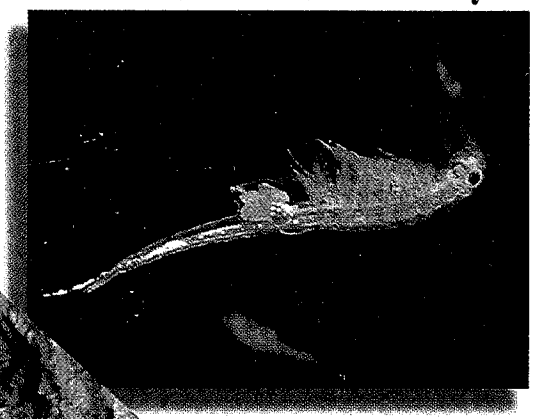
# Fairy Shrimps

## of California's Puddles, Pools, and Playas





by
Clyde Eriksen and Denton Belk

# FAIRY SHRIMPS OF CALIFORNIA'S PUDDLES, POOLS, AND PLAYAS

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irregular, is generally less than 11.5 cm, and much of this meager rainfall drops from summer storms originating in the Gulf of Mexico.

## Habitat categories and their associated species of fairy shrimps

A discussion of conditions required by fairy shrimps could be approached in a number of ways. We feel that presenting information based on an alphabetical listing of species would lead to a random discussion of habitats, and "Dullsville", as they say! A regional approach would certainly be better, but given such varied topography at that level, we could probably not avoid a similar pitfall, and "Dullsville II" would be the result. We believe our purpose will best be served by describing what we know about habitat requirements of the various species that live within what we call **habitat categories**. Because these categories approximate the eight geographic-vegetational regions just described, and will be noted in the same sequential manner, a comparison can readily be made between the two.

Remember, we have placed our habitat categories (Table 4.1) into a continuum which generally grades from cold to warm, and low- to high-salinity waters. Although predicting whether a

**Table 4.1.** Habitat categories and their representative species

| Habitat category | Representative species |
|---|---|
| Cold-water pools which are low in dissolved solids, predictable, and long-lived | *Eubranchipus bundyi*, *Eubranchipus oregonus*, *Eubranchipus serratus*, *Streptocephalus sealii* |
| Cold-water pools which are low to moderate in dissolved solids, predictable, and long-lived | *Branchinecta coloradensis*, *Branchinecta dissimilis* |
| Cool-water pools which are low to moderate in dissolved solids, moderately predictable, and long-lived | *Branchinecta coloradensis* (suggested two new species), *Branchinecta conservatio*, *Linderiella occidentalis*, *Linderiella santarosae* |
| Cool-water pools which are low to moderate in dissolved solids, less predictable, and short-lived | *Branchinecta lindahli*, *Branchinecta longiantenna*, *Branchinecta lynchi*, *Branchinecta sandiegonensis*, *Branchinecta* sp. (midvalley fairy shrimp) |
| Cold- and cool-water pools which are moderate to great in dissolved solids, predictable to less predictable, and long-lived | *Branchinecta mackini*, *Branchinecta gigas* |
| Warm-water pools which are low to moderate in dissolved solids, less predictable, and long-lived | *Streptocephalus woottoni* |
| Warm-water pools which are moderate in dissolved solids, less predictable, and short-lived | *Streptocephalus dorothae*, *Streptocephalus texanus*, *Thamnocephalus platyurus* |
| Cool-to warm-water pools which are great to impressive in dissolved solids, predictable, and temporary or permanent | *Branchinecta campestris*, *Artemia franciscana*, *Artemia monica* |

pool will fill with water each season is a risky proposition, it is also true that, in California, the general continuum described also leads from more to less predictability of the presence of water as well as its duration.

