Vernal Pool Fairy Shrimp

(Branchinecta lynchi)

Legal Status
Federal: Threatened.

State: None.

Global and State Conservation Status: G2G3S2S3: Global Rank, G2G3 somewhere between a G2 = Imperiled: At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors and a G3 = Vulnerable: At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors. State Rank, S2S3 = Same as global ranks but only for the range of taxa within California.

Recovery Plan: Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005).

Species Description and Natural History

The vernal pool fairy shrimp is a typical Branchinectid anostracan. They are typically off-white to grey. Depending on the rapidity of development, mature animals may vary in length from 3 to 38 mm (0.12 to 1.50 in).

The female is characterized by smooth second antennae, with no cephalic (on or near the head) ridges or cornices, and a thoracic surface with paired projections on the third and fifth to eleventh segments, as well as a pair of conical projections on the fourth segment. The brood pouch is pear-shaped and may be green or yellow (Eng et al. 1990; Rogers 2002c).

The basal fourth of the male vernal pool fairy shrimp's second antennal proximal segment bears an anteriomedial pulvillus (soft cushion-like pad) and a posteriobasal transverse ridge-like apophysis (natural swelling, projection, or outgrowth of an organ) (Eng et al. 1990, Eriksen and Belk 1999). The medial surface of the distal third of the proximal second antennal segment has a small sparsely spined tubercle (small, rounded projection).

Vernal pool fairy shrimp commonly co-occur with the California linderiella fairy shrimp (*Linderiella occidentalis*) (Eriksen and Belk 1999). This species has also been reported co-occurring with the mid-valley fairy shrimp (*Branchinecta mesovallensis*) (Belk and Fugate 2001) on three occasions, where the mid-valley fairy shrimp was probably washed

into the vernal pool fairy shrimp habitat by abnormally high rainfall (Eriksen and Belk 1999). Other species of *Branchinecta* (*B. lindahli, B. coloradensis, B. mackini, B. mesovallensis, B. conservatio,* and *B. longiantenna*) occur within the range of the vernal pool fairy shrimp but are typically found in different, although similar, habitats (Rogers 2002a).

During the dry phase of their habitat, the anostracans survive as diapausing (period of suspended growth or development) embryonated cysts in and on the substrate (Sars 1896, 1898; Eriksen and Belk 1999; Rogers and Fugate 2001). When the habitat inundates from seasonal rainfall, some of the cysts hatch, and the nauplii (early larval form of anostraca) swim into the upper water column (Eriksen and Belk 1999). These larval forms are typically indistinguishable between species.

The maturation rates of the vernal pool fair shrimp vary extensively, depending on temperature and habitat (Gallagher 1996, Helm 1998, Eriksen and Belk 1999, Rogers 2002a). Gallegher (1996) and Helm (1998) reported the vernal pool fairy shrimp as reaching maturity in 14 and 18 days, respectively when reared at an optimal 20 degrees Celsius (68 degrees Fahrenheit); however, Rogers observed this species reaching maturity in as little as 6 days under high temperatures. 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). In the genus *Branchinecta*, the brood pouch is truncate and as wide as the thoracic genital segments. However, when oocytes (unfertilized eggs) are present in the lateral pouches, the brood pouch is wider than the genital segments, forming an amplexial groove, and males can amplex (grasp for copulation) the female successfully. If the oocytes are not present in the lateral pouches, the female is sometimes able to escape the male's grasp (Rogers 2002b). Males approach the females from beneath to amplex. Amplexus is sustained for 1 or 2 seconds, as mating is rapid; and the female is released immediately afterward (Rogers 2002b). The female typically sheds her cysts as the shell forms over the fertilized oocyte (Murugan et al. 1996), and the cysts fall to the substrate.

The cysts lay dormant in the substrate until the pool dries and re-inundates during the subsequent rains. Beyond inundation of the habitat, the specific cues for hatching are unknown, although temperature (e.g., Hall 1959, Belk 1977, Al-Tikrity and Grainger 1990, Belk and Nelson 1995, Eriksen and Belk 1999) and conductivity (e.g., Anderson 1958; Bowen *et al.* 1988; Broch 1969, 1988; Brown and Capelan 1971; Brown 1972) are believed to play a large role. The vernal pool fairy shrimp is typically univoltine (i.e., one generation per year); however, animals of different ages may be present if a pool partially inundates, allowing some cysts to hatch, and then later increases in volume, hydrating cysts that were further upslope.

