society (2001) considers *N. myersii* ssp. *deminuta* to be extremely rare and in danger of extinction, and thus has added it to List 1B. No conservation efforts have been reported other than denial of a development permit by Lake County officials (L. Esposito pers. comm. 1997).

10. *PLAGIOBOTHRYS HYSTRICULUS* (BEARDED POPCORN FLOWER)

a. Description and Taxonomy

Taxonomy.—Piper (1920) first recognized bearded popcorn flower as a unique entity, assigning the name *Allocarya hystricula*. Jepson had collected the type specimen in 1892 from the Montezuma Hills, Solano County (Piper 1920). In his monograph on *Plagiobothrys*, Johnston (1923) considered *Allocarya hystricula* to be the same as *Plagiobothrys greenei* (Greene's popcorn flower). After several revisions to the name by various individuals, Johnston (1932 as cited in Abrams 1951) assigned the name by which bearded popcorn flower is known today, *Plagiobothrys hystriculus*. This taxon is in the borage family (Boraginaceae). Another common name for bearded popcorn flower is bearded allocarya (Smith *et al.* 1980).

Description and Identification.—*Plagiobothrys hystriculus* is an annual with erect or decumbent branched stems 10 to 45 centimeters (3.9 to 17.7 inches) long. The stem, leaves, and calyx are sparsely to densely covered with short, straight, appressed hairs. The narrow leaves are opposite near the base of the stem but alternate above. The leaves decrease in size up the stem, with the lower leaves 2 to 6 centimeters (0.8 to 2.4 inches) long. The flowers are widely spaced throughout the inflorescence. Each is supported by an individual stalk that is shorter than the flower, and many are subtended by bracts. The calyx consists of five sepals fused only at the base. When the flowers open, the calyx is 3 to 6 millimeters (0.12 to 0.24 inch) long, but the lobes increase in length as the flowers mature. The white corolla is tiny (1 to 2.5 millimeters [0.04 to 0.10 inch] wide) and has a tubular base with five lobes. Each flower produces four egg-shaped nutlets 1.5 to 2.5 millimeters (0.06 to 0.10 inch) long. The nutlets have narrow lengthwise and crosswise ridges that are covered with tubercles; each tubercle is broad at the base, blunt at the tip, and is about one-sixth the length of the nutlet. The tubercles and the nutlet surface in between are densely covered with tiny, barbed bristles (Piper 1920, Jepson 1925, Abrams 1951, Messick 1993). The chromosome number of *P. hystriculus* has not been reported.

Plagiobothrys hystriculus is difficult to distinguish from *P. acanthocarpus* (adobe popcorn flower), *P. greenei*, and *P. trachycarpus* (rough-fruited popcorn flower). Close inspection of the nutlets is necessary to identify the various species. Both *P. acanthocarpus* and *P. greenei* have long, pointed prickles instead of blunt tubercles. Furthermore, *P. acanthocarpus* has few bristles on the prickles or on the nutlet surface. *Plagiobothrys greenei* has longer nutlets than *P. hystriculus* and lacks crosswise ridges. *P. trachycarpus* rarely has tubercles on the nutlets but when present they lack bristles (Piper 1920, Abrams 1951, Messick 1993).

b. Historical and Current Distribution

Historical Distribution.—*Plagiobothrys hystriculus* was known historically from only two Solano County sites: the type locality and Elmira, where it was collected in 1883 (Piper 1920, Hoover 1937) (**Figure II-20**). The two reported occurrences of *P. hystriculus* would fall within the Solano-Colusa Vernal Pool Region, as defined by Keeler-Wolf *et al.* (1998).

Current Distribution.—This species has not been observed since 1892. Although classified as 1A (presumed extinct) by the California Native Plant Society, the California Natural Diversity Data Base (2005) still presumes the type locality to be extant. Various botanists have reported finding populations of *Plagiobothrys hystriculus*, but all recent reports have been determined to represent other species (Skinner and Pavlik 1994, Skinner *et al.* 1995).

c. Life History and Habitat

Reproduction and Demography.—The only information available on reproduction in *Plagiobothrys hystriculus* is that it flowers in April and May (Abrams 1951). Demographic data also are lacking.

Habitat and Community Associations.—The habitat of *Plagiobothrys hystriculus* is not well understood. The original collectors did not give detailed descriptions of the environment, and later botanists presented conflicting habitat descriptions. Jepson (1925:853), one of only two people who collected *P. hystriculus*, described the habitat as "low plains." Hoover (1937:22) included *P. hystriculus* in his "Hog-wallow Endemism Area." Abrams (1951:561) noted that the species grew on "grassy hillsides and plains." More recent descriptions give the habitat as "grassland, probably vernal pools, wet sites" (Messick 1993:389) and as Northern Claypan Vernal Pools (Sawyer and Keeler-Wolf 1995). Microhabitats, soil types, and associated species are not known. Both collection sites are less than 50 meters (164 feet) in elevation (California Natural Diversity Data Base 2001).

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 *Plagiobothrys hystriculus* include the conversion of the area around Elmira to agriculture; no natural land remains (Holland 1984). The type locality for *Plagiobothrys hystriculus* was not specific enough to allow determination of its probable current status, based on known land uses. Threats to the survival of *P. hystriculus* cannot be assessed until any possible extant populations are located.

e. Conservation Efforts

Plagiobothrys hystriculus has no Federal or State status. The California Native Plant Society originally considered it to be rare (Powell 1974) but now includes it on List 1A, among those species presumed to be extinct (Skinner and Pavlik 1994). Various groups have looked for *P. hystriculus* in the course of surveying, but it has not been relocated. Thus, no other protection measures have been possible. *Plagiobothrys hystriculus* is included in this recovery plan to bring attention to the species and to encourage comprehensive surveys so that any potentially extant populations may be located.

***Conservation Actions for Rediscovered Plants*.**—In the event of rediscovery, both immediate and long-term actions will be needed. Outlining these actions in a recovery plan increases the potential for participation by both State and Federal agencies and for funding to carry out needed actions. Three actions–status review, plant stabilization, and protection of plants and habitat–would be needed concurrently. First, a status review should be conducted immediately to assess if there are threats from current or planned activities such as grazing, fire, nonnative plant species, rodents, insects, habitat conversion, inbreeding depression, or others. The status review should include consideration of whether existing mechanisms for protection are adequate. The results of the status review would help determine if the plant warrants listing. Second, stabilizing the plants or populations of plants by alleviating threats to short-term survival would be essential. Such stabilization efforts may include controlling invasive nonnative or native vegetation, erosion, destructive rodents and/or insects, and providing insurance for the population by collecting and storing seed (if such collection would not further imperil the population's survival). Third, securing and protecting the habitat and the existing plants would be essential. If the plant is rediscovered on public lands, it would be important to work with the land manager to develop a site-specific management plan that would include yearly monitoring measures to minimize any threats. If the plant is rediscovered on private lands, the willingness of the land owner to participate in recovery efforts would need to be assessed and encouraged. If the landowner (and land manager or lessee) were amenable, an agreement should be developed to formalize plant protection. This agreement could be temporary or long-term, depending on the willingness of the landowner and the needs of the species.