Our organization leads us to begin with fairy shrimps requiring cold habitats, that is those in rather predictable pools occurring in or near areas of coniferous forest at high to moderate elevations in the North Coast Mountains, Sierra Nevada, and Great Basin Desert regions. Next come the low-elevation cool-weather species, most of which live in grassland pools in northern and central parts of the Central Valley where rainfall is moderate and reasonably predictable. Then we move south to species inhabiting more arid grass- and shrub-lands where rainfall is less in amount and predictability. Following the trend to greater aridity, we describe cold- and cool-weather forms that dwell in desert alkaline basins. Next come those that are found in desert waters of low alkalinity during warmer times of the year. In various regions of California, low rainfall, saline geology, and periods of high temperature produce salterns with a unique fauna. Because of their peculiarity they are our final consideration.

As for how cold "cold water" really is, or what the limits are for "moderate" amounts of dissolved solids and "low" pH, or where in the continuum of conditions "long-lived pools" might fall, we have set some limits so that when no information for California species is available, at least a reasonable "guesstimate" can be made of the conditions that actually prevail. By the way, the boundaries chosen (Table 4.2) have bases in the data presented by Eng, Belk, and Eriksen (1990).

Regarding water temperature we make two points. First, in California's northern and mountainous localities winter cold turns aquatic environments solid if water is present, and snow covers the landscape, sometimes in exceptional amounts. The species of fairy shrimps that live there are adapted to hatch as soon as snow melts and pool sediments thaw, that is at or near 0°C. Secondly, cold waters do warm with the season, and collections, along with temperature measurements, normally have been made later in the season when animals are partially, if not totally, developed, and during the warmth of the day. We must recognize, therefore, that elevated temperature readings, possibly those near maximal, are more likely to be the data we have to describe the thermal environment. For example, later-season events occasionally boost pool temperatures as high as 25°C for a brief afternoon period, but if they do, night-time cooling inevitably swings the temperature back into the neighborhood of 10-15°C (Daborn 1976; Eriksen unpubl.). Given these realities, "cold water" habitats are best con-

**Table 4.2** Quantification of pool habitat categories for California's fairy shrimps

| Environmental Measure | Quantification Range |
|---|---|
| cold water | 0 - 15°C |
| | 0 - 10°C for hatching |
| cool water | 5 - 25°C |
| | 5 - 20°C for hatching |
| warm water | 17 - 35°C |
| | 17 - 30°C for hatching |
| low alkalinity | few - 100 ppm |
| moderate alkalinity | 100 - 300 ppm |
| high alkalinity | 300 - <10,000 ppm |
| impressive alkalinity | >10,000 ppm |
| low TDS | few - 300 ppm |
| moderate TDS | 300 - 600 ppm |
| high TDS | 600 - >175,000 ppm |
| low pH | 4.8 -7.0 |
| moderate pH | 7.0 - 8.3 |
| high pH | 8.3 - 10.5 |
| short-lived pool | <3 weeks |
| long-lived pool | >3 weeks |

to be up there as well. *Branchinecta dissimilis* has not been collected with other anostracan species in California, but in a pool in the Great Basin Desert of Oregon it was recorded once with *B. mackini* (Lynch 1972).

## Fairy shrimps of cool-water pools which are low to moderate in dissolved solids, moderately predictable, and long-lived

### *Branchinecta conservatio*

(Map 5.6, p. 122)

*Branchinecta conservatio* was the first organism to be named in honor of The Nature Conservancy, an organization in the forefront of conserving natural diversity, and whose Vina Plains and Jepson Prairie preserves protect two of the few pool clusters which sustain this rare creature, Federally listed as endangered.

This fairy shrimp is found in grasslands of the northern two-thirds of the Central Valley, spanning a north-south distance of about 300 km, at elevations of 5-145 m. Within this limited range, its populations are even more restricted, occupying only a few disjunct localities: the Vina Plains of Tehama County; Sacramento NWR in Glenn County; Jepson Prairie Preserve and surrounding area immediately east of Travis Air Force Base, Solano County; Mapes Ranch west of Modesto, Stanislaus County; near Haystack Mountain northeast of Merced, and the San Luis NWR, in Merced County.

Rumor has it that a highly disjunct population occurs about 340 km to the south near the Ventura County village of Stauffer, at the also anomalous elevation of 1,700 m. This information came from Mike Fugate who raised animals from cysts contained in a dirt sample given to him when he was a graduate student at U.C. Riverside. Clyde attempted to verify this seemingly uncharacteristic location on April 1, 1996; he found a wet meadow, but no pool basin – and that's no joke! Until this population is further documented, we consider its existence anecdotal.

