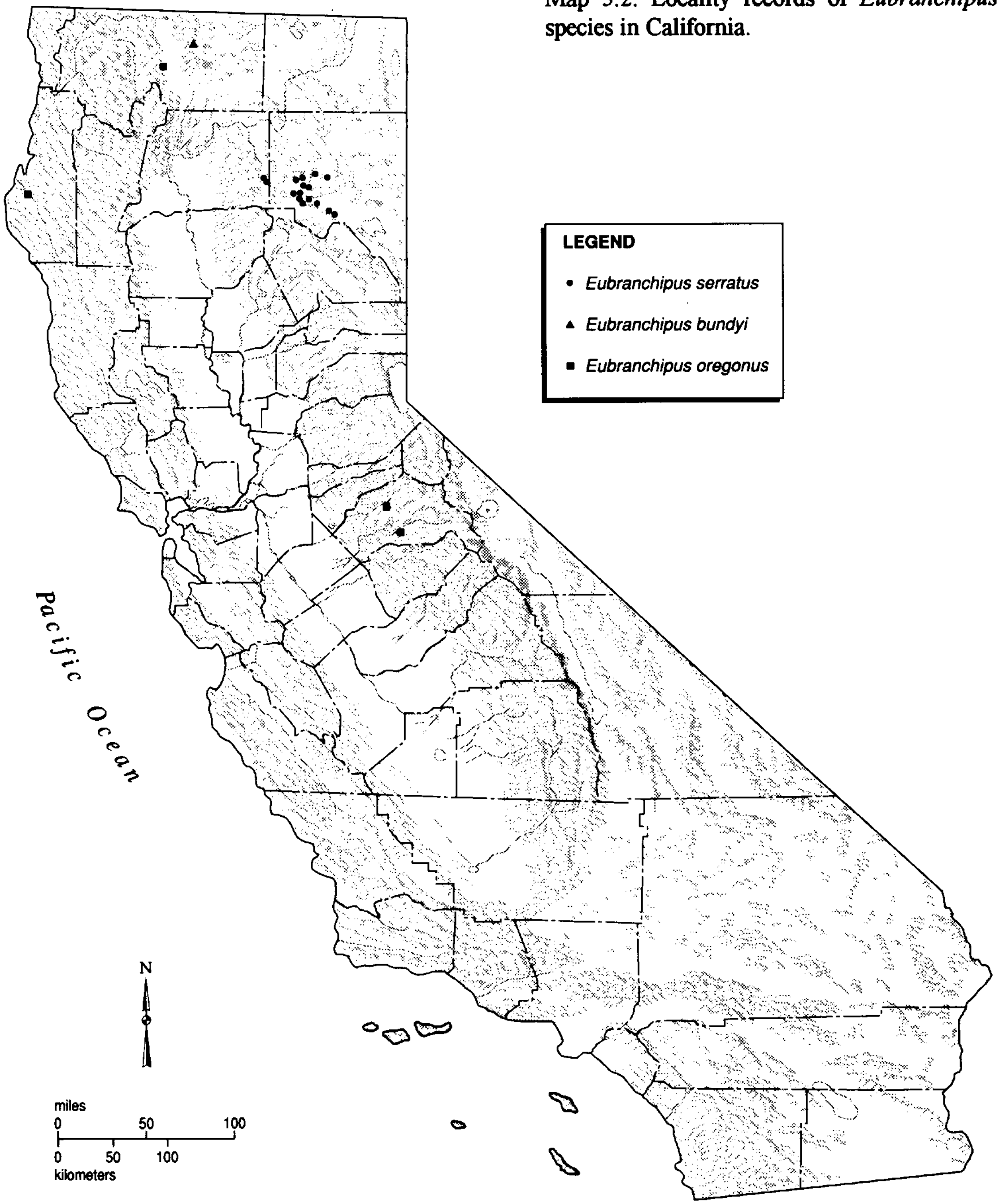
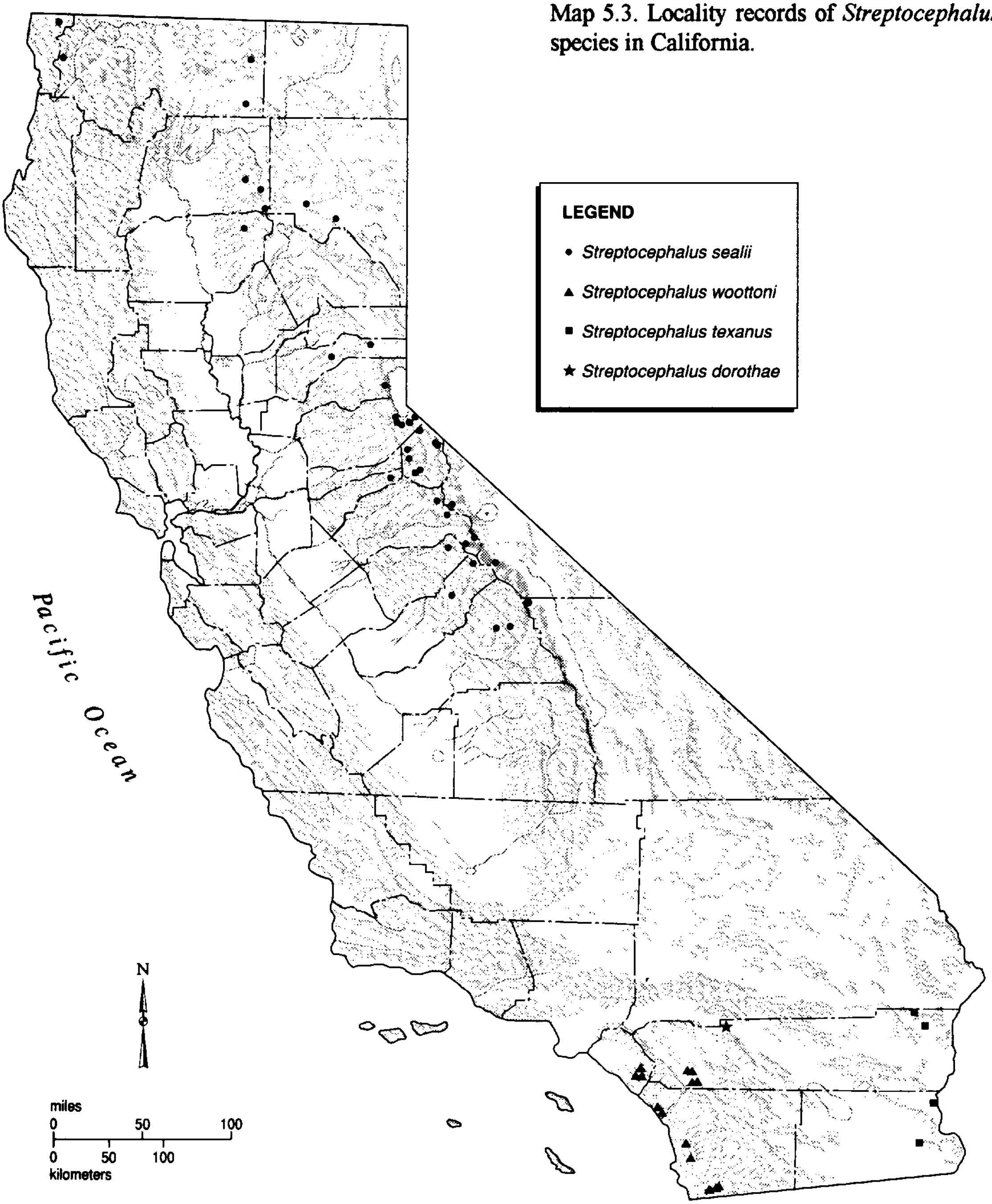
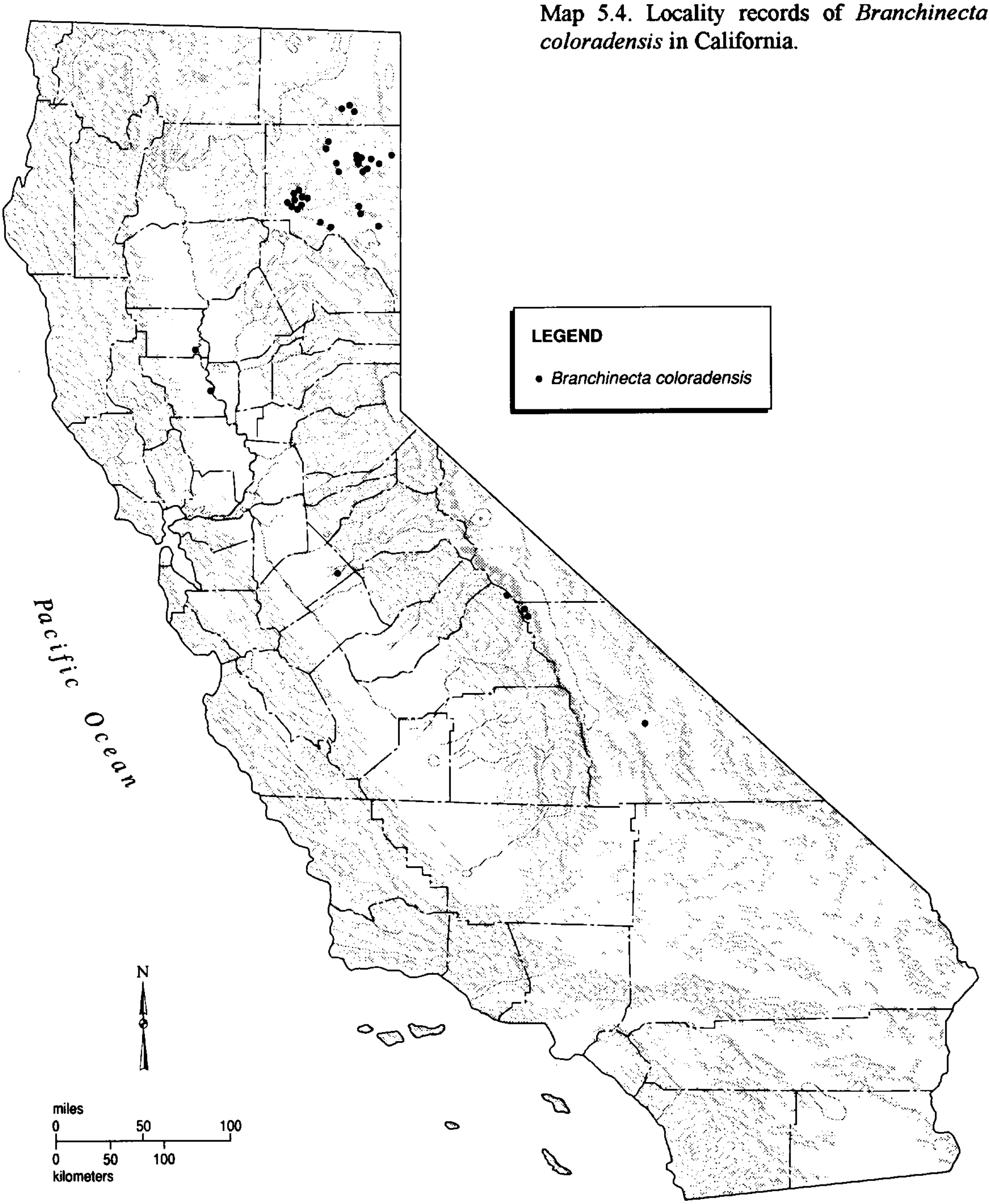