After short-term mechanisms for protection are in place, long-term management should begin. Different approaches should be evaluated. An implementation team, consisting of members with the expertise to determine appropriate measures and the means to implement such measures, would be of great benefit. Options include reintroduction to historical sites, propagation in greenhouses and/or botanical gardens, and seed collection and storage. Other necessary actions would include the alleviation of threats, securing sites, maintaining or enhancing abundance, developing and implementing a monitoring plan, conducting essential research (*e.g.*, demography, genetics, reproductive biology, and propagation techniques), reassessing status every 5 years to determine if Federal listing is warranted, and coordinating efforts with conservation and recovery actions for other species covered in this recovery plan or throughout the recovery plan area. Although actions are outlined here, they will not all necessarily be appropriate to the future situation, nor is the list complete.

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 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), 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

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 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 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).

D. Animal Species of Concern

1. Midvalley Fairy Shrimp (*Branchinecta mesovallensis*)

a. Description and Taxonomy

***Taxonomy.*—**The midvalley fairy shrimp (*Branchinecta mesovallensis*) was only recently described by Belk and Fugate (2000). The species was named for its limited range in the Central Valley of California. The type locality is on the Virginia Smith Trust land in Merced County, California (Belk and Fugate 2000). Midvalley fairy shrimp specimens had been collected as early as 1989.

***Description and Identification.*—** The midvalley fairy shrimp is characterized by relatively simple male antennae, lacking spines or protuberances. Male midvalley fairy shrimp range in length from 12 to 20 millimeters (0.5 to 0.8 inch), and females range from 7 to 20 millimeters (0.3 to 0.8 inch), measured from the front of the head to the tip of the cercopods (Belk and Fugate 2000).

Male midvalley fairy shrimp are most similar in appearance to the Conservancy fairy shrimp (Belk and Fugate 2000). These species are distinguished by the shape of the tip of their antennae. The midvalley fairy shrimp's antennae are bent such that the larger of the two humps possessed by both species is anterior, whereas the larger hump is posterior in the Conservancy fairy shrimp. Females of these two species differ in the shape of their brood pouches. The brood pouch of the midvalley fairy shrimp is pyriform, opens terminally, and extends to below segments 3 and 4. The brood pouch of the Conservancy fairy shrimp is fusiform and extends to below segments 5 and 7. Midvalley fairy shrimp females also closely resemble the vernal pool fairy shrimp, except that vernal pool fairy shrimp females have a pair of dorsolateral processes on each side of thoracic segment 3, whereas the midvalley fairy shrimp does not have any dorsolateral processes on this thoracic segment.

b. Historical and Current Distribution

***Historical Distribution.*—**Although the historical distribution of the midvalley fairy shrimp is unknown, vernal pool habitats in the regions where it is currently known to occur have been dramatically reduced since pre-agricultural times (Holland 1998). The habitat of the midvalley fairy shrimp may have been even more severely reduced than other vernal pool habitats since it can occur in swales and short lived pools that may escape detection in dry years or during the dry season (Helm 1999, Belk and Fugate 2000).

***Current Distribution*.—**The midvalley fairy shrimp is endemic to a small portion of California's Central Valley (**Figure II-39**). Helm (1998) found midvalley fairy shrimp in less than 0.5 percent of the vernal pools he examined. Based on the few known occurrences, the species' distribution is apparently limited to the Southeastern Sacramento, Southern Sierra Foothill, San Joaquin, and Solano-Colusa Vernal Pool Regions. In the Southeastern Sacramento region, most occurrences are clustered around the City of Sacramento and Mather Air Force Base in Sacramento County. In the Southern Sierra Foothills and San Joaquin Vernal Pool Regions, the midvalley fairy shrimp has been documented in the vicinity of the Virginia Smith Trust property in Merced County and from isolated occurrences in San Joaquin, Madera, and Fresno Counties. However, because this species was described only recently, it is likely additional occurrences will be found in the future.

c. Life History and Habitat

***Life History*.—**The life cycle of the midvalley fairy shrimp is well suited to the unpredictable conditions of vernal pool habitats. The midvalley fairy shrimp can mature and reproduce very rapidly; it has been observed to reach maturity in as little as 8 days and reproduction was observed in as few as 16 days after hatching (Helm 1998). Under the culturing conditions described in Helm (1998), the midvalley fairy shrimp lived for 147 days, about as long as other Central Valley species observed. Multiple hatchings of the midvalley fairy shrimp have been observed in a single rainy season as its vernal pool habitat repeatedly fills and dries. Helm (1998) found the midvalley fairy shrimp to be very tolerant of warm water, occurring in pools with water temperatures ranging from 5 to 32 degrees Celsius (41 to 89 degrees Fahrenheit). This temperature is higher than that measured for any other Central Valley fairy shrimp except for the California fairy shrimp. Little is known about the midvalley fairy shrimp's tolerance to variations in water chemistry, but it has been found in some relatively alkaline pools (Helm 1998).

***Habitat*.—**The midvalley fairy shrimp has been found in small, short-lived vernal pools and grass-bottomed swales ranging from 4 to 663 square feet (0.37 to 61.6 square meters) in area and averaging less than 4 inches (10 centimeters) in depth (Helm 1998). The species has been collected from pools on a volcanic mudflow landform of the Merhten Formation in Pentz Gravelly Loam and Raynor Clay soils. The midvalley fairy shrimp has also been found on San Joaquin Silt Loam soils on the Riverbank formation on Low Terrace landforms. At the time the type specimens were collected, the dominant macrophytes in the pool were the wetland grasses *Lolium multiflorum*, *Hordeum maximum gussoneanum* and *Deschampsia danthanoides*, species that are characteristic of extremely short-lived pools and swales.

***Community Associations*.—**The midvalley fairy shrimp has only been collected with one other fairy shrimp, the vernal pool fairy shrimp (Eriksen and Belk 1999). It may occupy habitats that are not inundated long enough for other species to inhabit.

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 midvalley fairy shrimp are described below.

Continued conversion of the grassland-vernal pool ecosystem matrix to urban or agricultural uses, and associated hydrological changes, is the largest threat to survival of the midvalley fairy shrimp. The small depressions in which midvalley fairy shrimp typically reside require less preparation prior to conversion to urban or agricultural uses because they are already relatively level, and thus may be more attractive to developers. During the wet season, they may not contain water continuously, even when nearby larger pools are full. Under these conditions, midvalley fairy shrimp pools may not be surveyed at all, and conversion may proceed without the required regulatory review.

Although the Act affords incidental protection to midvalley fairy shrimp where they co-exist with listed species, none of those listed species, except vernal pool fairy shrimp, have been found to co-occur with midvalley fairy shrimp in the same vernal pools (Eriksen and Belk 1999). Additionally, the co-occurrence with vernal pool fairy shrimp is believed to be a result of overland flow in a heavy precipitation event and not as a result of overlapping habitat requirements. Biological surveys are often inadequate and project proponents may miss detection of midvalley fairy shrimp due to its ability to occur in shallow pools which are inundated for short periods. In instances where co-existence of listed species and midvalley fairy shrimp are documented in the same complex, although there may be incidental protection, there is no consultation requirement to avoid take or minimize effects of the action on the midvalley fairy shrimp. The largest number of known locations are in Merced County and Sacramento County. The City of Sacramento is growing rapidly, thus threatening the continued existence of occurrences in the sphere of growth. Urban expansion in eastern Merced County also poses a threat to many midvalley fairy shrimp populations.

e. Conservation Efforts

Of the 53 midvalley fairy shrimp occurrences in the California Natural Diversity Data Base (2003), roughly 19 (36 percent) are directly threatened by proposed development projects, while 22 (41.5 percent) are on protected lands. The protected lands include two National Wildlife Refuges, several vernal pool mitigation banks, a California Department of Fish and Game ecological reserve, and several Nature Conservancy conservation easements. Sacramento and Merced Counties have the most threatened occurrences, with seven and five, respectively. Threats in Sacramento County mostly involve urban development projects, while the primary threat in Merced County is construction of the proposed University of California, Merced, campus. Merced County also has the highest number of protected occurrences, with a total of 14 occurrences located on lands that have been set aside for the conservation of vernal pool species. These lands are intended to function as conservation areas to offset the direct, indirect, and cumulative effects of the new university campus. Three ranches containing conservation easements held by The Nature Conservancy (totaling about 9,900 hectares [24,500 acres]) contain known midvalley fairy shrimp sightings. The easements are permanent, will generally be managed by The Nature Conservancy, and cannot be extinguished by selling the land to a new owner (J. Single *in litt*. 2003; U.S. Fish and Wildlife Service, *in litt*. 2003).

