

C. Federally Listed Animal Species

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

a. Description and Taxonomy

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

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

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

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

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

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

b. Historical and Current Distribution

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

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



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

c. Life History and Habitat

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

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

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

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

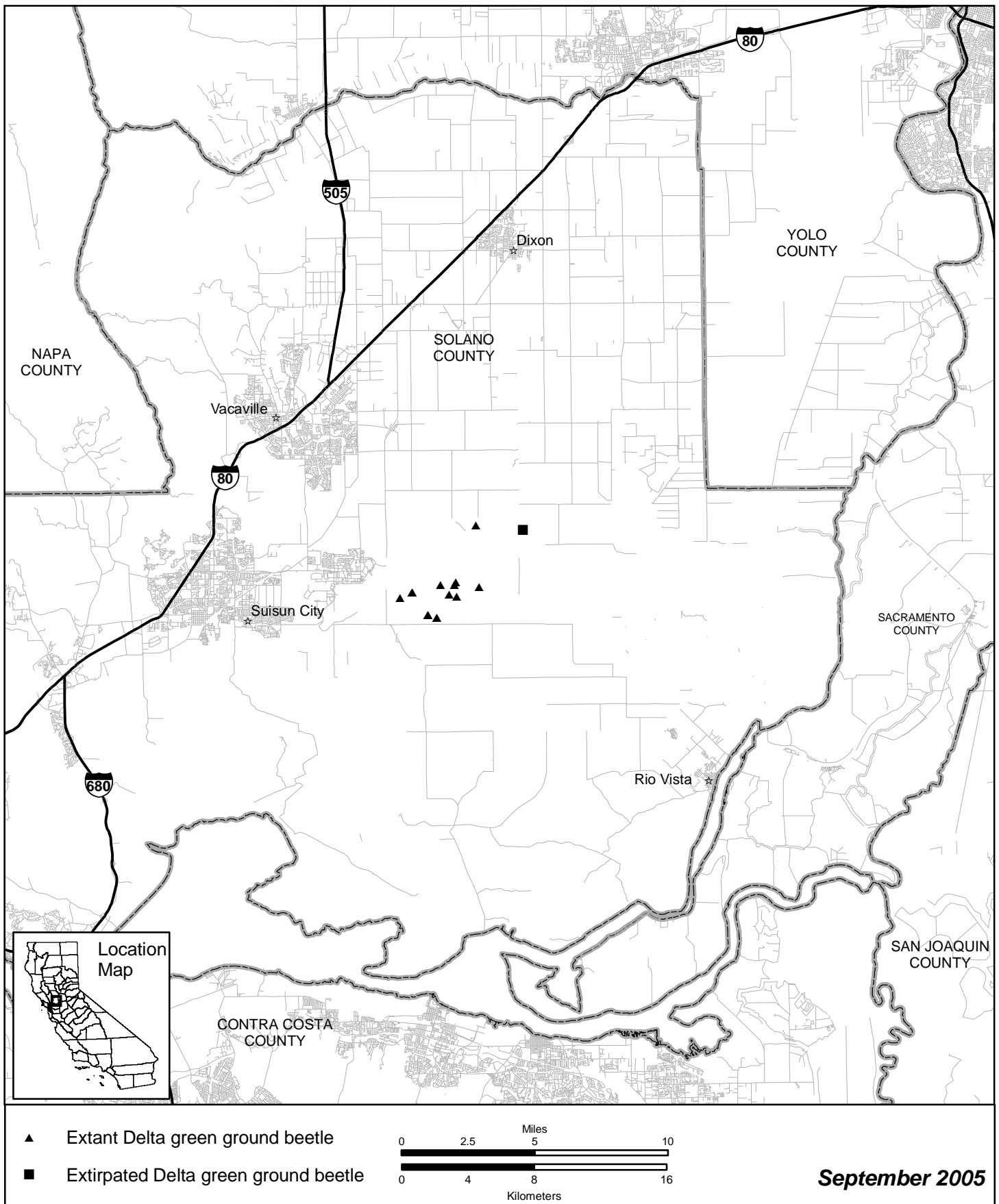


Figure II-34. Distribution of Delta green ground beetle (*Elaphrus viridis*).

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

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

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

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

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

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

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

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

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

Serpa (1985) observed golden-haired dung flies (*Scatophaga stercoraria*), a sallow 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 1985a), 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 repropoed (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.).