Map 5.2. Locality records of *Eubranchipus* species in California.

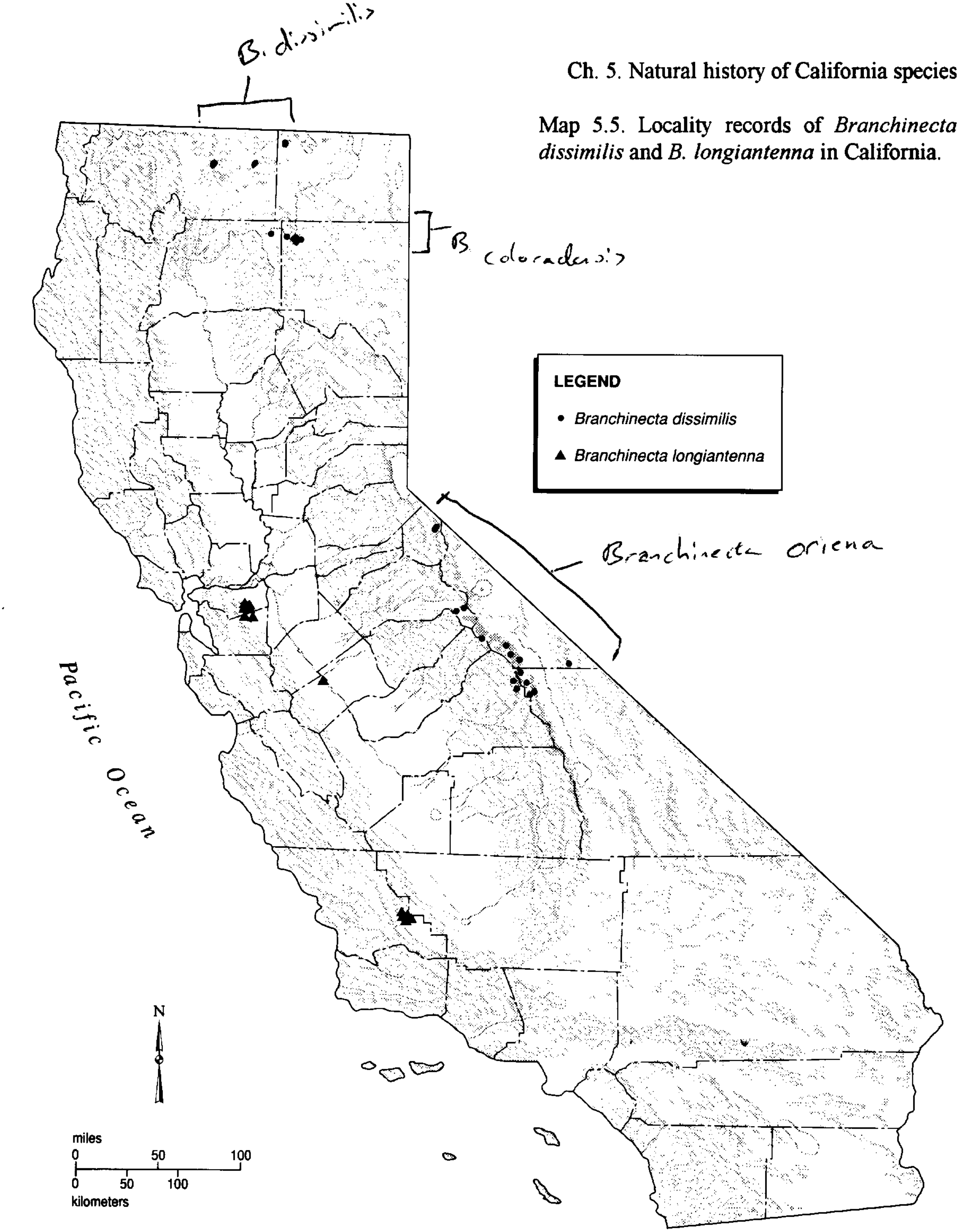


Map 5.3. Locality records of *Streptocephalus* species in California.

