

Midvalley Fairy Shrimp (*Branchinecta mesovallensis*)

Legal Status

Federal: None.

State: None.

Global and State Conservation Status: G2S2: Global Rank, G2 = Imperiled: At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors. State Rank, S2 = Same as global rank but referring only to range of taxa in California.

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

*The midvalley fairy shrimp meets the Species Survival Commission of The International Union for Conservation of Nature and Natural Resources (IUCN) criteria 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.

Species Description and Life History

The midvalley fairy shrimp (*Branchinecta mesovallensis*) is a typical Branchinectid anostracan. Live animals are typically off-white to grey, although the brood pouch may be green or yellow. Depending on the rapidity of development, mature animals may vary in length from 3 to 38 mm (0.12 to 1.5 in). The species may shrink as much as 11 to 32 percent upon preservation (Rogers 2002b).

Midvalley fairy shrimp commonly co-occur with California fairy shrimp (*Linderiella occidentalis*) (Eriksen and Belk 1999, Rogers in review). This species has also been reported co-occurring with the vernal pool fairy shrimp (*Branchinecta lynchi*) (Eng *et al.* 1990) on three occasions, where the midvalley 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. lynchi*, and *B. conservatio*) occur within the range of the midvalley fairy shrimp but are typically found in different, although similar, habitats (Rogers in review).

During the dry phase of their habitat, the anostracans survive as diapausing cysts (resting eggs) 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 species vary extensively, depending on temperature and habitat type (Helm 1998, Eriksen and Belk 1999, Rogers in review), and the midvalley fairy shrimp can reach maturity in as little as 4 days (Rogers in review). In the genus *Branchinecta*, the brood pouch is truncate and is 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, allowing the males to amplex (hold the female prior to mating) the female successfully. If the oocytes are not present in the lateral pouches, the female is 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 lie 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, Helm 1998, Eriksen and Belk 1999, Rogers in review) and conductivity (e.g., Anderson 1958; Broch 1969, 1988; Brown and Capelan 1971; Brown 1972; Bowen *et al.* 1988) are believed to play a large role. 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).

The midvalley 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 midvalley 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 the California's Central Valley.

The midvalley fairy shrimp needs the cold winter waters to hatch and grow—typically appearing after the first frosts, and the dry summers to dry the resting cysts to prevent them from fungusing. Habitats supporting the midvalley fairy shrimp are typical in Central Valley floristic provinces below 300-m (984-ft) elevation. Typical habitat for midvalley fairy shrimp in California includes vernal pools and seasonally ponded areas within vernal swales (Eng *et al.* 1990). 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 (Eriksen and Belk 1999).

Midvalley fairy shrimp have been found in habitats ranging from 0.0004 to 0.2 ha (0.001 to 0.5 acre) and typically is found in smaller, short-lived pools and other seasonal wetlands compared with other species within the same genus (Eriksen and Belk 1999).

Various physiochemical factors have been examined in laboratory experiments and existing midvalley fairy shrimp habitats, including alkalinity, total dissolved solids (TDS), and pH (Rogers in review). The importance of many of these parameters has recently been called into question with evidence that the type and amount of dissolved salts may be a more important habitat requirement. Considering the daily fluctuations in pH of a given habitat, this is to be expected. During daylight hours, hydrophytes are photosynthesizing, removing the CO₂ (from HCO₃) from the water, and raising pH. During the night, hydrophytes are respiring, increasing the CO₂ (and thereby, the HCO₃) 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, pH, alkalinity, TDS, and electrical conductivity will increase, just as they decrease when the pools inundate or reinundate.

Some vernal pools need a certain amount of grazing. Unless some other disturbance (i.e., weed control programs, vehicular use of pools, fire fuels control) prevents thatch deposition, 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. As this thatch layer decomposes, it 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 midvalley 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 midvalley 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 midvalley fairy shrimp 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 (*Eryngium* spp.), downingia (*Downingia ornatissima* 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 (*Scirpus* spp.).

Midvalley fairy shrimp are 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 rickseckeri*), 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 midvalley 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 species to complete their life cycles. Optimal midvalley fairy shrimp habitat tends to be small, with an abbreviated hydroperiod, 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, in review).

As prey items of birds, midvalley fairy shrimp are an intermediate host for avian cestodes (tapeworms) (Rogers in review). Anostracans that are hosting a cestode tend to be bright pink in color. The change in color is due to the presence of cestode cysticercoides (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 midvalley 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, where any foreign bacteria is infused with melanin to lethal levels (Bang 1983). Branchiopod crustaceans are commonly found with phoretic (carried) ciliate protozoan colonies around the mouth and portions of the head, which are abandoned with the exuvia (external shell) 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. However, the midvalley fairy shrimp is endemic to California (Eriksen and Belk 1999, Belk and Fugate 2000).