Planktonic Crustacea are important in the food web, as they represent a high-fat, high-protein resource for migratory waterfowl. Mallard (*Anas platyrhynchos*), green-winged teal (*A. crecca*), bufflehead (*Bucephala albeola*), greater yellowlegs (*Tringa melanoleuca*), and killdeer (*Charadrius vociferus*) all forage actively in Central Valley

vernal pools on the invertebrate and amphibian fauna during the winter months (Proctor 1964, Horne 1966, Mellors 1975, Silveira 1996, Dumont and Negrea 2002).

Predator consumption of fairy shrimp cysts aids in distributing populations of fairy shrimp. Predators (e.g., birds and amphibians) expel viable cysts in their excrement, often at locations other than where they were consumed (e.g., Proctor 1964, Wissinger *et al.* 1999). If conditions are suitable, these transported cysts may hatch at the new location and potentially establish a new population. Cysts are also transported by wind and in mud carried on the feet of animals, including livestock that may wade through habitat (Rogers in prep.). This type of dispersal aids ephemeral pool crustaceans in exploiting a wide variety of ephemeral habitats (Rogers 2000).

Habitat Requirements and Ecology

This species is entirely dependent on the aquatic environment provided by vernal pool wetland ecosystems. The vernal pool fairy shrimp depends on the presence of water in winter and early spring, and the absence of water during summer. These specific vernal pool wetlands are dependent on intact sub-watersheds and the surrounding uplands that support those watersheds. Vernal pool habitat is a component of the larger grassland ecosystem of California's Central Valley.

The vernal pool fairy shrimp requires cold winter waters to hatch and grow—typically appearing after the first frosts, and the dry summers to dry the resting cysts and prevent them from fungusing. Habitats supporting the vernal pool fairy shrimp are typically in Central Valley California floristic provinces below 300-m (984-ft) elevation. Typical habitat for vernal pool fairy shrimp in California includes vernal pools, seasonally ponded areas within vernal swales, rock outcrop ephemeral pools, playas, and alkali flats (Eng et al. 1990). Vernal pool fairy shrimp have also been found in water pooled in sandstone outcrops and in alkaline vernal pools. Vernal pools that support these fairy shrimp are often grass or mud-bottomed, with clear to tea-colored water, and are often in basalt flow depression pools in grasslands (USFWS 1994, Eriksen and Belk 1999).

Pool volume is important in determining potential shrimp habitat because deeper pools with a large surface area can more easily maintain their dissolved oxygen levels. Similarly, deep pools will pond long enough to allow the shrimp to complete their life cycle. Vernal pool fairy shrimp have been found in pools ranging from 0.04 to 0.61 ha (0.1 to 1.5 acres) (Eriksen and Belk 1999); however, most occupied sites described by Helm (1998) and Gallagher (1996) were small pools (<0.05 acre).

Various physiochemical factors have been examined in existing vernal pool fairy shrimp habitats including alkalinity, total dissolved solids (TDS), and pH (Keely 1984, Collie and Lathrop 1976, Eriksen and Belk 1999). The USFWS (1994) described the water in pools occupied by vernal pool fairy shrimp as having low conductivity and chloride; however, specific data were not provided. Eriksen and Belk (1999) presented a range of attributes measured by different workers, reporting alkalinity ranging from 22 to 274 parts per million (ppm), TDS of 48 to 481 ppm, and pH ranging from 6.3 to 8.5 in

occupied habitats. However, the importance of many of these parameters has recently been called into question with recent evidence that the type and amount of dissolved salts may be a more important habitat requirement (Rogers 2002a). During the daylight hours, the hydrophytes are photosynthesizing, removing the CO_2 (from HCO_3) from the water, and raising the pH. During the night, the hydrophytes are respiring, increasing the CO_2 (and thereby, the HCO_3) in the water, and lowering the pH. If there is rainfall, the distilled precipitation will lower the pH, as will winds that cause surface action. When the habitats are drying and losing volume through evaporation, the pH, alkalinity, TDS, and electrical conductivity will increase, just as they decrease when the pools inundate or reinundate (Rogers 2002a).