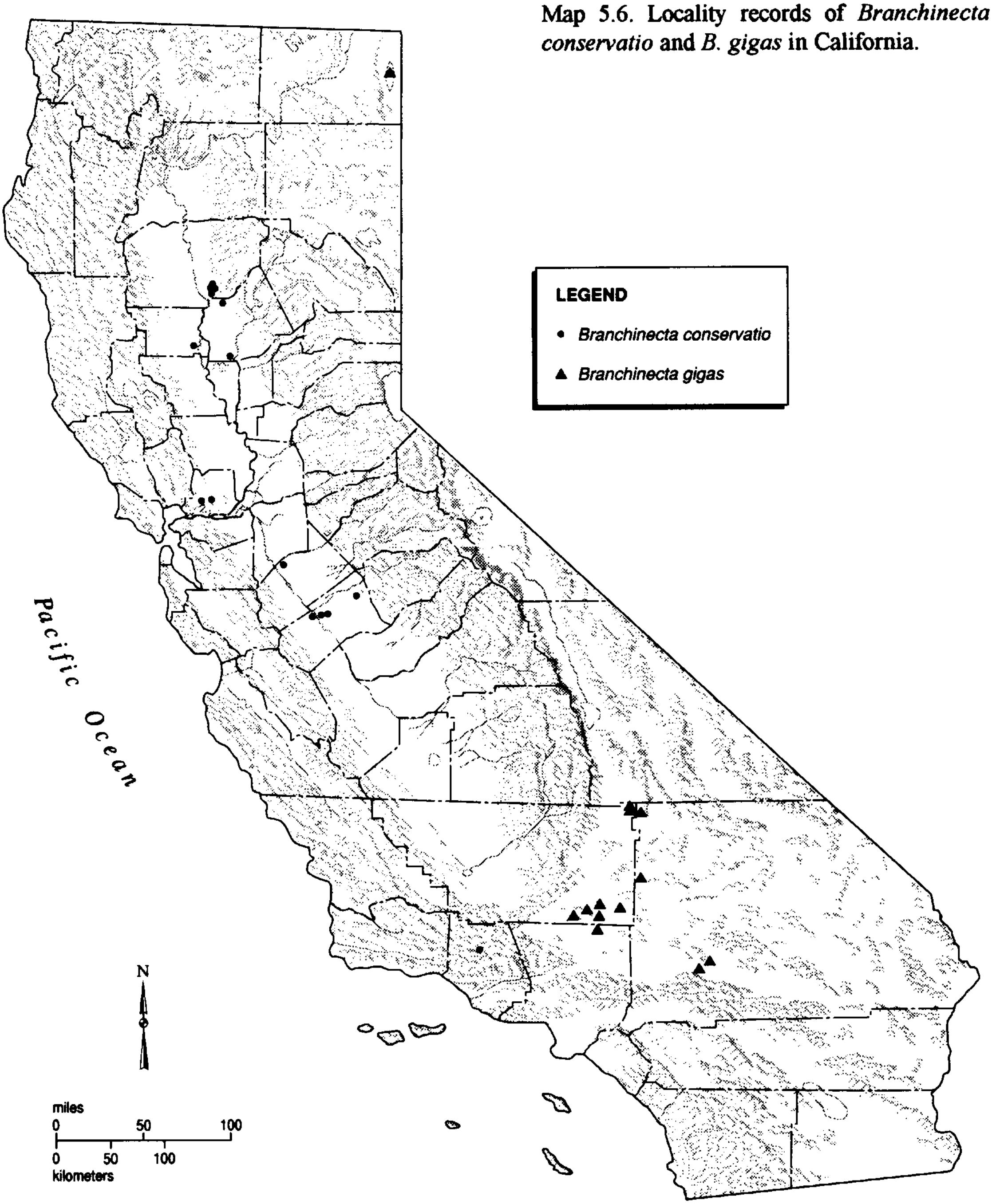
Map 5.4. Locality records of *Branchinecta coloradensis* in California.



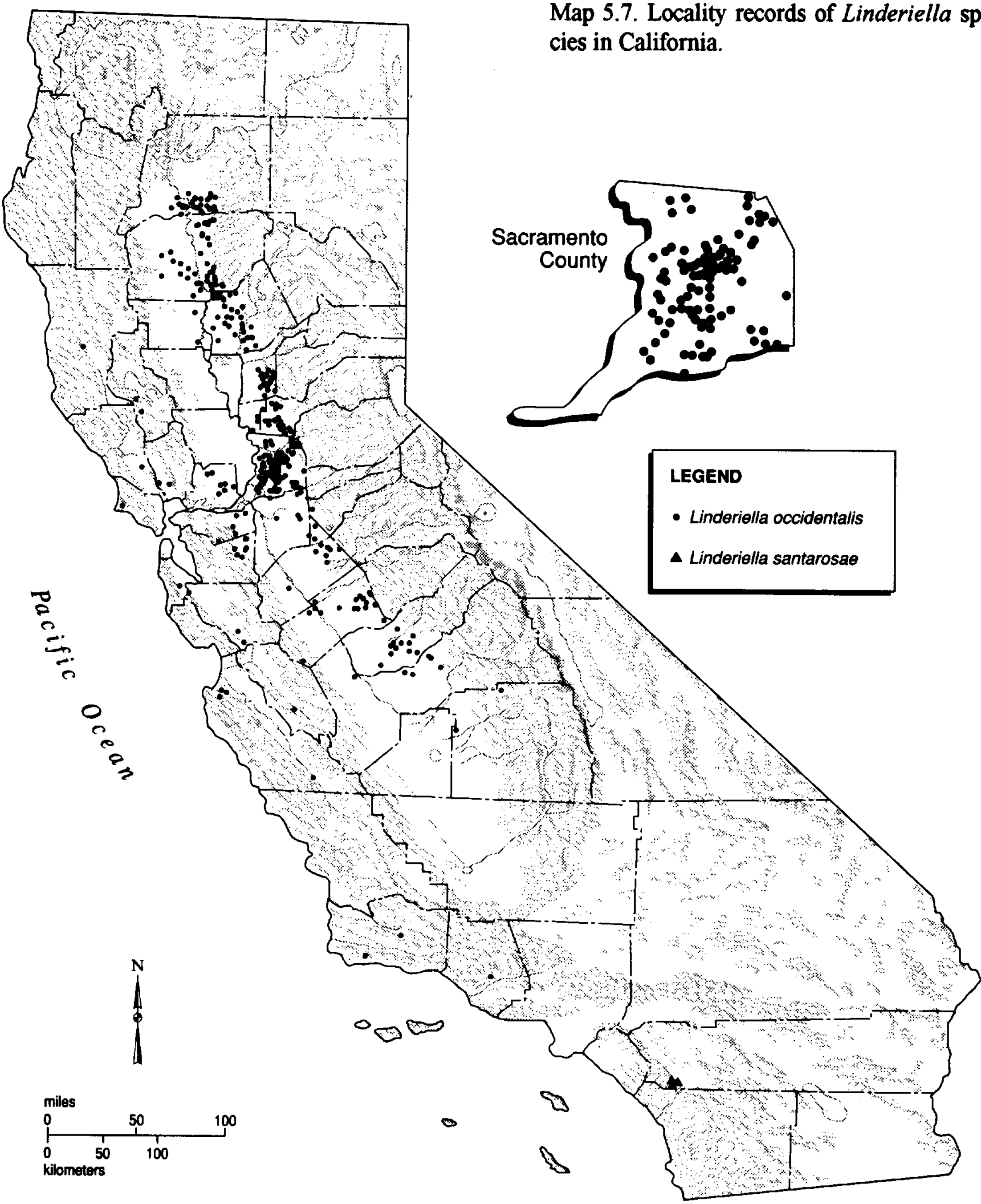
Map 5.5. Locality records of *Branchinecta dissimilis* and *B. longiantenna* in California.



