

# A "Living Fossil" in the San Francisco Bay Area?

By Bradley Goettle

What is a Living Fossil?



Anteriodorsal view of a vernal tadpole shrimp out of water.  
Photo by Larry Serpa

Quick!! How many "living fossils" can you name? Would you believe that there is a "living fossil" right here in the San Francisco Bay area? The Don Edwards San Francisco Bay National Wildlife Refuge, located in the South San Francisco Bay, has seasonal freshwater pools which contain the vernal pool tadpole shrimp (*Lepidurus packardii*), a freshwater crustacean "living fossil." The vernal pool tadpole shrimp derives its name from looking somewhat like a frog or toad tadpole at first glance, and from being found only in "vernal" pools (temporary springtime pools). Now you

ask, exactly what is a "living fossil?"

A living fossil is an organism living today that appears to be identical to specimens in the fossil record. The most famous example is probably the coelacanth (*Latimeria chalumnae*), a primitive, lobe-finned fish from the Cretaceous Period. Coelacanths were known only from their abundant fossils until a live coelacanth was recovered by a deep-sea trawler in the Indian Ocean in 1938. This fish still lives in the ocean depths, virtually unchanged from its fossil ancestors of approximately 70 million years ago.

Tadpole shrimp are considered living fossils because their basic body characteristics have remained the same for millions of years. General characteristics of tadpole shrimp include a shield-like carapace (shell), a fused pair of eyes on top of the carapace, a segmented abdomen, and paired tail filaments. Tadpole shrimp also have paired ventral appendages called phyllo-pods (phyllo = "leaf" and pod = "feet"), which beat in a wavelike motion from front to back and act as propulsion for the animal. At the base of these paired phyllo-pods is a ventral midline food groove, which effectively funnels microscopic food particles up to the animal's mouth. This basic design appears to be well-adapted to the vernal pool environment, since these basic body characteristics have remained unchanged over time.

Tadpole shrimp belong to either the genus *Triops* or the genus *Lepidurus*. The tadpole shrimp in the genus *Lepidurus* have a paddle-shaped flap between the tail filaments, which shrimp in the genus *Triops* do not. *Lepidurus packardii* is the only species in the genus *Lepidurus* known from California's Central Valley or the San Francisco Bay Area.

A ventral view of a vernal pool tadpole shrimp, note the paired pylopopods, paired ventral antennae, segmented abdomen, and orange egg sac.



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## Vernal Pool Habitat and Vernal Pool Tadpole Shrimp Life Cycle

Vernal pools are ephemeral (short-lived) wetlands that form in areas where a Mediterranean climate combines with shallow depressions underlain by soil types that restrict the downward percolation of water. A Mediterranean climate is a moderate climate with distinct and regular wet and dry seasonality. In California, the soils which form the water-restricting layer associated with vernal pools can consist of hardpan, clay, or basalt, and in the Bay area are often clays. The soils on which vernal pools form are patchy, so vernal pools are typically clustered into pool complexes. These complexes vary greatly in the number, size, and density of pools they contain. Some complexes have only a few large pools, while others contain hundreds of small pools.

In California, ephemeral pools are typically referred to as vernal pools (vernal = spring) because the pools are filled and wet during the winter and spring rainy season. The rest of the year, these pools are dry. Outside of the United States, ephemeral wetlands also are known from areas in Africa, Australia, Canada, Central America, India, the Mediterranean basin, and many of the countries in the former Soviet Union. Ephemeral wetlands in different regions are variously referred to as alpine wet meadows, dayas, hogwallows, pans, playas, rain pools, seasonal wetlands, springtime pools, temporary ponds, temporary pools, or tundra pools.