2. CALIFORNIA FAIRY SHRIMP (*LINDERIELLA OCCIDENTALIS*)

a. Description and Taxonomy

***Taxonomy*.—**The California fairy shrimp *(Linderiella occidentalis)* was first described as *Branchinecta occidentalis* by Dodds (1923) from specimens collected at Stanford University, Santa Clara County, California. Linder (1941) moved this species into the genus *Pristicephalus,* but discussed the possibility that the genus *Pristicephalus* should be absorbed into the genus *Eubranchipus*. However, he did not have the specimens necessary to make that determination. Pennak (1953) assigned California fairy shrimp specimens to the genus *Eubranchipus*. Brtek (1964) erected the family Linderiellidae, and placed the California fairy shrimp in the genus *Linderiella*. This taxonomic placement is still recognized (Belk and Brtek 1995). The California fairy shrimp was the only recorded species in the Family Linderiellidae in North America until 1994, when the Santa Rosa fairy shrimp *(Linderiella santarosae*) was collected and described from southern California by Thiery and Fugate (1994).

***Description and Identification.*—**Unlike the other fairy shrimp addressed in this recovery plan, the California fairy shrimp is a member of the family Linderiellidae. It is smaller than fairy shrimp in the family Branchinectidae, and has red eyes, and conical, horn-like antennae appendages. Male California fairy shrimp are approximately 9 millimeters(0.35 inch) long, and females are about 10 millimeters (0.39 inch) in length (Dodds 1923).

The California fairy shrimp is one of two species of *Linderiella* described in North America. Both the California fairy shrimp and the Santa Rosa fairy shrimp are endemic to California (Eng *et al.* 1990, Thiery and Fugate 1994). These two species can be identified by the male's second antennae, and by their cysts. The male California fairy shrimp has a thinner, straighter second antennae than the Santa Rosa fairy shrimp. The cysts of the California fairy shrimp have sharper and longer spines than the Santa Rosa fairy shrimp, whose cysts have more tulip-shaped spines (Thiery and Fugate 1994).

The California fairy shrimp may also be confused with species of *Branchinecta* or *Eubranchipus*, as evidenced by its being placed in both these genera in the past (Dodds 1923, Pennak 1953). However, *Eubranchipus* has an obvious frontal appendage, while the California fairy shrimp has no frontal appendage. In California, *Linderiella* and *Eubranchipus* have completely separate distributions as well. The California fairy shrimp can be differentiated from species of *Branchinecta* by its red eyes and smaller size. The second antennae of the California fairy shrimp are also simpler than those of *Branchinecta* species, lacking outgrowths or protuberances (Belk 1975, Eng *et al.* 1990, Eriksen and Belk 1999).

b. Historical and Current Distribution

Historical Distribution.—The California fairy shrimp was identified relatively recently, in 1990, and there is little information on the historical range of the species. However, the California fairy shrimp is currently known to occur in a wide range of vernal pool habitats in the Central Valley of California. It is likely the historical distribution of this species coincides with the historical distribution of Central Valley vernal pools. 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. He found that although the current distribution of vernal pools is similar to their historical distribution in extent, Central Valley vernal pools are now far more fragmented and isolated from each other than during historical times. Central Valley vernal pools currently occupy only about 25 percent of their former land area (Holland 1998).

The historical distribution of the California fairy shrimp in Southern California may also have been similar to the historical distribution of its vernal pool habitat in that region. Unlike the Central Valley, where vernal pool habitats where 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, 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 California fairy shrimp was likely historically present in available vernal pool habitats in Riverside, Los Angeles, Ventura, and Orange Counties. The historical distribution of the California fairy shrimp in the Central Coast, Carrizo, and Santa Barbara Vernal Pool Regions is not known.

***Current Distribution*.—**The current distribution of the California 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 during pre-agricultural times. The California fairy shrimp is currently known from the Central Valley and Coast ranges of California (**Figure II-40**). There are currently 238 reported occurrences of California fairy shrimp in the California Natural Diversity Data Base (2005). In the Northwestern Sacramento Valley Vernal Pool Region the California fairy shrimp is found in the vicinity of Redding on the Stillwater Plains in Shasta County and at a single occurrence in Tehama County. In the Northeastern Sacramento Valley Vernal Pool Region the species is known from the vicinity of Vina Plains and the Dales Lake Ecological Reserve in Tehama County and from a single occurrence in Butte County. In the Southeastern Sacramento Valley Vernal Pool Region the California fairy shrimp is found at Beale Air Force Base in Yuba County, at scattered locations in western Placer County, at McClellan Air Force Base and other locations in Sacramento County, and at a single location in San Joaquin County. In the Santa Rosa Vernal Pool Region (as identified by Keeler-Wolf *et. al*.1998), the California fairy shrimp is known from the vicinity of the cities of Healdsburg, Santa Rosa, and Sebastopol in Sonoma County (refer to the Draft Santa Rosa Plains Recovery Plan [in development] regarding these populations). The California fairy shrimp is also known from a single occurrence in the Livermore Vernal Pool Region in Alameda County. The California fairy shrimp occurs in the vicinity of Jepson Prairie in the Solano-Colusa Vernal Pool Region. In the Central Coast Vernal Pool Region the California fairy shrimp occurs on private property and at Fort Ord and Fort Hunter Liggett in Monterey and San Benito Counties. In the San Joaquin Vernal Pool Region the California fairy shrimp is known from the Grasslands Ecological Area in Merced County and from a single occurrence in Stanislaus County. In the Southern Sierra Foothills Vernal Pool Region the species is known from the Big Table Mountain Preserve and private land in Fresno County, from Bureau of Reclamation and private lands in Madera County, and from a few scattered locations on private land in Merced, and Stanislaus Counties. The California fairy shrimp is also known from isolated occurrences in Santa Barbara and Ventura Counties in the Santa Barbara Vernal Pool Region.

c. Life History and Habitat

Life History.—The California fairy shrimp is uniquely adapted to the astatic conditions of vernal pool habitats. This species is the longest lived of the Central Valley fairy shrimp species (Eriksen and Belk 1999). Helm (1998) found that the California fairy shrimp required a minimum of 31 days and an average of 43 days to reproduce, and was observed to live as long as 168 days. California fairy shrimp eggs can hatch when temperatures drop below 20 degrees Celsius (68 degrees Fahrenheit), although optimum hatching may occur at 10 degrees Celsius (50 degrees Fahrenheit) (Eriksen and Belk 1999). The California fairy shrimp may have relatively small clutch sizes. Dodds (1923) reported that brood pouches he examined never contained more than six eggs. California fairy shrimp have been observed in pools with 4- to 16-week durations, and mortality was caused by pool drying (Gallagher 1996). When pools almost dried, Gallagher (1996) observed California fairy shrimp surviving in the pool bottoms, suggesting they may be tolerant of high temperatures and low levels of dissolved oxygen.