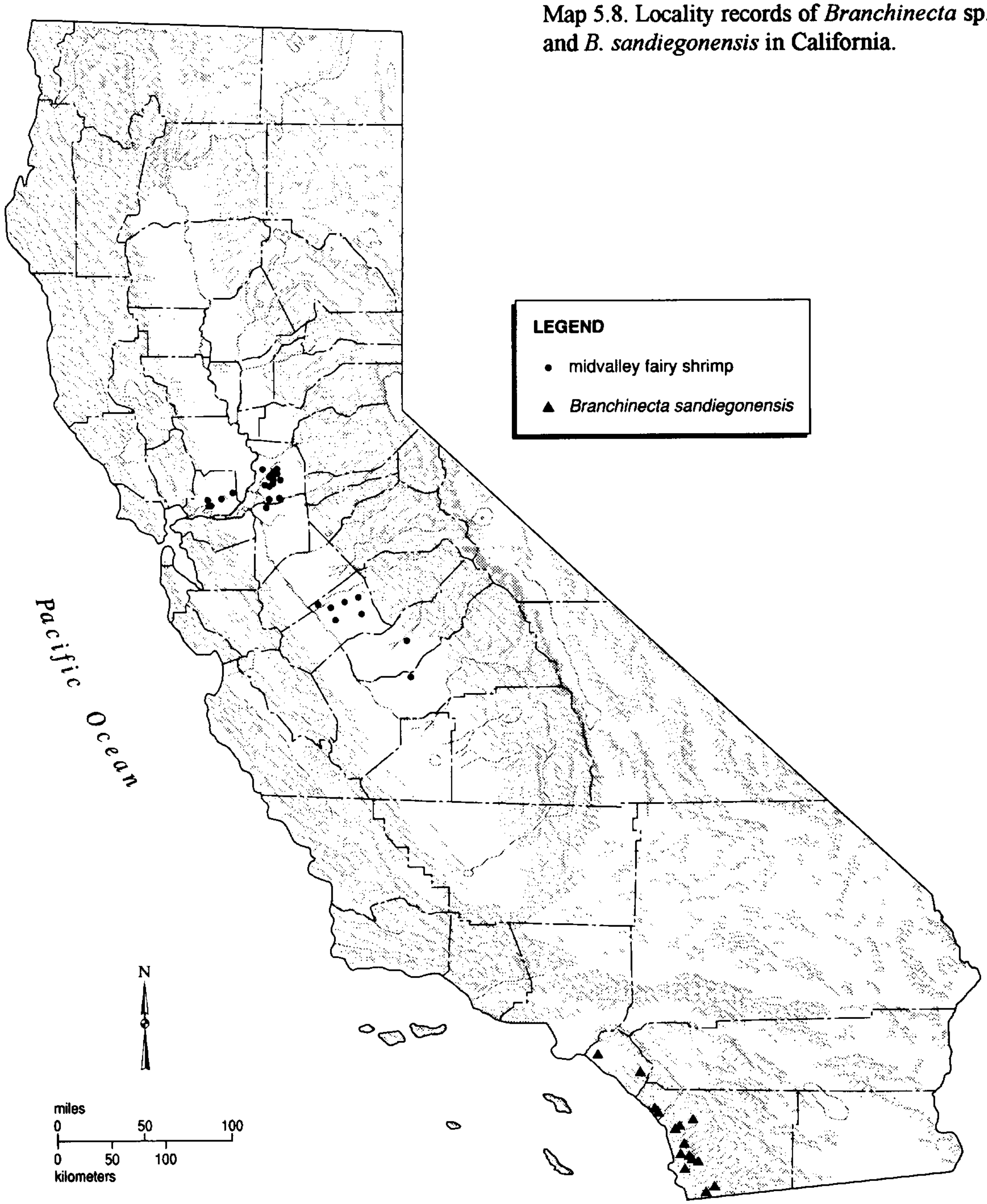
Map 5.6. Locality records of *Branchinecta conservatio* and *B. gigas* in California.



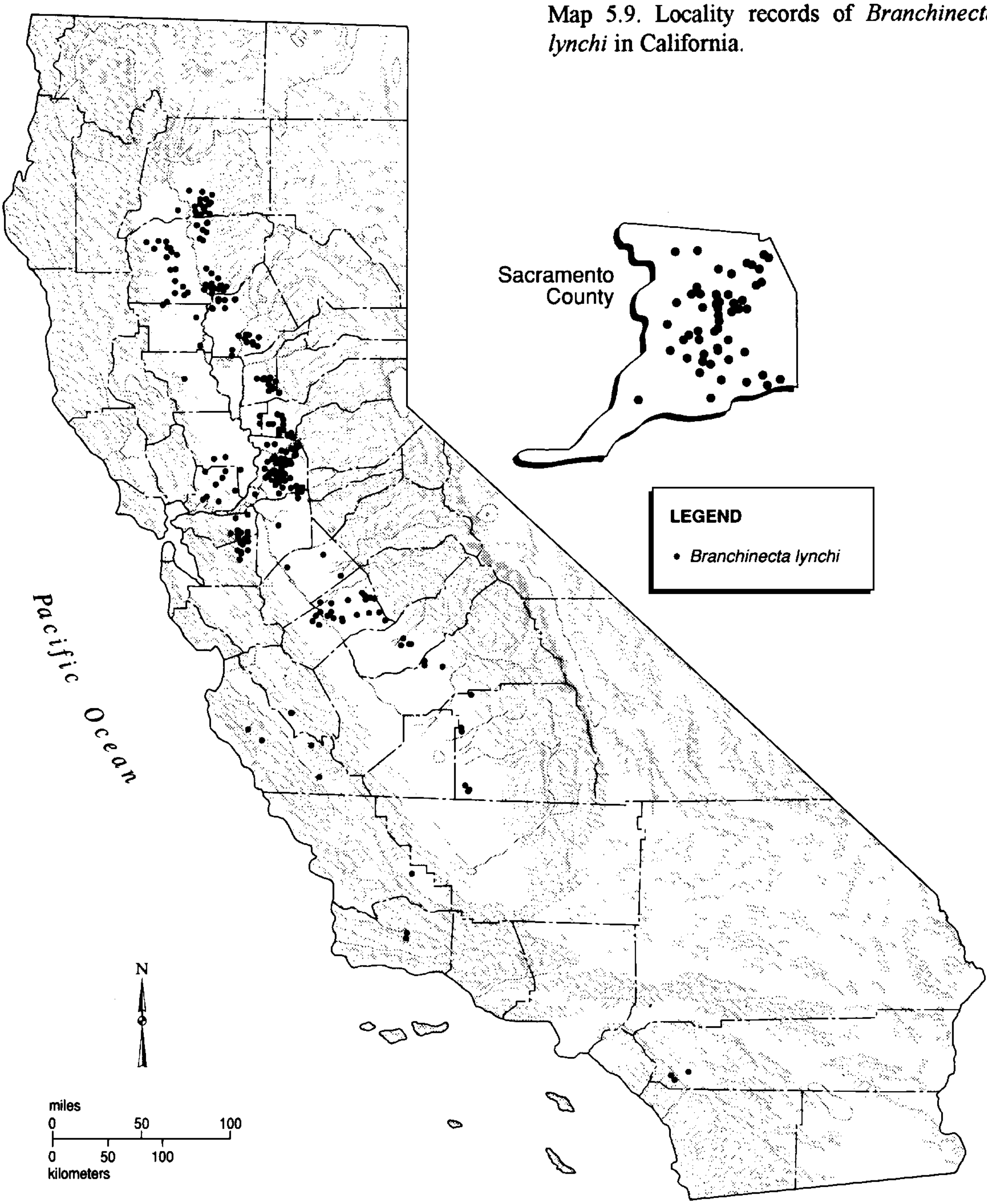
Map 5.7. Locality records of *Linderiella* species in California.