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*King Differences in size and body shape in vernal pool tadpole shrimp taken from the same pool in one dipnet sweep.*

As California's rainy season begins in the fall, dry soil in pool bottoms becomes saturated. As rains continue to fall throughout winter, the pools fill with water and a rich community begins to develop. This community includes invertebrate animals such as crustaceans, flatworms, snails, and insects, as well as vertebrates such as amphibians, birds, and some mammals. Vernal pools are important breeding sites for frogs and

salamanders, as well as feeding and resting sites for migrating waterfowl. As pools gradually dry down during the spring, the well-known "bathtub ring" of flowers forms at the pool margins. This is the time period when vernal pools are at their showy best, with a striking profusion of yellow, white, and purple blooms often totally carpeting the pool bottoms and pool margins. At this time, mobile animals begin to disperse from the vernal pools and the vernal pool plants start to produce seeds. As the pools continue to dry, plants turn brown, and the soil dries and may crack. Very few perennial plants have adapted to the vernal pool environment, since California rainfall patterns can include extended drought-like conditions. Annual wetland plants are the most common plants in typical vernal pool communities.

Vernal pools are a unique type of habitat, since they are freshwater aquatic ecosystems that are typically dry 7-8 months out of the year. Vernal pool tadpole shrimp (like the related "fairy shrimp" species) only live in ephemeral freshwater habitats, an environment with very few aquatic predators, especially fish. These shrimp are unknown from any marine, estuarine, or riverine system. Vernal pool tadpole shrimp and fairy shrimp serve as food for a variety of vertebrate and invertebrate animals in vernal pools. Both tadpole shrimp and fairy shrimp are readily consumed if there is a temporary connection of vernal pools to more permanent water bodies containing fish. If the connection becomes permanent, these vernal pool crustaceans will eventually disappear, since they have no defenses against direct predation by fish.



© Photomicrograph by Bradley Goettle  
Note the uneven, granular surface and "parchment" coloration of this vernal pool tadpole shrimp cyst.

A key adaptation of the vernal pool tadpole shrimp to this alternately wet and dry vernal pool environment is the numerous drought-resistant cysts (eggs) they produce. When the vernal pool eventually dries down, these cysts remain dormant and viable for up to ten years while waiting for the next rains to initiate their hatching. These cysts also can withstand the often extremely high temperatures of California summers while embedded in the top layers of the vernal pool soil sediments. A female vernal pool tadpole shrimp may produce thousands of cysts during her lifespan. Some of these cysts hatch out during the same wet season. However, for reasons that still remain unclear, a

large portion of these cysts produced in any given wet season will only hatch after the pool dries down and subsequently refills, possibly several years later. The vernal pool tadpole shrimp is different from almost all California fairy shrimp since it is able to produce more than one generation in a single wet season. Another strategy for adapting to the vernal pool environment is reaching sexual maturity rapidly (in as little as three weeks). Rapid sexual maturity allows the vernal pool tadpole shrimp to hatch, mature,

and produce numerous drought-resistant cysts quickly after the pools refill, thereby effectively using such a short-lived environment. This temporal isolation (separated by time) allows the vernal pool tadpole shrimp to occupy a harsh environment to which few predator species have adapted.

Vernal pool tadpole shrimp differ from the related fairy shrimp by the way they move; vernal pool tadpole shrimp swim or scoot along typically muddy or rocky bottom sediments "right side up," whereas fairy shrimp swim higher up in the water "upside down." Adult vernal pool tadpole shrimp are much larger in body mass than adult fairy shrimp and may reach an inch and a half in length, whereas fairy shrimp are often less than half an inch in length. Fairy shrimp can be whitish or have some orange body parts, but they are almost translucent in comparison to vernal pool tadpole shrimp, which are typically olive or grey colored. This olive or grey coloration is sometimes mottled, and helps provide good camouflage for the vernal pool tadpole shrimp to blend in with aquatic plants or when they burrow horizontally in muddy bottom sediments. Vernal pool tadpole shrimp are often quite hard to spot in the water unless they are seen in motion.