Habitat.—The California fairy shrimp is the most widely distributed fairy shrimp in California. The California fairy shrimp has been documented on most land forms, geologic formations, and soil types supporting vernal pools in California. Helm (1998) found the California fairy shrimp in pools ranging in size from 1 to 52,500 square meters (from 10.8 square feet to13 acres). Other studies have also documented California fairy shrimp in vernal pools ranging widely in size (Syrdahl 1993, Alexander and Schlising 1997). However, the California fairy shrimp tends to be in deeper pools (Platenkamp 1998). The California fairy shrimp is tolerant of a wide range of water temperatures, and has been found in pools with temperatures from 5 to 29.5 degrees Celsius (41 to 85 degrees Fahrenheit) (Syrdahl 1993). California fairy shrimp are often found in pools with clear to turbid water with pH ranging from 6.1 to 8.5, low (13 to 170 parts per million) alkalinity and low (33 to 273 parts per million) total dissolved solids (Eng *et al.* 1990, Syrdahl 1993, Eriksen and Belk 1999). California fairy shrimp have been found in vernal pools ranging in elevation from 10 to 1,159 meters (30 to 3,800 feet) above sea level (Eriksen and Belk 1999).

Community Associations.--The range of the California fairy shrimp overlaps the range of most other large branchiopods that occur in the Central Valley of California. The California fairy shrimp is frequently collected from the same pools as the vernal pool fairy shrimp, where the former is usually numerically dominant (Eriksen and Belk 1999).

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 California fairy shrimp are described below.

According to the California Natural Diversity Database (2005), 42 occurrences of California fairy shrimp are threatened by development, and 13 occurrences are threatened by agricultural conversion.

In the Northwestern Sacramento Valley Vernal Pool Region, the California fairy shrimp is threatened by development on private lands in Shasta and Tehama Counties. In the Northeastern Sacramento Valley Vernal Pool Region the species is threatened by development on private land in Butte County.

The California fairy shrimp is threatened by development in Alameda County in the Livermore Vernal Pool Region. The California fairy shrimp is threatened by development where it occurs on private land in Solano County in the Solano-Colusa Vernal Pool Region. In the Central Coast Vernal Pool Region the California fairy shrimp is threatened by development on private land in Monterey County.

In the San Joaquin Vernal Pool Region the California fairy shrimp is threatened by development on private land in Stanislaus County.

In the Southern Sierra Foothill Vernal Pool Region the species is threatened by development and incompatible land uses on Bureau of Reclamation land in Madera County, and on private land in Madera, Merced, and Stanislaus Counties.

Refer to the Draft Santa Rosa Plains Recovery Plan (in development) for information regarding threats facing the California fairy shrimp in the Santa Rosa Vernal Pool Region, as identified by Keeler-Wolf *et. al*. (1998). The California fairy shrimp is also threatened by development in Santa Barbara and Ventura Counties in the Santa Barbara Vernal Pool Region.

e. Conservation Efforts

While no actions have been taken specifically to conserve California fairy shrimp, a number of populations occur on protected lands. There are currently 238 reported occurrences of California fairy shrimp in the California Natural Diversity Data Base (2005). Approximately 33 percent of the documented populations are on private land without protection and ownership is unknown for 18 percent (California Natural Diversity Data Base 2003). Of these occurrences, 25 are within existing reserves or mitigation sites: 17 private reserves or mitigation sites, 4 State-owned reserves, and 4 federally-owned reserves (California Natural Diversity Data Base 1997). The California fairy shrimp is protected from direct habitat loss at the Stillwater Plains in Shasta County in the Northwestern Sacramento Valley Vernal Pool Region. In the Northeastern Sacramento Valley Vernal Pool Region the species is protected at the Vina Plains and the Dales Lake Ecological Reserve in Tehama County. In the Southeastern Sacramento Valley Vernal Pool Region the California fairy shrimp is protected from development at Beale Air Force Base in Yuba County, McClellan Air Force Base in Sacramento County, and on a variety of private mitigation areas throughout the region. In the Central Coast Vernal Pool Region the California fairy shrimp is protected from direct habitat loss at Fort Ord and Fort Hunter Liggett in San Benito County. In the San Joaquin Vernal Pool Region the California fairy shrimp is protected from direct habitat loss at the Grasslands Ecological Area in Merced County. In the Southern Sierra Foothill Vernal Pool Region the species is protected from direct habitat loss at the Big Table Mountain Preserve in Fresno County. A cooperative group consisting of the California Department of Fish and Game, California Department of Parks and Recreation, Sierra Foothills Conservancy, Bureau of Land Management, and Bureau of Reclamation has developed a management and monitoring plan for the Big Table Mountain Preserve. Initial efforts focus on grazing as a means to control nonnative grasses while comparing population trends of threatened and endangered species in grazed and ungrazed portions of the tableland (M. Griggs *in litt*. 2000). The California Department of Fish and Game conducted botanical studies on this Preserve in conjunction with a grazing study for the last 5 years and will continue monitoring the Big Table Mountain Preserve in conjunction with the grazing lease (M. McCrary, pers comm). The California fairy shrimp is also protected on the Santa Rosa Plateau in Riverside County in the Western Riverside County Vernal Pool Region.

3. WESTERN SPADEFOOT TOAD (*SPEA HAMMONDII*)

a. Description and Taxonomy

Taxonomy.—Spadefoot toads are members of the family Pelobatidae. Two closely related genera of spadefoot toads have been recognized within this family: *Scaphiopus* and *Spea* (Cannatella 1985, Weins and Titus 1991). We will collectively refer to members of this family in this document as spadefoot toads unless otherwise stated. Western spadefoot toads are officially recognized within the genus *Spea* (Weins and Titus 1991), although many literature sources reference *Scaphiopus* as the genus. Species relationships within *Spea* have been difficult to define due to morphological homogeneity among species. At least four species are currently recognized (Weins and Titus 1991). Named by Baird in 1859, *Spea hammondii* was regarded as having a broad geographic range from California to western Texas and Oklahoma with a distributional gap in the Mojave Desert of California (Storer 1925, Stebbins 1966). However, Brown (1976) identified morphological, vocalization, and reproductive differences between eastern (Arizona eastward) and western (California) populations, justifying species recognition for each. The California populations retained the name *Spea hammondii* (western spadefoot toad) while the eastern populations were designated as *Spea multiplicata* (southern spadefoot toad) This distinction was further supported by electrophoretic analyses conducted by Sattler (1980) and by allozymic and morphological analyses conducted by Weins and Titus (1991). Genetic variation across the range of *Spea hammondii* has not been studied to date.

Description and Identification.—Spadefoot toads are distinguished from the true toads (genus *Bufo*) by their cat-like eyes (their pupils are vertically elliptical in bright light but are round at night), the single black sharp-edged “spade” on each hind foot, teeth in the upper jaw, and rather smooth skin (Stebbins 1985) (**Figure II-41**). The parotid glands (large swellings on the side of the head and behind the eye) are absent or indistinct on spadefoot toads. Males may have a dusky throat and dark nuptial pads on the innermost front toes (*i.e.*, thumb).