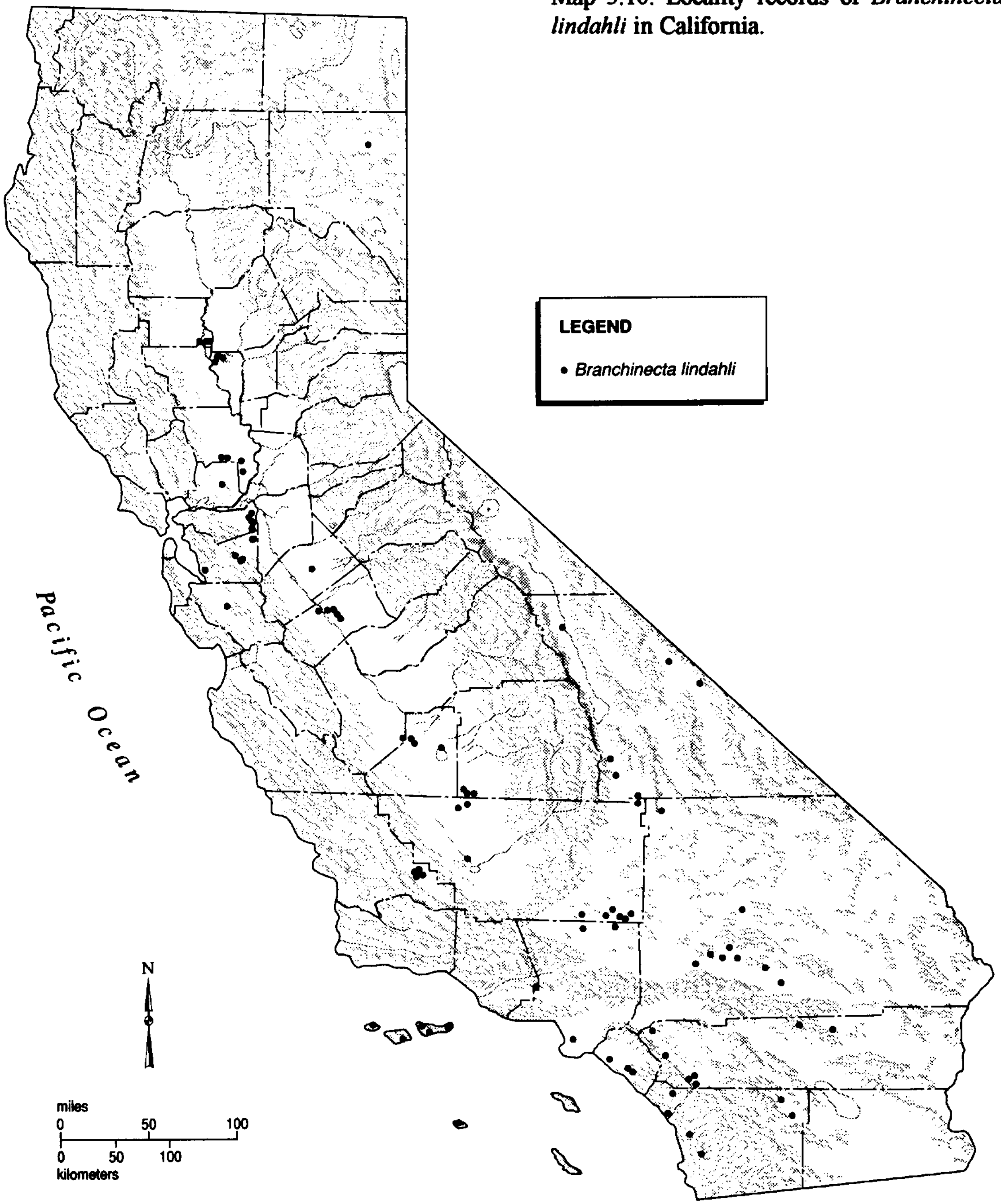
Map 5.8. Locality records of *Branchinecta* sp. and *B. sandiegonensis* in California.



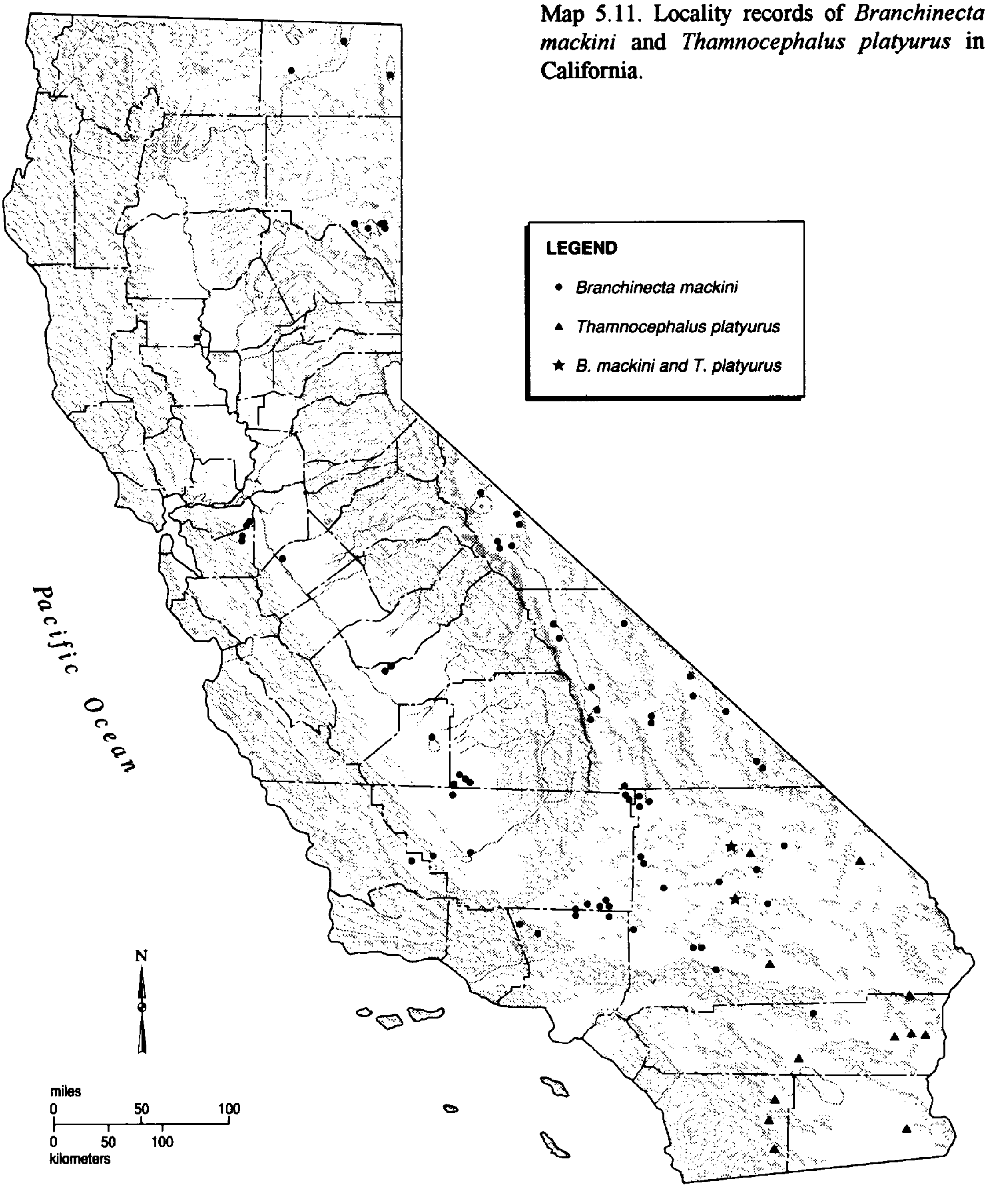
Map 5.9. Locality records of *Branchinecta lynchi* in California.

