

cysts hatch after their vernal pool habitats fill with water. This strategy reduces the probability of complete reproductive failure if a vernal pool dries up prematurely. This strategy has been suggested as a mechanism by which rare species may persist in unpredictable environments (Chesson and Warner 1981; Chesson and Huntly 1989; Ellner and Hairston 1994).

Although the vernal pool crustaceans, and particularly the fairy shrimp, addressed in this rule are not often found in the same vernal pool at the same time, when coexistence does occur, it is generally in deeper, longer lived pools (Eng *et al.* 1990; Thiery 1991; Gallagher 1996; Simovich 1998). In larger pools, closely related species of fairy shrimp may coexist by hatching at different temperatures, and by developing at different rates (Thiery 1991; Hathaway and Simovich 1996). Vernal pool crustacean species may also be able to coexist by utilizing different physical portions of the vernal pool, or by eating different food sources (Daborn 1978; Hamer and Appleton 1991; Mura 1991; Thiery 1991).

The primary historic dispersal mechanisms for the vernal pool crustaceans probably consisted of large-scale flooding resulting from winter and spring rains and dispersal by migratory birds. As a result of widespread flood control and agricultural water diversion projects developed during the twentieth century, large scale flooding is no longer a major form of dispersal for the vernal pool crustaceans. When being dispersed by migratory birds, the eggs of these crustaceans are either ingested (Krapu 1974; Swanson 1974; Driver 1981; Ahl 1991) and/or they adhere to the bird's legs and feathers and are thereby transported to new habitats. Cysts may also be dispersed by a number of other species, such as salamanders, toads, cattle, and humans (Eriksen and Belk 1999).

The vernal pool crustaceans addressed in this rule are generally confined to habitats that are low to moderate in alkalinity and dissolved salts when compared with other aquatic systems (Eriksen and Belk 1999). Although potentially moderated by soil type, vernal pools are generally unbuffered and exhibit wide fluctuations in pH and dissolved oxygen (Keeley and Zedler 1998). Vernal pool water ion concentrations, such as sodium, potassium, calcium, chlorine, and magnesium, also experience large daily and seasonal variations. These variations are due to the concentration of ions as a result of evaporation, and the dilution of ions with additional rainfall throughout the wet season

(Barclay and Knight 1981). How vernal pool crustacean species adapt to these fluctuations in water chemistry varies. Definitive conclusions on why the species has certain water chemistry habitat preferences is unknown due to the anecdotal nature of observations.

This final rule addresses four vernal pool crustaceans: the Conservancy fairy shrimp (*Branchinecta conservatio*), longhorn fairy shrimp (*Branchinecta longiantenna*), vernal pool fairy shrimp (*Branchinecta lynchi*) and the (*Lepidurus packardii*). Conservancy fairy shrimp, longhorn fairy shrimp, and vernal pool fairy shrimp are members of the aquatic crustacean order Anostraca, while the vernal pool tadpole shrimp is a member of the aquatic crustacean order Notostraca. Vernal pool fairy shrimp are found in California and southern Oregon, while the other three shrimp species are found only in California. These species have all evolved similar adaptations to the unique habitat conditions of their vernal pool habitats. The general appearance and life history characteristics of these four species will be described in combination below.

Conservancy fairy shrimp, longhorn fairy shrimp, and vernal pool fairy shrimp (fairy shrimp) have delicate elongate bodies, large stalked compound eyes, and 11 pairs of phyllopods, which are swimming appendages that also function as gills. They swim or glide gracefully upside down by means of complex beating movements that pass in a wavelike anterior-to-posterior direction. Fairy shrimp are filter feeders, and consume algae, bacteria, protozoa, rotifers, and bits of detritus as they move through the water. The second pair of antennae in fairy shrimp adult males are greatly enlarged and specialized for clasping the females during copulation. The females carry eggs in an oval or elongate ventral sac (brood pouch). Once fertilized, the eggs are coated (encysted) with a protective protein layer that allows them to withstand heat, cold, and prolonged dehydration. These dormant embryos are known as cysts. The cysts are either dropped to the pool bottom or remain in the brood pouch until the female dies and sinks. The cysts can remain viable in the soil for decades after deposition (Eriksen and Belk 1999). When the pools refill in the same or subsequent seasons, some but not all of the cysts may hatch (Eriksen and Belk 1999). The cyst bank in the soil may consist of cysts from several years of breeding. The cysts that hatch may do so within days after the vernal pools fill, and the hatchlings rapidly develop into adults within weeks. In pools that persist for several

weeks to a few months, fairy shrimp may have multiple hatches during a single season.

Vernal pool tadpole shrimp have dorsal compound eyes, a large shieldlike carapace (shell) that covers most of their body, and a pair of long cercopods or appendages at the end of the last abdominal segment. They are primarily benthic (living on the bottoms of the pools) animals that swim with their legs down. Vernal pool tadpole shrimp climb or scramble over objects, and plow along bottom sediments as they forage for food. Their diet consists of organic detritus and living organisms, such as fairy shrimp and other invertebrates (Fryer 1987). The females disperse their fully developed cysts into the pool, where the cysts are then deposited into the sediment. Like fairy shrimp, vernal pool tadpole shrimp pass the summer months as dormant cysts in the soil. Some of the cysts hatch as the vernal pools are filled with rainwater in the next or subsequent seasons, while other cysts may remain dormant in the soil for many years. When winter rains refill inhabited pools, tadpole shrimp reestablish from dormant cysts and may become sexually mature within 3 to 4 weeks after hatching (Ahl 1991; Helm 1998). Mature adults may be present in pools until the habitats dry up in the spring (Ahl 1991; Gallagher 1996).

Additional information specific to each of the four individual vernal pool crustacean species described in this rule is provided below.

Conservancy Fairy Shrimp

Conservancy fairy shrimp were first described in 1990 by Eng, Belk, and Eriksen. The type specimens were collected in 1982 at Olcott Lake, Solano County, California. Conservancy fairy shrimp are currently known from only eight disjunct areas: Vina Plains and vicinity in southern Tehama and northern Butte County, Jepson Prairie in Solano County, Suisun Slough in southern Solano County, Sacramento National Wildlife Refuge in Glenn County, near Caswell Memorial State Park in Stanislaus County; Haystack Mountain Area in eastern Merced County, San Luis National Wildlife Refuge Complex in central Merced County, and the Mutau Flat area in the Los Padres National Forest area of northern Ventura County. Conservancy fairy shrimp are known from 18 occurrences (California Natural Diversity Database (CNDDB) 2002).

Conservancy fairy shrimp look similar to other fairy shrimp species, but can be distinguished by characteristics of the male second antenna. The second antennae of Conservancy fairy shrimp