The western spadefoot toad ranges in size from 3.7 to 6.2 centimeters (1.5 to 2.5 inches) snout-vent length. They are dusky green or gray above and often have four irregular light-colored stripes on their back, with the central pair of stripes sometimes distinguished by a dark, hourglass-shaped area. The skin tubercles (small, rounded protuberances) are sometimes tipped with orange or are reddish in color, particularly among young individuals (Storer 1925, Stebbins 1985). The iris of the eye is usually a pale gold. The abdomen is whitish without any markings. Spadefoot toads have a wedge-shaped, glossy black “spade” on each hind foot, used for digging. The call of western spadefoot toads is hoarse and snore-like, and lasts between 0.5 and 1.0 second (Stebbins 1985).

The eggs of western spadefoot toads are pigmented and are found in irregular cylindrical clusters of about 10 to 42 eggs attached to plant stems and other submerged objects in temporary pools (Stebbins 1985). Spadefoot toad larvae (tadpoles) can reach 7 centimeters (2.8 inches) in length (Storer 1925). They have an upper mandible that is beaked and a lower mandible that is notched. The larvae have oral papillae (small nipple-like projections that encircle the mouth), and their eyes are set close together and situated well inside the outline of the head as viewed from above. Their body is broadest just behind the eyes (Storer

Figure II-41. Photograph of western spadefoot toad *(Spea hammondii).*
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1925). Western spadefoot toad larvae resemble those of other *Spea* species in that both cannibal and non-cannibal morphotypes display coloration that is variable relative to their habitat. They also show a uniform iridescence in their pigmentation.

Western spadefoot toads and southern spadefoot toads lack a cranial boss (a ridge between the eyes). This trait distinguishes these species from the plains (*Spea bombifrons)* and the Great Basin (*Spea intermontanus*) spadefoot toads, which each have a cranial boss. Compared to western spadefoot toads, southern spadefoot toads have a more elongate spade, are brownish above, and have a copper-colored iris.

b. Historical and Current Distribution

***Historical Distribution*.—**The western spadefoot toad is nearly endemic to California, and historically ranged from the vicinity of Redding in Shasta County southward to Mesa de San Carlos in northwestern Baja California, Mexico (Stebbins 1985). In California, western spadefoot toads ranged throughout the Central Valley, and throughout the Coast Ranges and the coastal lowlands from San Francisco Bay southward to Mexico (Jennings and Hayes 1994).

***Current Distribution*.—**The western spadefoot toad has been extirpated throughout most of the lowlands of southern California (Stebbins 1985) and from many historical locations within the Central Valley (Jennings and Hayes 1994, Fisher and Shaffer 1996) (**Figure II-42**). According to Fisher and Shaffer (1996), western spadefoot toads have suffered a severe decline in the Sacramento Valley, and a reduced density of populations in the eastern San Joaquin Valley. Declines in abundance have been more modest in the Coast Ranges. This species occurs mostly below 900 meters (3,000 feet) in elevation (Stebbins 1985), but has been found up to 1,363 meters (4,500 feet) (Morey 1988). The average elevation of sites where the species still occurs is significantly higher than the average elevation for historical sites, suggesting that declines have been more pronounced in lowlands. Since 1996, approximately 146 new occurrences have been reported to the California Natural Diversity Data Base (2005), primarily in Riverside and San Diego Counties. Approximately 44 new occurrences were reported from the San Joaquin Valley and 8 from the Sacramento Valley. Additional sightings of the spadefoot, not reported to the California Natural Diversity Database, were made during 1998-1999 at the Coles Levee Ecosystem Preserve in Kern County (J. Jones pers. comm. 2005).

Three relatively recent sources of data have presented information regarding the current status and distribution of the western spadefoot toad. Jennings and Hayes

Table II-1. Western Spadefoot Toad Occurrence Information

County	Jennings and Hayes (1994)	Fisher and Shaffer (1996)	California Natural Diversity Data Base (2005)
Alameda	Extant	Extant	Extant
Amador	Extant	No Detection	No Data
Butte	Extant	No Detection	Extant
Calaveras	Extirpated	Extant	Extant
Colusa	No Data	No Data	Extant
Fresno	Extirpated	No Detection	Extant
Glenn	No Data	Extant	Extant
Kern	Extant	Extant	Extant
Kings	No Data	No Data	Extant
Los Angeles	Extirpated	No Data	Extant
Madera	Extant	Extant	Extant
Mariposa	Extant	No Data	No Data
Merced	No Data	Extant	Extant
Monterey	Extant	Extant	Extant
Orange	Extant	No Data	Extant
Placer	No Data	No Data	Extant
Riverside	Extant	No Data	Extant
Sacramento	Extant	Extant	Extant
San Benito	Extant	Extant	Extant
San Bernardino	Extirpated	No Data	No Data
San Diego	Extant	No Data	Extant
San Joaquin	Extant	No Detection	Extant
San Luis Obispo	Extant	Extant	Extant
Santa Barbara	Extant	Extant	Extant
Shasta	Extirpated	No Detection	No Data
Siskiyou	No Data	No Data	Extant
Stanislaus	Extant	Extant	Extant
Tehama	Extant	No Detection	Extant
Tulare	Extant	Extant	Extant
Ventura	No Data	No Data	Extant
Yolo	Extirpated	No Detection	Extant

(1994) examined 832 museum and sighting records from 346 locations and concluded that western spadefoot toads were extant in18 California counties and had been extirpated from 6 others. Fisher and Shaffer (1996) conducted field surveys of 315 sites in the Sacramento Valley, San Joaquin Valley, and Coast Ranges from 1990 to 1992. These surveys confirmed the presence of western spadefoot toads in 13 counties and failed to detect the species in an additional 8 counties. The California Natural Diversity Data Base (2005) lists 316 occurrences of western spadefoot toads from 27 counties. These records range from 1978 to 2005 and do not represent a systematic survey. The status of many of the sites recorded prior to 2000 where western spadefoot toads were observed is unknown. Many of these sites have not been revisited since the early 1990s and may no longer exist due to subsequent development. Some records were submitted by biological consultants who were conducting surveys on sites that were about to be developed. **Table II-1** below summarizes the collective findings of these three cited sources.

Western spadefoot toads have been recorded in 11 of the 17 vernal pool regions described by Keeler-Wolf *et al.* (1998). The species has been documented to co-occur with several other rare species, some of which are federally protected. Among the 316 locations for western spadefoot toads in the California Natural Diversity Data Base (2005), the following special status animals have been documented to co-occur: California tiger salamander, California red-legged frog (*Rana aurora draytonii*), vernal pool tadpole shrimp, vernal pool fairy shrimp, and California fairy shrimp.   Federally-listed plants covered in this plan that co-occur with the spadefoot toad include *Orcuttia inaequalis*, *Orcuttia pilosa*, *Castilleja campestris* ssp. *succulenta*, *Neostapfia colusana*, and *Chamaesyce hooveri*. Such co-occurrences provide an opportunity to conserve multiple species at one location.

c. Life History and Habitat

Food and Foraging.—Typical of toads, adult western spadefoot toads will forage on a variety of insects, worms, and other invertebrates. Morey and Guinn (1992) examined the stomach contents of 14 western spadefoot toads and found 11 different food items, including grasshoppers (order Orthoptera, family Gryllacrididae), true bugs (order Hemiptera), moths (order Lepidoptera, family Noctuidae and unidentified moths), ground beetles (order Coleoptera, family Carabidae), predaceous diving beetles (order Coleoptera, family Dytiscidae), ladybird beetles (order Coleoptera, family Coccinellidae), click beetles (order Coleoptera, family Elateridae), flies (order Diptera, family Heleomyzidae), ants (order Hymenoptera, family Formicidae), and earthworms (order Haplotaxida). Adult toads can consume 11 percent of their body mass during a single feeding bout, and Dimmit and Ruibal (1980) speculated that in only a few weeks, adults may be able to acquire sufficient energy for their long dormancy period (8 to 9 months).