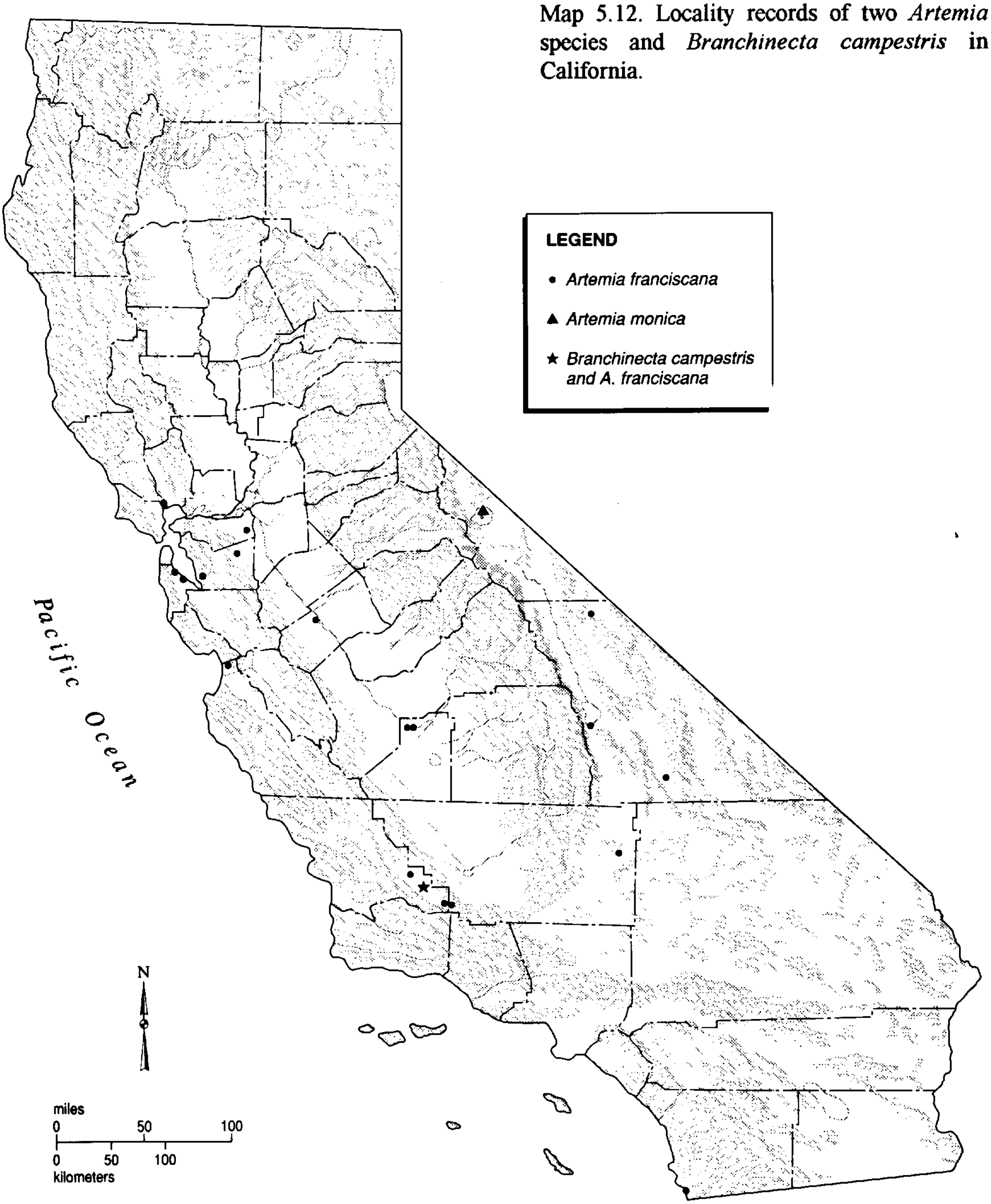


Map 5.10. Locality records of *Branchinecta lindahli* in California.



Map 5.11. Locality records of *Branchinecta mackini* and *Thamnocephalus platyurus* in California.





Map 5.12. Locality records of two *Artemia* species and *Branchinecta campestris* in California.

Chapter 6

STATUS, INCLUDING ENDANGERMENT, AND CONSERVATION

The degree of threat facing any particular fairy shrimp species is directly related to the extent of its range and desirability of its habitat for conversion to human uses that are destructive to seasonal wetlands. Widespread species which live in high mountain pools or periodically inundated basins in the most inhospitable reaches of desert landscapes are the fortunate ones. They tend to enjoy the obscurity and security of never making it onto the list of threatened or endangered species. Cases in point are a number of California's rare, though not endemic, fairy shrimps and include *Branchinecta campestris*, *B. gigas*, *Eubranchipus bundyi*, *E. oregonus*, *Streptocephalus dorothae*, and *S. texanus*. On the other hand, *Branchinecta conservatio*, *Branchinecta longiantenna*, *Branchinecta sandiegonensis*, and *Streptocephalus woottoni*, which have limited ranges within land forms highly desirable for agriculture and urban development, hold the dubious distinction of having their names emblazoned on the U.S. Fish and Wildlife Service's roster of endangered animals. The larger range and broader ecological scope of *Branchinecta lynchi* resulted in it being assigned to the threatened category. Strong political opposition kept *Artemia monica* off the Federal Endangered Species List long enough for a resolution of the water needs of its habitat to be worked out, and delayed the listing of *Branchinecta sandiegonensis* until February of 1997 (Federal Register 1997).

The intrigue swirling around *Artemia monica* and its habitat is interesting indeed. The story began in the forties with the initial diversions of water to Los Angeles from the supplies that would normally have maintained the species' only home, Mono Lake. The result was a gradual lowering of the lake's level and, at its extreme, an approximate doubling of its salt content. For a number of reasons, including the fact that increasing salinity began to reduce the reproductive rate of *A. monica*, the Federal Government designated Mono Basin a National Scenic Area, and the courts ordered the rewatering of Mono Lake's inlet streams, and thus the lake itself. Now that the future looks better for Mono Lake and its inhabitants, pursuing endangered status for *Artemia monica* has been put on hold.

With regard to *Branchinecta sandiegonensis* and its living sites, careful studies of old maps revealed that by the mid-1980s over 97% of vernal-pool habitat in San Diego County had been destroyed by development (Bauder 1986). With its range restricted to coastal mesas of San Diego County and small sections of Orange County and northern Baja California, Mexico, it was clear that *B. sandiegonensis* was in serious trouble, thus its Federal listing as endangered. Survival of this species depends on the outcome of actions, large and small, of agencies and individuals. The largest is the U. S. Fish and Wildlife Service's proposed San Diego National Wildlife Refuge. A high-priority goal of this proposal is to "protect the remaining vernal pool habitat". A smaller action is the relocation of soils from a vernal pool on an Albertson's Supermarket construction site to the safety of a basin created on the campus of Mt. Woodson School in Ramona, California. These efforts were spearheaded by Alisha Pentis, a Mt. Woodson School student and Science Club member, with the aid of her environmental-activist parents. Thanks to those involved, this reconstructed vernal pool will continue to provide hands-on learning experiences for students at the school and, we hope, remain a continuing home for a once doomed population of *B. sandiegonensis*.

We use the word "hope" because building a basin and filling it with tap water is one thing, making it work long-term is another. A pool is truly a complex place, and humans know and understand few of those complexities! Although some pools made for purposes of mitigation seem to have functioned for a few years, there are many which have ultimately failed. One case in point was spread across several pages of the July 10, 1995 edition of the *L.A. Times* (Miller 1995). The article noted that CalTrans threw nearly a million dollars at creating an 18-acre wetland near the southern California town of Moorepark. After a time, they found that sediment build-up would eliminate the wetland in 20 years. Their scientist in charge, Paul Caron, was quoted as saying "Like most biologists in the state and nation, I firmly believe that creating wetlands should be a last-ditch alternative. A lot of people seem to think it's easy to do. But it is extremely detailed and complex." The problem for society and the future, though, lies in his comment that "Our obligation to this project is essentially over.... We've satisfied our mitigation requirements". Our shorthand for such remarks is that knowledgeable individuals are concerned about long-term outcomes, while agencies, businesses, governments, and landowners all too often involve themselves with short-term solutions that suffice only to relieve their responsibilities if not their consciences.