All known pools containing *B. conservatio* are seasonally astatic. In the Vina Plains, basins that hold vernal pools are of the Northern Hardpan type and occur in swales of old braided alluvium derived from the volcanic Tuscan Formation. Jepson Prairie basins are of the Northern Claypan type and form as large playa-like depressions on deep alluvial soils of Pescadero Clay Loam (Keeler-Wolf *et al.* 1995). Origins of the other pools are unknown. All sites are filled by winter and spring rains and usually last into June.

*Branchinecta conservatio* has been taken from November to late April, when pool temperatures were as low as 5°C early in the ponding cycle, to as high as 24° near the end of the season (Syrdahl 1993). Little other ecological information is available for this species. However, the type locality was studied by Barclay and Knight (1984). They describe Olcott Pond on the Jepson Prairie Preserve as covering about 4 ha with a maximum depth of 30 cm. Clays from its bottom are swept into the water by wind-mixing and the activity of animals, resulting in such turbidity (a white disc disappears at 5 cm) that rooted vegetation is absent except in shallows around its edges. All pools containing this species were at least moderately turbid and most were rather large; the smallest was 30 $m^2$. Barclay and Knight's data, and Syrdahl's (1993) and ours from the Vina plains, show habitat pH straddling neutral (6.8-7.5), with a few readings of 8.0, and TDS (mainly 20-60 ppm) and alkalinity (16-47 ppm) are both very low.

Brent Helm (1998) provides almost all the information about the biology of *Branchinecta conservatio*. He notes that hatching occurs in the week after pool filling at temperatures around 10°C, and that at least 19 days are required to

reach maturity if pool temperatures slowly increase to at least 20°C. However, the average time to maturity, 49 days, demonstrates not only that cooler temperatures slow development, but that this species normally requires a longer time to mature than do others found within its realm. Its cysts (mean diameter of 0.23 mm; Hill & Shepard in press) are comparatively small for California fairy shrimps, and are produced in rather large, though uncounted, numbers. Individuals have lived as long as 154 days in Brent's back-yard rearing pools; however, 123 days was the average longevity. Because only one cohort is produced each year, both sexes normally disappear long before their native pools dry, apparently males first, because they appear to be less tolerant of stressful conditions than females (Serpa, pers. comm.)

*Branchinecta conservatio* occurs sympatrically with *B. lynchi* and *Linderiella occidentalis* on the Vina Plains (Tehama County), at the Jepson Prairie in Solano County, and near Haystack Mountain and on the San Luis NWR Complex in Merced County. Though it seldom appears in the same pools with these species, one of its rare co-occurrences with the pair also included *B. lindahli*, this at the San Luis NWR Complex. We hasten to remind you that *B. conservatio* not only occurs in great numbers by comparison to these other species, but that it is an especially hyperactive swimmer and filter feeder. You might wish to refer to page 41 to review how these factors are thought to influence the co-occurrence of *B. conservatio* and *B. lynchi*.

## *Linderiella occidentalis*

(Map 5.7, p. 123; front cover)

Ah, *Linderiella occidentalis*, that wonderful red-eyed California endemic fairy shrimp (check out its picture on the front cover) that wiggled in our dip-nets, swam gracefully in the gallon pickle jar that Don Wootton always carried to the field to display our catches, and stimulated Clyde's career-long interest in these graceful creatures! It is the most common inhabitant of cool, soft-water pools of California's Central Valley grasslands. Here, at elevations from 40-168 m, it ranges from near Redding in the north to as far south as Fresno County, mainly to the east of the Sacramento and San Joaquin rivers. In the Sacramento area, it crosses the Valley and enters the Central, then the South Coast, Mountains Regions where it appears in a series of disjunct populations from Willits and Boggs Lake (430 and 850 m in elevation, respectively) in Mendocino and Lake counties north of San Francisco Bay, to Ventura and Santa Barbara counties far to the south. In the last county, where housing for the University of California at Santa Barbara now sprawls, Don Wootton and Clyde collected *L. occidentalis* just back from the sea cliffs, 10 m above the surf; and in the nearby backcountry, on the wildflower-painted slopes of Cachuma Canyon, they dipped this little gem from the highest pool (1,159 m) in which it is known.