The specific food habits of western spadefoot toad larvae are unknown. However, the larvae of southern and plains spadefoot toads consume planktonic organisms and algae, and also will scavenge dead organisms, including other spadefoot toad larvae (Bragg 1964). Larvae of plains spadefoot toads reportedly will prey on fairy shrimp (*e.g., Branchinecta* spp.) (Bragg 1962). Both adult and larval western spadefoot toads consume food items that also are used by other co-occurring amphibians (*e.g.,* Pacific tree frog [*Pseudacris* (*Hyla*) *regilla*], California tiger salamander, and western toad [*Bufo boreas*]) (Morey and Guinn 1992). Thus, some degree of resource competition may occur, depending upon the abundance of food resources.

***Reproduction and Demography*.**—Western spadefoot toads breed from January to May in temporary pools and drainages that form following winter or spring rains. Water temperatures in these pools must be between 9 degrees Celsius (48 degrees Fahrenheit) and 30 degrees Celsius (86 degrees Fahrenheit) for western spadefoot toads to reproduce (Brown 1966, 1967). Oviposition (egg laying) does not occur until water temperatures reach the required minimum of 9 degrees Celsius (48 degrees Fahrenheit) (Jennings and Hayes 1994). Depending on the temperature regime and annual rainfall, oviposition may occur between late February and late May (Storer 1925, Burgess 1950, Feaver 1971, Stebbins 1985). During breeding, highly vocal aggregations of more than 1,000 individuals may form (Jennings and Hayes 1994). Breeding calls are audible at great distances and serve to bring individuals together at suitable breeding sites (Stebbins 1985). Amplexus, the copulatory embrace by males, is pelvic (Stebbins 1985). Females deposit their eggs in numerous small irregularly cylindrical clusters of 10 to 42 eggs (average is 24) (Storer 1925), and may lay more than 500 eggs in one season (Stebbins 1951). Eggs are deposited on plant stems or pieces of detritus in temporary rain pools, or sometimes in pools of ephemeral stream courses (Storer 1925, Stebbins 1985).

Eggs hatch in 0.6 to 6 days depending on temperature (Brown 1967). At relatively high water temperatures (*e.g.*, 21 degrees Celsius [70 degrees Fahrenheit]), Storer (1925) noted that about half of the western spadefoot toad eggs failed to develop, possibly due to a fungus that thrives in warmer water and invades toad eggs. Larval development can be completed in 3 to 11 weeks (Burgess 1950, Feaver 1971) depending on food resources and temperature, but must be completed before pools dry. In eight vernal pools examined by Morey (1998), the average duration to complete larval development (hatching to metamorphosis) was 58 days (range 30 to 79 days). Metamorphosing larvae may leave the water while their tails are still relatively long (greater than 1 centimeter [0.4 inch]) (Storer 1925). Longer periods of larval development were associated with larger size at metamorphosis. Pools that persist for longer periods would permit longer larval development, resulting in larger juveniles with great fat reserves at metamorphosis (Morey 1998). These larger individuals have a higher fitness level and survivorship (Pfennig 1992). Annual reproductive success probably varies with precipitation levels, with success being lower in drier years (Fisher and Shaffer 1996). Recently metamorphosed juveniles emerge from water and seek refuge in the immediate vicinity of natal ponds. They spend several hours to several days near these ponds before dispersing. Weintraub (1979) reported that toadlets of plains spadefoot toads seek refuge in drying mud cracks, under boards, and under other surface objects including decomposing cow manure. Age at sexual maturity is unknown, but considering the relatively long period of subterranean dormancy (8 to 9 months), individuals may require at least 2 years to mature (Jennings and Hayes 1994).

Virtually no data are available on demographic values for western spadefoot toads. Long-term population dynamics, survival rates, reproductive success, and dispersal rates for western spadefoot toads are unknown. It is assumed that connectivity corridors between populations is essential for the conservation of metapopulations. Morey and Guinn (1992) reported that western spadefoot toad abundance appeared to remain stable from 1982 to 1986 at a vernal pool complex in Stanislaus County, California. Based on systematic collections of road-killed western spadefoot toads at this same site, the proportions of adults and juveniles were 70 percent and 30 percent, respectively, and the proportions of adult males and females were about equal.

***Behavior and Species Interactions*.**—Western spadefoot toads are almost completely terrestrial and enter water only to breed (Dimmitt and Ruibal 1980). However, typical of amphibians, western spadefoot toads require a certain level of moisture to avoid desiccation, which can be a challenge in the arid habitats occupied by the species. Spadefoot toads have behavioral and physiological adaptations that facilitate moisture retention.

During dry periods, spadefoot toads construct and occupy burrows that may be up to 0.9 meter (3 feet) in depth (Ruibal *et al.* 1969). Individuals may remain in these burrows for 8 to9 months. While in these burrows, individuals are completely surrounded by soil, and they appear to enter a state of torpor. Like all amphibians, western spadefoot toads have very permeable skin that allows them to absorb moisture from the surrounding soil. Spadefoot toads may retain urea to increase the osmotic pressure within their bodies, which prevents water loss to the surrounding soil and even facilitates water absorption from soils with relatively high moisture tensions (Ruibal *et al.* 1969, Shoemaker *et al.* 1969). Spadefoot toads appear to construct burrows in soils that are relatively sandy and friable as these soil attributes facilitate both digging and water absorption (Ruibal *et al.* 1969).

Spadefoot toads emerge from burrows to forage and breed following rains in the winter and spring. The factors that stimulate emergence are not well understood. In Arizona, spadefoot toads emerged after as little as 0.25 centimeter (0.1 inch) of precipitation, which barely wet the soil surface and obviously did not soak down to burrows (Ruibal *et al.* 1969). Sound or vibration from rain striking the ground appears to be the primary emergence cue used by spadefoot toads, and even the vibrations of a motor can cause toads to emerge (Dimmitt and Ruibal 1980). Spadefoot toads may move closer to the surface prior to precipitation and may even emerge to forage on nights with adequate humidity. Most surface activity is nocturnal. Morey and Guinn (1992) report that surface activity is related to both moisture and cooler temperatures following storms. Surface activity has been observed in all months from October to May (Morey 1988, Morey and Guinn 1992).

Above-ground activity is primarily nocturnal, presumably to reduce water loss. Even when exposed to artificial light, spadefoot toads will immediately move away or begin burrowing underground (Storer 1925, Ruibal *et al.* 1969). During the day, spadefoot toads dig and occupy relatively shallow burrows 2 to 5 centimeters (0.5 to 2 inches) in depth (Ruibal *et al.* 1969), and may even use small mammal burrows. In addition to breeding during periods of above-ground activity, spadefoot toads must acquire sufficient energy resources prior to reentering dormancy (Seymour 1973).