A final important thought is that a pool is not an entity unto itself. Substantiating evidence is gained from experiences, particularly on the Bernard Biological Field Station of The Claremont Colleges. One pool created for *Branchinecta mackini* lost its alkali chemicals after about five years, and, as a result, the population ceased to exist. Other pools seemed to suffice for *Streptocephalus woottoni* and *Branchinecta lindahli* as long as plentiful and sequential precipitation put run-off water in their basins. During a time of insufficient rain, tap water was added to maintain the pools; it killed the fairy shrimps. Particularly in the Central Valley, where California Vernal Pools are unique because of their endemic plants, we now know the flora will **not** survive unless **native** bees which pollinate those specific plants are found on immediately adjacent land. The reason for the latter truth is that, unlike honeybees, these bees fly only short distances. Suffice it to say, that constructing a basin which merely impounds water probably provides few of the necessities, let alone amenities, required by the bevy of organisms inhabiting specific life-giving pools.

Returning to the real world of real pools, The Nature Conservancy provides protected habitat for three of the five Federally-listed fairy shrimps, all California species. The type locality for *Branchinecta conservatio* is the large Olcott Pond, a vernal pool on the Jepson Prairie Preserve. Additional populations swim in protected habitats on the Vina Plains Preserve. *Branchinecta lynchi* may also be found living on the latter preserve, but in separate, typically smaller, basins. In addition, *B. lynchi* dwells unmolested, except by normal ecological pressures, in pools at the Conservancy's Santa Rosa Plateau Preserve, and possibly on the Carrizo Plain Preserve as well. Basins in the latter swatch of land also give protection to one of California's rarest fairy shrimps, *Branchinecta longiantenna*. But the rarest of them all, *Linderiella santarosae*, is saved from being listed as an endangered species because its entire range is contained within The Nature Conservancy's Santa Rosa Plateau Preserve.

The same three federally listed species that find sanctuary on The Nature Conservancy lands are also found in vernal pools at a number of National Wildlife Refuges. These include Kesterson NWR for *B. longiantenna*; Sacramento NWR, San Luis NWR, Kesterson NWR, and Arena Plains NWR for *B. conservatio*; and all the above refuges, in addition to the Pixley NWR, for *B. lynchi*.

The only listed fairy shrimps not yet found on lands managed to save natural habitats, and thus the species, are *Branchinecta sandiegonensis* and *Streptocephalus woottoni*. Such a situation puts these species at greater risk than the others currently receiving federal protection. In what is potentially a helpful circumstance, both *B. sandiegonensis* and *S. woottoni* are now known from sites at Camp Pendleton, a U.S. Marine Corps facility in San Diego County. And if the San Diego NWR comes on line, further habitat protection will be realized.

Well-managed ranch land generally supports good fairy shrimp habitat. Loss of range land to "higher development" of course constitutes a loss of pools and their fairy shrimp inhabitants. In addition to development, invasive species often endanger native wildlife, including fairy shrimps. Foreign annual grasses, and even native vegetation, threaten vernal pool habitats by ultimately choking them with accumulated plant litter if it is not harvested or removed by herbivores. Barry (undated) presents photographic evidence supporting the role of grazing in protecting vernal pools from invasive weeds and native vegetation. In Germany, army tanks have been documented performing the role of reducing vegies and maintaining open water necessary for the support of some anostracans (Hössler *et al.* 1995). And guess what? Never to be outdone, California too has its tanks maintaining fairy shrimp habitat...on the Camp Pendleton Marine Corps Base near Oceanside in San Diego County.

Only time and public support will determine whether anostracans will continue to live scattered broadly across the California landscape, or if one day they will be relegated only to nature reserves, cyst banks, museum collections, and pictures in books like the one in which you are presently absorbed.

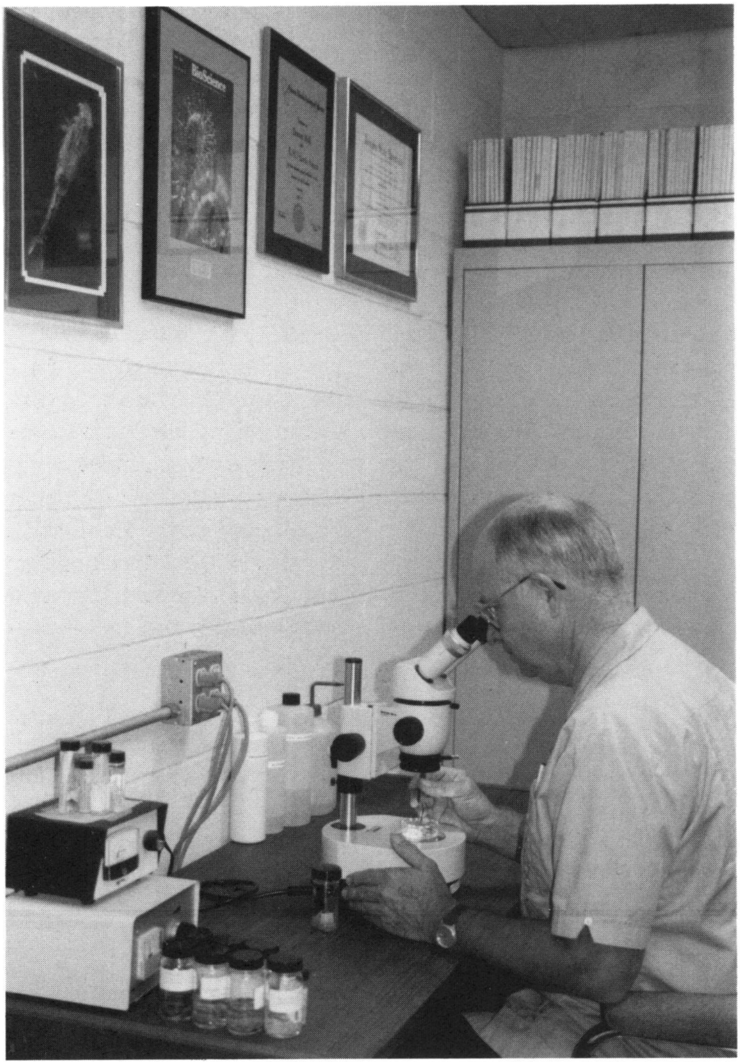


Fig. 7.0. Denton identifying a fairy shrimp.

Chapter 7

HOW TO KNOW THE CALIFORNIA FAIRY SHRIMPS

Introduction

At one point or another we all want to pin a name on what is before us. In order to do so, that is to identify a particular organism, biologists "key it out". A KEY is constructed so that you may work your way through a series of choices, each with only two alternatives. Our key for the fairy shrimps of California is designed to be used only with mature animals. Females show the best indicator of maturity because their brood pouches are conspicuously filled with brownish-shelled cysts. However, the key is based on male characters because only with mature males can identification be made with confidence. Luckily, both sexes reach maturity at the same time, so if you see a female carrying cysts, you know the males are mature. Checking female traits is desirable, and will increase accuracy in a few cases, but one cannot normally identify a species utilizing only female characteristics.

Be alert to the fact that some collections may be a mixture of species, and perhaps generations also. Different species of fairy shrimps may hatch at different times under different stimuli, and maturation rates may vary as well. Not only that, as the water level of a pool recedes, cysts, caught in the desiccating ring of mud, may hatch should the pool refill, thus providing a second generation (cohort) to swim with the remainder of the previous population(s). The result is that while you usually have but one mature species in your collection, at times there may be more than one. Males and females of the same generation will be approximately the same size. However, adult size, usually 15-30 mm, may vary with environmental conditions. It's that old adage "you are what's in your genes"...as modified by environment.

There are three ways to find the meaning of terms and location of parts mentioned in the key. One is to check the Figure(s) referred to in the key where you first encounter the unfamiliar item. The second is to look in this book's Glossary for technical terms. The third applies to words of "standard usage" and involves joy-reading in your favorite dictionary.