Some vernal pools need a certain amount of grazing. Vernal pools from which all grazing has been removed become overgrown with native and exotic plants that generate deep thatch layers on the pool substrate, unless some other disturbance (i.e., weed control programs, vehicular use of pools, fire fuels control) prevents thatch deposition. As this thatch layer decomposes, it also oxidizes the water, which can suffocate gill-breathing invertebrates (Rogers 1998). Therefore, moderate grazing may be a necessary habitat suitability component. Conversely, excessive livestock grazing can be detrimental to vernal pool fairy shrimp. High stocking rates tend to deposit a great deal of manure into vernal pools. The organic waste oxidizes the water, leaving the gill-breathing invertebrates like the vernal pool fairy shrimp without oxygen (Rogers 1998). It is important not to alter grazing regimes in conservation areas until the importance of grazing to those particular systems are assessed.

Common wetland plant species that co-occur with vernal pool shrimp species generally need the same hydrological conditions. Therefore, the presence of these plant species within a potential habitat implies a greater potential for a population of these shrimp to be present. These plants may include: toad rush (*Juncus bufonius*), coyote thistle (*Eryringium* spp.), downingia (*Downingia ornatissma* or *bicornuta*), goldfields (*Lasthenia* spp.), woolly-marbles (*Psilocarphus* spp.), and hair grass (*Deschampsia* spp.).

Similarly, the hydrology of pools that are dominated by vernal pool plant species that require short inundation periods may not support shrimp species. These plants may include Mediterranean barley (*Hordeum murinum*), toad rush, false dandelion (*Hypochoeris. radicata*), and Italian rye grass (*Lolium multiflorum*).

Conversely, wetland habitats that support plant species that need water year round cannot support special-status shrimp species because the shrimp's cysts must dry out before they can hatch (Eriksen and Belk 1999). If they remain wet or moist through the warmer summer months, the cysts will fungus. These plants include cattails (*Typha* spp.), willow (*Salix* spp.), cottonwood (*Populus* spp.), duckweed (*Lemna* spp.), nut grass (*Cyperus* spp.), Baltic rush (*Juncus balticus*), and bulrush (*Schenoplectus* spp.).

The vernal pool fairy shrimp is a component of a larger invertebrate community structure (Rogers 1998). This invertebrate community includes mostly planktonic Crustacea dependent on temporary wetlands, including copepods, cladocerans, and ostracodes—as

well as flatworms and a suite of insect species, including vernal pool haliplid beetle (*Apterliplus parvulus*), scimitar backswimmers (*Buenoa scimitra*), Ricksecker's hydrochara (*Hydrochara ricksecker*i), and many others (Rogers 1998). These habitats are usually low in opportunistic species like mosquitoes and chironomid midges in the genus *Chironomus* (Rogers 1998). Therefore, potential vernal pool fairy shrimp habitat is defined as vernal pools and seasonal wetlands of sufficient size (depth and area) and seasonality that may also support specific vegetation and invertebrate community structure that indicate the potential for ponding for a sufficient duration to allow vernal pool shrimp species to complete their life cycles and to maintain water temperatures conducive to the species.

Optimal vernal pool fairy shrimp habitat tends to be neutral to slightly alkaline, clear vernal pools that are low in dissolved salts, dominated with vernal pool plants, and sustain a complex vernal pool invertebrate community (Eriksen and Belk 1999; Rogers 1998, 2002a). Unfortunately, little effort has been made to accurately quantify these parameters.

As objects of prey for birds, vernal pool fairy shrimp are an intermediate host for avian cestodes (tapeworms) (Rogers 2002a). Anostracans that are hosting a cestode tend to be bright pink in color. The change in color is due to the presence of cestode cysticercoids (intermediate life stage). The parasitic tapeworm castrates the host, which causes the host animal to accumulate lipids (probably linked to carotenoid pigments) that would otherwise be expended by the host during reproduction (Amat *et al.* 1991).

No specific bacterial, viral, or protozoan diseases have been reported for the vernal pool fairy shrimp. Occasionally, specimens with black markings or lesions will appear in collections. These black markings, sometimes referred to as "black disease", are actually evidence of the normal immune response of all Crustacea to any bacteria (Bang 1983). Branchiopod crustaceans are commonly found with phoretic ciliate protozoan colonies around the mouth and posterioventral portions of the head, which are abandoned with the exuvia by the crustacean with each molt.