The role of predation on the population dynamics of western spadefoot toads is unclear. The extended dormancy period of adult and juvenile toads reduces their exposure to predators. Also, toxic secretions from dermal glands provide a significant deterrent to predators. Predators pose a much greater threat to larval western spadefoot toads. Larval toads are preyed upon by a variety of native predators, including waterbirds, garter snakes (*Thamnophis* spp.), and raccoons (*Procyon lotor*) (Childs 1953, Feaver 1971). According to Feaver (1971), western spadefoot toad larvae were preyed upon by California tiger salamander larvae whenever the two species co-existed in the same pools and the California tiger salamander larvae matured first. However, if western spadefoot toad and California tiger salamander larvae are the same size, no predation may occur (Anderson 1968).

Nonnative predators introduced within the range of western spadefoot toads include crayfish (order Decapoda), fish, and bullfrogs (*Rana catesbeiana*) (Hayes and Warner 1985, Hayes and Jennings 1986, Morey and Guinn 1992, Jennings and Hayes 1994, Fisher and Shaffer 1996). Nonnative fish, many of which are predatory, have been introduced for sportfishing and other purposes. These fish negatively affect native amphibians by preying upon eggs and larvae (Jennings 1988). In some locations, mosquito fish (*Gambusia affinis*) purposely introduced to control mosquitos also prey on western spadefoot toad eggs and larvae (Grubb 1972, Jennings and Hayes 1994, Fisher and Shaffer 1996). Nonnative species may also compete for resources with western spadefoot toads, thus potentially limiting their foraging success.

Introduced bullfrogs have been implicated in the declines of native amphibians (Moyle 1973, Hayes and Jennings 1986). Bullfrogs may not be significant predators of adult western spadefoot toads, although adults have been found in the stomachs of bullfrogs on at least two occasions (Hayes and Warner 1985, Morey and Guinn 1992). Bullfrogs may present more of a threat to larval western spadefoot toads. During dispersal between permanent water sources, juvenile bullfrogs will use temporary water sources (*e.g.*, vernal pools) as resting and feeding areas, which increases the potential for predation on western spadefoot toad larvae (Morey and Guinn 1992). Thus, bullfrogs are of concern regarding the conservation of western spadefoot toads.

Some significant ecological differences exist that may minimize interactions between bullfrogs and western spadefoot toads. Some spatial segregation may exist because bullfrogs may occur less frequently in the temporary wetlands (*e.g.*, vernal pools) used by western spadefoot toads. Also, western spadefoot toads increase activity in response to moisture and low temperatures following storms whereas bullfrogs increase activity in response to warmer temperatures prior to storms (Morey and Guinn 1992). Thus, some temporal segregation may occur as well. Nonetheless, some studies indicate that declining population trends may be associated with introduced predators, including bullfrogs (see general threats discussion in the Introduction section). At a site in Stanislaus County, California, western spadefoot toad abundance remained stable during 1982 to 1986 despite dramatic increases in bullfrog abundance during this same period (Morey and Guinn 1992).

***Habitat and Community Associations*.**—Western spadefoot toads are primarily a species of lowland habitats such as washes, floodplains of rivers, alluvial fans, playas, and alkali flats (Stebbins 1985). However, they also occur in the foothills and mountains. Western spadefoot toads prefer areas of open vegetation and short grasses, where the soil is sandy or gravelly. They are found in the valley and foothill grasslands, open chaparral, and pine-oak woodlands.

Western spadefoot toads require two distinct habitat components in order to meet life history requirements, and these habitats probably need to be in close proximity. Spadefoot toads are primarily terrestrial, and require upland habitats for feeding and for constructing burrows for their long dry-season dormancy. However, little is known regarding the distance that western spadefoot toads may range from aquatic resources for dispersal and estivation. As further discussed in the conservation strategy section, current research on amphibian conservation suggests that average habitat utilization falls within 368 meters (1,207 feet) of aquatic habitats (Semlitsch and Brodie 2003). Typical of amphibians, wetland habitats are required for reproduction. Western spadefoot toad eggs and larvae have been observed in a variety of permanent and temporary wetlands including rivers, creeks, pools in intermittent streams, vernal pools, and temporary rain pools (California Natural Diversity Database 2000), indicating a degree of ecological plasticity. However, it appears that vernal pools and other temporary wetlands may be optimal for breeding due to the absence or reduced abundance of both native and nonnative predators, many of which require more permanent water sources.

Western spadefoot toads have also exhibited a capacity to breed in altered wetlands as well as man-made wetlands. Western spadefoot toads, including eggs and larvae, have been observed in vernal pools that have been disturbed by activities such as earthmoving, discing, intensive livestock use, and off-road vehicle use. Western spadefoot toads, again including eggs and larvae, have also been observed in artificial ponds, livestock ponds, sedimentation and flood control ponds, irrigation and roadside ditches, roadside puddles, tire ruts, and borrow pits (Fisher and Shaffer 1996, California Natural Diversity Database 2000). This behavior again indicates a degree of ecological plasticity and adaptability. However, although western spadefoot toads have been observed to inhabit and breed in wetlands altered or created by humans, survival and reproductive success in these pools have not been evaluated relative to that in unaltered natural pools. In addition, at this time our knowledge of the land surface types that can be successfully traversed by western spadefoot toads is incomplete.

Based on calculations from upland habitat use data analyzed by Semlitsch and Brodie (2003), a minimum conservation area to preserve the ecological processes required for the conservation of amphibians may fall within a distance of approximately 368 meters (1,207 feet) from suitable breeding wetlands. Given a square preserve surrounding a single breeding pond, this estimate would suggest a minimum preserve size of approximately 54.2 hectares (134 acres). In any given western spadefoot toad metapopulation, we expect that some subpopulations will disappear, but the habitat they occupied will eventually be recolonized if it remains acceptable. To enable natural recolonization of unoccupied habitat, and to allow for gene flow that is vital for preventing inbreeding, opportunities for dispersal and interbreeding among subpopulations of the western spadefoot toad must be maintained. Where possible, habitat corridors between breeding sites should be protected and maintained.

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 the western spadefoot toad are described below.

Most habitat of the western spadefoot toad is not protected and those areas that are protected are relatively small and therefore still highly subject to external threats. This species likely suffered dramatic reductions in the mid to late 1900s when urban and agricultural development were rapidly destroying natural habitats in the Central Valley and southern California (Jennings and Hayes 1994). According to Jennings and Hayes (1994), over 80 percent of the habitat once known to be occupied by the western spadefoot toad in southern California (from the Santa Clara River Valley in Los Angeles and Ventura Counties southward) has been developed or converted to uses that are incompatible with successful reproduction and recruitment. In northern and central California, loss of habitat has been less severe, but nevertheless significant; it is estimated that over 30 percent of the habitat once occupied by western spadefoot toads has been developed or converted (Jennings and Hayes 1994). Regions that have been severely affected include the lower two-thirds of the Salinas River system, and much of the areas east of Sacramento, Fresno, and Bakersfield. Many of the remaining suitable rainpool or vernal pool habitats, which are concentrated on valley terraces along the edges of the Central Valley floor, have disappeared or been fragmented (Jennings and Hayes 1994).