The earliest collections of the midvalley fairy shrimp were made by Clyde Eriksen in the late 1960s at Mather Air Force Base. Eriksen collected the midvalley fairy shrimp with some specimens of the vernal pool tadpole shrimp. The midvalley fairy shrimp was not recognized as a new species until Anne Huber collected material from south of Mather Field and sent the specimens to Mike Fugate for identification. Fugate sent the material on to Denton Belk, who identified them as an undescribed species.

The midvalley fairy shrimp is endemic to California Central Valley grassland vernal pools (Belk and Fugate 2000). Known occurrences include scattered occurrences from the Mather Field area of Sacramento, south through Galt from Sacramento County; Jepson Prairie, Travis Air Force Base, and Vacaville areas in Solano County; from Lodi, north to the county border in San Joaquin County; the Byron Airport in Contra Costa County; the Virginia Smith Trust (Haystack Mountain), and Arena Plains National Wildlife Reserve in Merced County; one location in central Madera County; and one in northern Fresno County (Erickson and Belk 1999, Belk and Fugate 2000, Rogers in prep.). In Yolo County the midvalley fairy shrimp is reported from two locations in the Yolo Bypass, both in small vernal pools southwest of Saxon (CNDDDB 2007).

Habitat occupied by midvalley 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 in California have been broadly converted by human use.

Population Trends

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

Adequate determination of remaining midvalley fairy shrimp occurrences throughout the animal's range, as well as population trends, is difficult. Eriksen and Belk (1999) present a map of localities for the midvalley fairy shrimp with less than 30 localities represented; the greatest density of occurrences is in southern Sacramento County.

The CNDDDB 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 CNDDDB is not updated when a particular site or population is extirpated. Because of issues such as these, 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 special-status 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

As described previously, the greatest threat to vernal pool invertebrates is the elimination, loss, or modification of their habitat by development. Filling of vernal pools or modification of the watershed that supports those pools either eliminates the habitat or disrupts the pool ecosystem to where it is overcome by opportunistic invertebrate species and invasive, opportunistic, and non-native plants that out-compete the obligatory vernal pool species (Rogers 1998).

Excessive livestock grazing in vernal pool terrain can be detrimental to vernal pool invertebrate communities. High stocking rates tend to deposit 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, woolly-marbles) 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 (Rogers 1998). Therefore, moderate grazing or other disturbance may be a necessary habitat suitability component, and removal of grazing or excessive grazing are threats to the midvalley 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). Run-off from paved roads entering the watershed may carry petroleum by-product residue or sediment from vehicles or road maintenance activities. Furthermore, pesticide, herbicide, fertilizer, and sediment run-off from agricultural activities may enter the watershed and may be injurious to vernal pool invertebrates. Ground disturbance from development activities may also loosen soil and enter the watershed.

Non-native invasive species are 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, which tend to produce heavy thatch and eventually organic loads upon decomposition, which oxidize the water (Rogers 1998). It has also been demonstrated that introduction of the non-discriminating, predatory mosquitofish (*Gambusia affinis*) into vernal pools to control perceived local mosquito problems reduces fairy shrimp populations (Leyse et al. 2004).

Habitat fragmentation is also a threat to vernal pool invertebrates because development surrounding small pool complexes may prevent waterfowl or shorebirds from feeding at the pools, thereby 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 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.

Actual acreages of potential midvalley 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 should be an overall net gain of occupied midvalley fairy shrimp habitat within the Plan Area, with specific preserve areas encompassing optimal habitat.

Restoration and creation of midvalley fairy shrimp habitat have been demonstrated to be feasible (Rogers 1998). However, specific habitat parameters for this and other vernal pool invertebrate species are still poorly understood. For example, this species appears to need a minimum pool volume and a minimum pool surface area within a given habitat to

be occupied. Because this species has been found in a wide variety of natural and artificial vernal pool habitats, it is likely an opportunist, similar to most temporary water fauna.

The primary data gap regarding conservation of vernal pool invertebrates is lack of 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. However, it may be expedient to estimate midvalley fairy shrimp distribution through aerial photographic interpretation. Some specific areas will need to be physically verified as to whether they support potential midvalley fairy shrimp habitat. Artificial habitats, like railroad toe-drains, stock tanks, roadside scrapes, also will need to be verified. 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.

Guidelines in selecting vernal pool habitat for conservation of the midvalley fairy shrimp and other vernal pool dependant 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., Proctor 1964; Eng *et al.* 1990; Amat *et al.* 1991; Rogers 1998, in prep.; Eriksen and Belk 1999; Wissinger *et al.* 1999; Rogers and Fugate 2001).
- 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 midvalley 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 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 topography, 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 midvalley 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”).

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