Species Distribution and Population Trends

Distribution

There are more than 40 species of *Branchinecta* world-wide (Belk and Brtek 1995, 1997; Rogers and Fugate 2001; Belk and Rogers 2002) distributed throughout the Holarctic and Neotropical regions, with one species ranging into the Antarctic. The vernal pool fairy shrimp is endemic to Oregon and California (Eng *et al.* 1990, Eriksen and Belk 1999).

In North America, Dr. G. Eisen made the earliest collections of the vernal pool fairy shrimp at "San Francisco" in 1874 (Lilljeborg 1889, Linder 1941), although they were misidentified as *Branchinecta coloradensis* (Eng *et al.* 1990). Linder (1941) used Eisen's misidentified material for his sketch of *B. coloradensis*; the vernal pool fairy shrimp is clearly pictured on page 191 of Linder's definitive monograph of the Anostraca.

The vernal pool fairy shrimp is found in California from the Redding/Bella Vista area of Shasta County in the north, throughout the Central Valley, and west to the central Coast Ranges, and from northern Solano County to Pinnacles National Monument in San Benito County. Disjunct occurrences were also reported to occur in San Luis Obispo County, Santa Barbara County, and Riverside County. A disjunct population(s) has been reported in Jackson County near Medford, Oregon (Eng *et al.* 1990, USFWS 1994, 2007, Eriksen and Belk 1999).

In 1994, the U.S. Fish and Wildlife Service (USFWS) reported 32 known occurrences of vernal pool fairy shrimp in California, ranging from the Stillwater Plain in Shasta County through most of the length of the Central Valley to Paisley in Tulare County. Since then, vernal pool fairy shrimp have been reported from throughout Sacramento, Colusa and Glenn Counties; the Central Valley portions of Tehama, Butte, Sutter, Yuba, Placer, Stanislaus, Madera, Fresno, and Tulare Counties on the east side of the valley (Eriksen and Belk 1999); and Alameda, Solano, Yolo, Colusa, and Glenn Counties on the west side (Eriksen and Belk 1999, USFWS 2007). In Yolo County the vernal pool fairy shrimp has been reported from vernal pools in the Yolo Bypass along the Sacramento Northern Electric Railroad Grade southwest of Saxon; on the campus of D-Q University northwest of Davis, and in the vicinity of the Winters (CNDDB 2008).

Habitat occupied by fairy shrimp tends to exist on level open ground. This geomorphic setting also tends to be the most desirable for agricultural, urban, or industrial development. As a result, the grassland plateaus and floor of the Central Valley have been broadly converted by human use.

Population Trends

In North America, an unknown amount of vernal pool habitat and vernal pool fairy shrimp occurrences has been lost; however, attempts have been made to calculate lost vernal pool acreages (e.g., Holland 1978, 1988, 1998; Bauder and McMillan 1998). Due to current pressures of the increasing human populations in California and Oregon, more vernal pool fairy shrimp habitat is being encroached on and affected throughout the species' range.

The existence of recently discovered occurrences near Medford, Oregon (Eriksen and Belk 1999) may indicate other undiscovered occurrences between Shasta County, California and Medford. In California, an adequate determination of remaining vernal pool fairy shrimp occurrences throughout the animal's range as well as population trends is difficult. The USFWS (1994) listed 32 known occurrences of the vernal pool fairy shrimp. These data were collected during a prolonged drought in California. Sugnet and Associates (1993) submitted a study claiming 178 "discrete locations" supporting the vernal pool fairy shrimp; however, as specific localities were not divulged, the data are unverifiable and therefore not scientifically useful in an analysis. Eriksen and Belk (1999) presented a map of localities for the vernal pool fairy shrimp with more than 200 localities represented, with the greatest density of occurrences in Sacramento County. In

2007, CNDDB reported 558 occurrences in California with a similar distribution as reported in Ericksen and Belk (1999) (CNDDB 2007, USFWS 2007).

The CNDDB vernal pool crustacean records (2005) may be somewhat misleading, due to the inconsistency of the data presented. Some records refer to individual pools, while others refer to pool complexes, and others still refer to groups of complexes. Additionally, the CNDDB is not updated when a particular site or population is extirpated. Because of these issues, it is difficult to determine what actually constitutes a population or occurrence.