Changes in vernal pool hydrology may adversely affect spadefoot toad populations. In particular, grazing may play an important role in maintaining vernal pool hydrology by decreasing the abundance of vegetation and therefore reducing evapotranspiration from the pools during the spring. In a study conducted in pools inhabited by spadefoot toads, Marty (2004) found that removal of grazing led to a reduction in the inundation period of the pools below the amount of time required by the toads to successfully metamorphose. Conversely, livestock may crush or even consume egg clusters while utilizing ponds and cause direct mortality to adult and juvenile toads through trampling. Continued use may deplete water levels from ponds, preventing complete metamorphosis of tadpoles or, in some cases, causing accelerated metamorphosis to occur which according to Morey (1998) may result in individuals that are less fit (J. Darren *in litt*., 2005).

Another reason for the population decline of the western spadefoot toad is the introduction of nonnative predators, specifically bullfrogs, crayfishes (*e.g., Procambarus clarkii*), and fishes (*e.g.*, mosquito fish) (Hayes and Warner 1985, Hayes and Jennings 1986, Fisher and Shaffer 1996). All of these were introduced into California in the late 1800s and early 1900s, and through range expansions, additional introductions, and transplants, these exotics have become established throughout most of the state. Fisher and Shaffer (1996) reported an inverse relationship between the presence of western spadefoot toads and that of nonnative predators. Additionally, nonnative predators may have displaced western spadefoot toads at lower elevations, resulting in the toads being found primarily at higher elevation sites where these predators apparently are less abundant (Fisher and Shaffer 1996). Fisher and Shaffer (1996) assessed native amphibian populations in the Coast Ranges, Sierra foothills, and Central Valley. They predicted that widespread declines of western spadefoot toads would occur if nonnative species continued to spread into low-elevation Coast Range habitats. However, in the San Joaquin Valley they found that relatively few nonnative predators were present, but native amphibians still had declined significantly. The San Joaquin Valley was the most intensively farmed and most modified of the three regions examined. It has been subject to extensive habitat loss, degradation, and fragmentation (U.S. Fish and Wildlife Service 1998*a*). Adverse impacts from these activities as well as isolation from other western spadefoot toad populations may have caused the observed declines. Discing the soil as a part of row-cropping and other forms of intensive agriculture are likely to cause mortality of western spadefoot toads in their underground burrows.

Roads represent an additional threat to the western spadefoot toad. Road construction can result in direct mortality of the western spadefoot toad, and can cause direct loss and fragmentation of habitat. Roads cause indirect loss of habitat by facilitating transportation and urban development, a major cause of habitat loss for the western spadefoot toad. Mortality of western spadefoot toads from motor vehicle strikes has been observed by multiple researchers (Morey and Guinn 1992, Jennings 1998, California Natural Diversity Database 2000), and appears to be both widespread and frequent. For instance, Jennings (1998) reported road mortality at all seven sites that he surveyed in Kings and Alameda

Counties. The impact of motor vehicle-caused mortality on populations of western spadefoot toads is unknown. Roads can be a barrier to movements and effectively isolate populations. Roads are significant barriers to gene flow among common frogs (*Rana temporaria*) in Germany, which has resulted in genetic differentiation among populations separated by roads (Reh and Seitz 1990). Similarly, Kuhn (1987, in Reh and Seitz 1990) determined that approximately 24 to 40 cars per hour on a given road resulted in mortality of 50 percent of common toads (*Bufo bufo*) attempting to migrate across the road. In another study, Heine (1987, in Reh and Seitz 1990) identified that 26 cars per hour resulted in 100 percent mortality of common toads attempting to cross a road. Vehicle traffic on dirt roads adjacent to breeding areas can also significantly impact spadefoot toads during certain times of year. Spadefoot toad metamorphs attempting to disperse across dirt roads have been killed, possibly because they often try to bury themselves in the road to avoid an approaching vehicle (J. Vance pers. comm. 2005).

Amphibians typically have complex life cycles and thus more opportunities for exposure to chemicals and more potential routes of exposure than other vertebrates. The western spadefoot toad is exposed to a variety of toxins throughout its range, but the sensitivity of this species to pesticides, heavy metals, air pollutants, and other contaminants is largely unknown. Each year, millions of kilograms (millions of pounds) of fertilizer, insecticides, herbicides, and fungicides are used on crops, forests, rights of way, and landscape plants in California. Some of these chemicals are extremely toxic to aquatic organisms such as amphibians and their prey. Industrial facilities and motor vehicles also release contaminants that may harm the western spadefoot toad. Contaminants from road materials, leaks, and spills also could adversely affect western spadefoot toads by contaminating the water in wetlands. Refer to Appendix E for a list of chemicals most likely to be harmful to the western spadefoot toad.

Activities that produce low frequency noise and vibration, such as grading for development and seismic exploration for natural gas, in or near habitat for western spadefoot toads, may be detrimental to the species. Dimmitt and Ruibal (1980) determined that spadefoot toads were extremely sensitive to such stimuli and would break dormancy and emerge from their burrows in response to these disturbances. Disturbances that cause spadefoot toads to emerge at inappropriate times could result in detrimental effects such as mortality or reduced fitness.

e. Conservation Efforts

The western spadefoot toad was a Category 2 candidate for listing in 1994 (U. S. Fish and Wildlife Service 1994*b*). Due to a change in policy regarding candidate species (U.S. Fish and Wildlife Service 1996*c*), western spadefoot toads are now considered a *species of concern*. Species of Concern are sensitive species that have not been listed, proposed for listing or placed in candidate status. "Species of concern" is an informal term used by some but not all U.S. Fish and Wildlife Service offices. Species of concern receive no legal protection and the use of the term does not necessarily mean that the species will eventually be proposed for listing as a threatened or endangered species. The western spadefoot toad was designated a species of special concern by the State of California in 1994 (Jennings and Hayes 1994, California Department of Fish and Game 1998).

A number of sites with suitable habitat for western spadefoot toads are already being protected through National Wildlife Refuges, National Monuments, State Parks, State Ecological Reserves, private preserves, mitigation banks, and conservation easements. Specific protected sites where the presence of western spadefoot toads has been confirmed include the Kesterson Unit of the San Luis National Wildlife Refuge (Merced County), the Arena Plains Unit of the Merced National Wildlife Refuge (Merced County), the Carrizo Plain National Monument (San Luis Obispo County), a reserve for the endangered Stephens' kangaroo rats (*Dipodomys stephensi*) at March Air Force Base (Riverside County), Corral Hollow State Ecological Reserve (San Joaquin County), Allensworth State Ecological Reserve (Tulare County), Stone Corral State Ecological Reserve (Tulare County), the Center for Natural Land Management's Pixley Vernal Pool Preserve (Tulare County), The Nature Conservancy's Simon-Newman Ranch (Stanislaus County), Mather Regional Park (Sacramento County), the Howard Ranch protected with a conservation easement (Sacramento County), Casper Regional Park (Orange County), two Caltrans mitigation sites (Madera County), and private habitat mitigation sites in Sacramento, Placer, and Merced Counties. Western spadefoot toad observations have also been reported from Camp Roberts and Fort Hunter Liggett Military Reservations (San Luis Obispo and Monterey Counties), Naval Air Station Lemoore (Kings County), and a site owned by the California State University - Fresno (California Natural Diversity Database 2000), and at Coles Levee Ecosystem Preserve (Kern County) (J. Jones pers. comm. 2005). These locations on public lands present conservation opportunities for the species. Some conservation measures have already been implemented at Camp Roberts and Fort Hunter Liggett. The western spadefoot toad is also included for conservation under several habitat conservation plans currently in existence or under development. Additionally, 23 vernal pool species are now federally protected including 18 plants and 5 animals. This protection will result in habitat conservation and management efforts that will contribute to the conservation of western spadefoot toads.