*Linderiella occidentalis* has been netted from late December to early May, at 5-29.5°C (Syrdahl 1993). According to Helm (1998), it is the most tolerant of warm water, and consequent low dissolved oxygen, of all fairy shrimps endemic to the Central Valley. In fact, *L. occidentalis* may thrive in some of these pools until they perish, not from heat stroke, but from desiccation. This species occurs in basins with a variety of geological origins (e.g., Northern Hardpan in old braided alluvium, Northern Volcanic Ash Flow, earth slumps, depressions in lava flows and sandstone caused by weathering) which are filled by winter and spring rains and are seasonally astatic. Most of its residences are vegetated California Vernal Pools (Helm 1998), and contain clear though often tea-colored water. However, not uncommonly, *L. occidentalis* swims in mud-bottomed habitats with

10-18°C have been recorded but no water chemistry was undertaken. However, given some work that Clyde did in a rock pool elsewhere, and the fact that sandstone is very low in soluble substances, we can reasonably assume that pH is in the neighborhood of 6.5-7.0, and TDS and alkalinity are very low. By contrast, *B. longiantenna*'s clear to rather turbid, clay- and grass-bottomed pools, 1-62 m in diameter, exhibited temperatures from 10.0-28.0°C. No observations have been made on predictability or longevity of these waters, however, given their positions in the rainshadow of the Central Coast Ranges, they are undoubtedly less predictable, and probably short-lived (Bob Brown estimates about three weeks). TDS (130-590 ppm) and alkalinity (58-156 ppm) are low to moderate, as they are in habitats of other grassland fairy shrimps, but the range of values is slightly greater. A median pH of 7.2, with a range of 6.7-7.9, is similar to that of other grassland species as well.

*Branchinecta longiantenna* certainly vies for the distinction of being one of the least known of California's fairy shrimps. Several of Clyde's students studied it, two of its tolerance of heavy metals (Mizutani *et al.* 1991), another its filter-feeding rate (Patten 1980). Mizutani (1982) also used this species to develop a model demonstrating how a clay particle, dissolved organic molecules, and bacteria form a complex large enough to be filter fed by anostracans (see p. 50 in section: What do fairy shrimps eat?).

Once more Brent Helm (1998) provides our only information on natural history. Like other Central Valley endemics, larvae of *Branchinecta longiantenna* hatch soon after winter and spring rains fill their swimming pools with water hovering around 10°C. We assume they emerge as nauplii because the average cyst diameter of 0.26 mm (Hill & Shepard in press) falls within the size range of others which do so. In any event, whatever pops forth, these shrimps need temperatures of 15-20°C to attain maturity. If conditions are optimal, maturation is reached in 23 days, more typically it requires 43 days. If their pools remain for an extended period of time, then individuals of *B. longiantenna* are known to swim right along for up to 147 days.

The preceding is interesting and ultimately useful information, but none of it helps much to explain why the distribution of this species, and its co-occurrence with other anostracans, is so restricted. We do not know why it is tucked away only in or near the eastern foothills of the Central Coast Mountains, nor do we clearly understand why it and *Branchinecta lynchi*, which also lives in the three major areas where *B. longiantenna* occurs, have only twice been found together. For example, in its small rock pools, with but one exception, *B. longiantenna* apparently swims alone, although these are very close to other seemingly identical sites that contain only *B. lynchi* or *Linderiella occidentalis*. *Branchinecta conservatio* and *B. lindahli*, as well as *B. longiantenna* and *B. lynchi*, share the Kesterson pool complex, but each claims its separate residences. In the Soda Lake area, only once were *B. lynchi* and *B. longiantenna* taken together. The latter has been found a few times with *B. lindahli* around Soda Lake, but co-occurrence has not been observed at Kesterson. Ah, as yet there still remain some very private lives amongst fairy shrimps!