In addition, survey maps and records tend to show where vernal pool crustaceans are located and do not emphasize where they are not located. Compounding these difficulties, records are typically a reflection of where surveys have been conducted, rather than a delineation of vernal pool fairy shrimp distribution. Therefore, it is difficult to establish baseline conditions for this species across the entire species range, as well as within the Plan Area. Where adequate data do not exist, consistent data reporting would help to prevent ambiguous interpretation or mischaracterization of species conservation needs.

Threats to the Species and Other Conservation Issues

The Species Survival Commission of The International Union for Conservation of Nature and Natural Resources (IUCN) lists the vernal pool fairy shrimp as VU A2c (IUCN 2000). This means that the species is vulnerable, and a population reduction of at least 80 percent is suspected or projected within the next 10 years, based on a decline in area occupancy, extent of occurrence, or quality of habitat. As described previously, the greatest threat to vernal pool invertebrates is the elimination, loss, or modification of their habitat by agricultural conversion or ongoing agricultural practices and urban development. Filling of vernal pools or modification of the watershed that supports those pools eliminates the habitat and disrupts the pool ecosystem. Opportunistic invertebrate species and invasive, opportunistic, non-native plants further degrade adequate habitat. (Rogers 1998.)

Excessive livestock grazing in vernal pool terrain can be detrimental to vernal pool invertebrate communities. High stocking rates tend to allow a great deal of manure into vernal pools. The organic waste oxidizes the water, leaving gill-breathing invertebrates without oxygen (Rogers 1998). Conversely, vernal pool grasslands are disturbance systems and need a certain amount of grazing. Vernal pools from which all grazing has been removed may become overgrown with native (i.e., spikerush [*Eleocharis* spp.], coyote thistle [*Eryngium* spp.]) and exotic (i.e., manna grass [*Glyceria declinata*], Italian rye grass, etc) plants that generate deep thatch layers on the pool substrate. As this thatch layer decomposes, it also oxidizes the water, which can suffocate gill-breathing invertebrates (Rogers 1998). Both lack of grazing and excessive grazing cause an increase in organic matter in the habitat that eliminates the natural vernal pool invertebrate community, and promotes opportunistic and invasive species that constrain the obligatory vernal pool species (Rogers 1998). Therefore, moderate grazing or other

disturbance may be a necessary habitat element, and the removal of grazing or excessive grazing are threats to the vernal pool fairy shrimp.

Damage to the watershed that supports vernal pools and vernal pool complexes will affect vernal pool invertebrate communities. Elimination of the watershed will not allow the pools to pond properly and will curtail the movement of nutrients into the pool from overland flow (Rogers 1998). Road run-off entering the watershed and conveyed to occupied pools may carry petroleum by-product residue or sediment from vehicles from paving or road maintenance activities. Furthermore, pesticide, herbicide, fertilizer, and sediment run-off from agricultural activities that may enter the watershed and occupied habitat may be injurious to vernal pool invertebrates. Finally, ground disturbance from development activities loosens soil that may enter the watershed and be conveyed to vernal pool habitat.

Non-native invasive species are also a threat to vernal pool invertebrate communities. There is concern that bullfrogs (*Rana catesbeiana*) may feed on federally protected vernal pool crustaceans (Balfour and Morey 1999). Manna grass and Italian rye grass are both exotic vernal pool plants that tend to produce heavy thatch and organic loads upon decomposition, which oxidize the water (Rogers 1998). In addition, people may introduce the non-discriminating predatory mosquitofish (*Gambusia affinis*) into vernal pools to control perceived local mosquito problems.

Habitat fragmentation is a threat to vernal pool invertebrates by preventing waterfowl or shorebirds from feeding at the pools, and thus preventing genetic flow between occupied habitats. Furthermore, small pool complexes surrounded by development may not be buffered against the run-off from developed areas and concomitant changes in the watershed hydrology.

Additional threats to the vernal pool invertebrate community structure include off-road vehicle use of vernal pool habitat for recreational mud-bogging, conversion of vernal pools into deep stock tanks that do not dry during summer, and draining of vernal pools.