## Impacts to Vernal Pool Habitat

The main threat to the continued existence of the vernal pool tadpole shrimp, as well as almost all other vernal pool species, is continuing loss of habitat, especially due to residential/commercial development and lands converted to agricultural uses. Vernal pool habitat is rapidly diminishing throughout California. This conversion or use of lands containing the remaining vernal pools is expected to continue because of the desirability of and economic feasibility of building on essentially flat lands (slopes of no more than 3-4 %) which are often close to metropolitan areas. Present estimates for the loss of vernal pool habitat in California's Central Valley range from 65-90% of its former extent. In Southern California, San Diego County has documented the loss of 90-95% of its historic vernal pool habitat. Vernal pools and vernal pool complexes also are subject to threats in the form of: interrupted watersheds for pools and complexes, invasions of aggressive non-native plant species, gravel mining, fertilizer and pesticide contamination, overgrazing by livestock, off-road vehicle use, and contaminated stormwater runoff.

## Species Range and Status as Federally Endangered

The vernal pool tadpole shrimp is a species found only in California. The shrimp ranges in the Central Valley from around Visalia (Tulare County) in the south to the Redding area (Shasta County) in the north. The easternmost known location is around 3,000 feet in elevation in the central Sierra Nevada foothills (Merced County). The westernmost known location is on the Warms Springs Seasonal Wetlands of the Don Edwards San Francisco Bay National Wildlife Refuge in Alameda County. This property, which contains some of the very few vernal pools in the South San Francisco Bay Area, was acquired by the U.S. Fish and Wildlife Service in 1992. The vernal pool tadpole shrimp also was recently discovered on the privately owned Pacific Commons Project site in

Fremont which is adjacent to the Don Edwards San Francisco Bay National Wildlife Refuge. These two locations are unique since they comprise the only known population of the vernal pool tadpole shrimp outside of the Central Valley.

A very important thing to remember is that even though the vernal pool tadpole shrimp may be locally abundant in some places, it is globally rare. The vernal pool tadpole shrimp was listed by the U.S. Fish and Wildlife Service as endangered on September 19, 1994, due to its very limited distribution, the small number of remaining populations, and the number and nature of threats to this species' continued existence. A species is listed by the Federal Government when scientific information has substantiated that the species' continued existence is in jeopardy, and that the species will likely go extinct without protections afforded by the Endangered Species Act. The Endangered Species Act is jointly administered by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. A species may be federally listed as either threatened (when a species is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range if not protected) or endangered (when a species is in danger of extinction within the foreseeable future throughout all or a significant portion of its range if not protected.) Anyone proposing an action or project which would either directly or indirectly affect the vernal pool tadpole shrimp, or any other species federally listed as threatened or endangered, must obtain a permit from the Service. This permit allows for the "take" ("...to harass, harm, capture, or... kill...") of threatened or endangered species protected by the Endangered Species Act. However, these take permits are only issued if the proposed take would not jeopardize the continued existence of the species.

## The Next Million Years

What can we do to help ensure that these remarkably well-adapted and virtually defenseless animals have a chance to make it the next million years? One long-range planning method is to formulate a Habitat Conservation Plan to plan future land uses for a project or a region, such as an entire watershed or a County. A Habitat Conservation Plan is designed to try to accommodate both the resource needs and economic needs of everyone involved, including the project proponents, regions or counties, other regulatory agencies, and the U.S. Fish and Wildlife Service. Other efforts currently underway include: conservation easements with landowners allowing compatible land uses while retaining vernal pool habitat intact; the establishment of preservation banks and creation banks to preserve and create vernal pool habitat, respectively; establishment of National Wildlife Refuges; consultation with Federal agencies to reduce or avoid effects on threatened or endangered species; and research on the rearing and reproduction of this endangered crustacean species. Individuals, municipalities, and agencies also can help protect the vernal pool tadpole shrimp and other vernal pool species by preventing or reducing impacts to vernal pools, as previously mentioned in this article.

But, by far, the most important thing we can do is to ensure that vernal pool tadpole shrimp have enough suitable habitat to be able to continue to hatch, mate and

reproduce for the next million years. Then, hopefully, like us, future generations will also have the chance to marvel at this remarkable animal. As a child once responded when asked why we should save endangered species: "Because we can."

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