## *Branchinecta lynchi*

(Map 5.9, p. 125; Fig. 1.2, p. 2)

*Branchinecta lynchi* is an uncommon, common fairy shrimp. How's that for a seeming contradiction? Consider the beast common because it appears to be rather widely distributed in the grasslands of the state, from near Red Bluff in Shasta County, south through much of the Central Valley, and ultimately via several disjunct populations to the Santa Rosa Plateau in Riverside

County in the South Coast Mountains Region. Deem it uncommon because *B. lynchi* is not abundant anywhere; and when it co-occurs with other fairy shrimp species, which is reasonably often, it is always far outnumbered.

Throughout its range *Branchinecta lynchi* has been taken from early December to early May. In and near the Central Valley, its residences range from about 10-290 m in elevation; in the South Coast Mountains Region some are as high as 1,159 m. Habitats are of two major kinds. One, which includes the type locality, is restricted to the Slanted Rocks area west of Byron Hot Springs in the southeast corner of Contra Costa County. There, clear water is held in small depressions, usually less than 1.0 m diameter, in sandstone outcrops which are surrounded by foothill grasslands. These puddles each contain only a few shrimps which face unknown water quality, though alkalinity and TDS are undoubtedly quite low. The more common habitat is a small swale, earth slump, or basalt-flow depression basin with a grassy or, occasionally, muddy bottom, in unplowed grassland. Normally these are smaller pools than those occupied by other Central Valley anostracans (except the mid-valley fairy shrimp). These are predominantly the California Vernal Pools discussed by Holland (1978), Keeler-Wolf *et al.* (1995), Thorne (1984), and Zedler (1987). However, their pool basins display the greatest diversity of origins found amongst Central Valley fairy shrimp haunts, and this variety includes disturbed and constructed sites unfavorably received by other species (Helm 1998). These places of residence vary dramatically in size, from one exceeding 10 ha, to an uncommonly small puddle only 3 cm deep and covering but 0.56 $m^2$. *B. lynchi* occurs in waters at least 4.5-23°C, with low to moderate TDS (48-481 ppm, mean of 185) and alkalinity (22-274 ppm, average of 91), and a mean pH of 6.8 with a range of 6.3-8.5 (Collie & Lathrop 1976; Keeley 1984; Syrdahl 1993; Eriksen unpubl.).

*Branchinecta lynchi* can beget cysts speedily, which places it in the company of the midvalley fairy shrimp and *B. lindahli*, both of which have similar hurry-up-and-reproduce adaptations. For example, Gallagher (1996) and Helm (1998) observed that *B. lynchi*, which hatches soon after water of 10°C or less fills its pools, will reach maturity in close to 18 days under optimal conditions, that is when daytime water temperatures rise to at least 20°C. However, 41 days are more typical if the water remains in the vicinity of 15°C. Helm's records also divulge that, of the Central Valley endemic anostracans, *B. lynchi* has the shortest maximum longevity at 139 days, although 90 was the mean longevity in his artificial backyard pools. Sean Gallagher (1996) studied a cluster of natural pools in Butte County and watched most individuals disappear around 70 days, and vanish completely after about 84 days, even when water remained in their basins.

The number of cysts produced per clutch, and how many clutches can be generated during a life span, are unknown quantities. However, once cysts have been dropped, all that is necessary for another hatching is a frost or major storm which lowers water temperature to around 10°C (Helm 1998). Gallagher (1996) reports three separate hatches in a season, while Helm has observed 6! This ability of being ready and able to launch more than one cohort per year sets *B. lynchi* and the mid-valley fairy shrimp apart from other Central Valley endemic anostracans.

These biological realities certainly paint a telling picture of why *Branchinecta lynchi* dwells in some of the shortest-lived of fairy shrimp settings – pools which persist for only 6-7 weeks in winter, and perhaps three weeks in spring. Since *B. lynchi* develops faster in warmer spring pools than in colder winter ones, it probably averages about a week of cyst production unless individuals dwell in deeper longer-lived pools. In the latter