The primary data gap regarding conservation of vernal pool invertebrates lacks distributional data for the species within and adjacent to the Plan Area. It is not feasible, economically or temporally, to survey the entire Plan Area; therefore species models have been developed to estimate vernal pool fairy shrimp distribution through aerial photographic interpretation. Some specific areas will need to be physically verified as to whether they support potential vernal pool fairy shrimp habitat. Artificial habitats like railroad toe-drains, stock tanks, and roadside scrapes also will need to be field verified. In addition, quantitative bioassessment may be necessary to determine the ecological functions and values of selected preserve area vernal pools in order to assess their suitability and value as preservation habitats. Management data gaps include the role of the surrounding uplands in vernal pool habitats and the role, seasonality, and intensity of grazing and other disturbances in vernal pool ecosystems.

Acreages of potential vernal pool fairy shrimp habitat within the Plan Area are unknown at this time. In addition, areas to be specifically set aside for preservation have not been identified. There must be an overall net gain of occupied vernal pool fairy shrimp habitat within the Plan Area, with specific preserve areas encompassing optimal habitat, and protection and management as appropriate in perpetuity. Rare, threatened, and endangered species are indicator organisms of imperiled habitat. Compensation habitat should reflect any vernal pool habitat for the vernal pool fairy shrimp. Impacts to vernal pool fairy shrimp within the Plan Area should be greatly minimized through acquisition of prime occupied habitats for this and other interdependent vernal pool species.

Guidelines in selecting vernal pool habitat for conservation of the vernal pool fairy shrimp and other vernal pool-dependent organisms should consider the following general principals:

- Vernal pools are not independent microcosms. Active movement of organisms occurs between adjacent pools within complexes, between adjacent complexes, and between distant complexes (e.g., Amat *et al.* 1991; Eng *et al.* 1990; Eriksen and Belk 1999; Proctor 1964; Rogers 1998, in prep.; Rogers and Fugate 2001; Wissinger *et al.* 1999).
- Vernal pools are dependent on the surrounding topography (which may be mound-intermound) as a watershed.
- Vernal pools selected for conservation must exhibit the same biological and geomorphological functions as the habitat being compensated for (e.g., pools occurring on Mehrten formations tend to be very shallow, and cannot be used to replace deeper pools occurring on other landforms.
- Unimpaired vernal pools exhibiting a diverse invertebrate and botanical community are desirable as compensation for artificial habitat (such as a railroad toe-drain that supports vernal pool fairy shrimp but no other vernal pool invertebrates or plants).
- Vernal pool habitat comprises a spectrum of variation, including pools that are shallow, deep, of long ponding duration, of short ponding duration, of varying densities, occurring on various geomorphic surfaces and different soil types, and supporting various invertebrate and plant communities. It is imperative to preserve the greatest range of variation and attributes within vernal pool complexes to reflect the diversity of vernal pool habitats.
- Vernal pools within complexes tend to vary broadly between geomorphy, area, depth, botanical community structure, invertebrate community structure, and vertebrate use. Therefore, restored or constructed vernal pool habitats must reflect the diversity of natural, adjacent, unimpaired reference systems.
- No estimates are currently available regarding the minimum self-sustaining population size, vernal pool size, or habitat complex size for vernal pool fairy shrimp, or other vernal pool organisms. The estimated loss of extant habitat (e.g., Holland 1978, 1988, 1998; Bauder and McMillan 1988) suggests that these species need the maximum amount of available habitat.

- Vernal pools are systems that require participation from all aspects of the floristic and faunistic community, including vertebrates. To ensure success, moderate, managed grazing is needed (see discussion above under "Habitat Requirements and Ecology").

Restoration and creation of vernal pool fairy shrimp habitat have been demonstrated to be feasible (e.g., Rogers 1998). However, specific habitat parameters for this and other vernal pool invertebrate species are still poorly understood. For example, this species appears to require a minimum pool volume and a minimum pool surface area within a given habitat to be occupied. Because the species has been found in a wide variety of natural and artificial vernal pool habitats, it is likely that it is an opportunist, a common trait among temporary water fauna.

A habitat suitability summary and preliminary draft model for the vernal pool fairy shrimp are provided below. The model predicts there are 1,054 ha (2,604 acres) of suitable habitat for vernal pool fairy shrimp in Yolo County. The preliminary draft models may be refined during future phases of the NCCP/HCP program to incorporate additional parameters or new data.

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