Drawings for the key were constructed to satisfy not only a real taxonomist (Denton), but also several who consider themselves novices at such an art-form (Clyde, and our artist Ina Rae Lengyel). Denton then field-tested our product at a number of workshops. Student "feed-back" was really helpful in working out rough spots.

When examining a preserved fairy shrimp you will often see what appear to be two lines around the periphery of its surfaces. Preservation causes the body wall to separate from its cuticle (exoskeleton) so we have faithfully represented this appearance in several of the drawings, but do realize that if you view a living specimen, you will see only one line.

Friendly advice has it that you should NOT attempt to take short-cuts with the key. Begin at the beginning, for that is the way it was designed to be used! Make a choice between the alternatives in the first couplet (1a or 1b). If, when you arrive at a distant couplet and decide you need to go back to where you came from and review your options, the number and letter in parenthesis to the right of the couplet number tells you "where to go". This format is continued throughout. When you are fully familiar with the key you may occasionally want to match your material with one of the drawings and then work backwards, checking to be sure your specimen has all of the characters itemized. As a final comment, you may wonder about the meaning of the name(s) and date immediately following each scientific name. This is typical scientific format identifying the scientist(s) who described the species and the year in which the author(s) perpetrated the deed.

Key

1 **a.** Cercopods fused to sides of telson and lateral abdominal ridges (Fig. 7.1A) **2**

b. Cercopods not fused to sides of telson or lateral abdominal ridges; cercopods attached only to posterior border of telson (Figs. 7.1B, 7.2A,B) **3**

2(1a) **a.** Branch 1MD of frontal appendage (see "frontal appendage" in Glossary) conical with a distinct spine on its medially directed terminus; branch 2D with three subbranches (Fig. 7.3)

Thamnocephalus platyurus **Packard, 1879**

Note: Only one other species of *Thamnocephalus* is known from North America, *T. mexicanus*, the Mexican beavertail fairy shrimp. Populations of *T. mexicanus* occur in southern Arizona (Belk 1977a). Branch 1MD of *T. mexicanus* is flat, broad, and leaf-like; branch 2D has four or five subbranches, the proximal one being very short and small (see Belk & Pereira 1982).

3(1b) **a.** Cercopods long tapering cones, each with a row of short plumose setae extending most of its length on the ventrolateral surface, and with much longer plumose setae extending from distal end for only about half the distance back to telson on dorsomedial surface (Fig. 7.1B); antennae of female as long as antennae of male (Fig. 4.1); largest species known, adults may reach 150 mm in total length; frontal view of male head in Fig. 7.20

Branchinecta gigas **Lynch, 1937**

b. Cercopods not as above **4**

4(3b) **a.** Distal (second) segment of antenna shifted to ventrolateral position and largely replaced by a distal outgrowth which forms a large folded tube-like limb (peduncle) ending in a cheliform structure (hand) (Fig. 7.4, 7.5, 7.6, 7.7, 7.8)..................... **5**

b. Distal (second) segment of antenna extends ventrally from distal end of basal (first) segment (Figs. 7.10, 7.11, 7.12, 7.20)... **8**

5(4a) **a.** Cercopods of adult male with plumose setae located proximally along both medial and lateral edges and with spines located along both edges distally (Fig. 7.2A,C); shoulder on lateral side of distal tooth less than one-third height of distal tooth (Fig. 7.7) (in Eng, Belk, & Eriksen 1990, fig. 5a is a lateral view, not medial as stated)
Streptocephalus sealii **Ryder, 1879**

b. Cercopods of adult male with plumose setae along entire lengths of both medial and lateral edges **6**

6(5b) **a.** Distal end of spur on thumb shaped similar to a human foot when viewed in profile; finger with a subterminal swollen part lacking spines or processes (Fig. 7.5)
Streptocephalus dorothae **Mackin, 1942**

Note: *Streptocephalus mackini*, the Chihuahua fairy shrimp, differs from *S. dorothae* only in having a slender spine on the lateral surface of the subterminal swollen part of the finger. *S. mackini* occurs in Arizona (Belk 1977a) and may one day be found in California.

b. Spur on thumb tapering to a point (Figs. 7.6, 7.7, 7.8); finger terminating variously
.... **7**

7(6b) **a.** Reflexed end of finger terminating smoothly without a spine, process, or subterminal lateral lamella; distal edge of proximal tooth with a slight to prominent triangular projection; shoulder on lateral side of distal tooth about half as high as distal tooth (Fig. 7.8) (in Eng, Belk, & Eriksen, 1990, fig. 5b is a lateral view, not medial as stated)
Streptocephalus woottoni **Eng, Belk, & Eriksen, 1990**

b. Reflexed end of finger with a subterminal lateral lamella which possesses a projecting lobe; no lateral shoulder on distal tooth (Fig. 7.6)
Streptocephalus texanus **Packard, 1871**

8(4b) **a.** Distal segment of antenna flattened into a wide, roughly triangular blade with apex directed medially (Fig. 7.11) **9**

b. Distal segment of antenna not as above **10**

9(8a) **a.** Occurring in Mono Lake
***Artemia monica* Verrill, 1869**

b. Occurring elsewhere; probably
***Artemia franciscana* Kellogg, 1906**

Note: The genus *Artemia* encompasses a complex of sibling species with no morphological characters useful in separating the North American species. Biochemical characters must be used to establish identity with certainty for any individuals not collected from Mono Lake, or another site where identity has been properly determined – see Browne and Bowen (1991).

10(8b) **a.** Antennal appendages present (Figs. 7.9, 7.10, 7.12, 7.13, 7.14) **11**

b. Antennal appendages absent **15**

11(10a) **a.** Antennal appendage rigid and pyramidal, with spines on its relatively flat medial surface (Figs. 7.9, 7.10) **12**

b. Antennal appendage flexible and lamelliform, with finger-like processes along its edges (Figs. 7.12, 7.13, 7.14) **13**

12(11a) **a.** Tip of antennal appendage relatively straight, with spines on medial surface often extending to tip (Fig. 7.9)
***Linderiella occidentalis* (Dobbs, 1923)**

b. Tip of antennal appendage clearly curled laterally; spines absent from curled tip (Fig. 7.10)
***Linderiella santarosae* Thiéry & Fugate, 1994**

Note: *Linderiella santarosae*, the Santa Rosa Plateau fairy shrimp, is known only from the Santa Rosa Plateau in Riverside County.

13(11b) **a.** Labrum with a knob-like protuberance at anterior end projecting between flanking outgrowths on bases of antennae (Fig. 7.12)
Eubranchipus bundyi **Forbes, 1876**

b. Labrum without a knob-like protuberance **14**

14(13b) **a.** Antennal appendage does not extend beyond distal end of basal segment of antenna, triangular in outline with finger-like processes along both edges of distal half; distal segment of antenna with a short, knobby medially directed process near proximal end (Fig. 7.13)
Eubranchipus oregonus **Creaser, 1930**

b. Antennal appendage longer than basal segment of antenna; shape as in Fig. 7.14 with finger-like processes along both edges of distal two-thirds; a group of about 7 near center of lateral edge much longer than others. Distal segment of antenna with a medially directed process near its proximal end; this process about half as long as distal segment (Fig. 7.14)
Eubranchipus serratus **Forbes, 1876**

15(10b) **a.** Pulvillus (see note below) on medial surface of antenna near proximal end; an apophysis may or may not be present in posteromedial position near proximal end of antenna (Figs. 7.15, 7.19, 7.23, 7.24, 7.25, 7.26) **16**

b. No pulvillus on antenna; basal segment of antenna with an apophysis in posteromedial position near proximal end (Fig. 7.16) **17**

Note: The pulvillus is a mound-like area covered with minute cuticular spinules. It appears as a cloudy or milky patch which is most easily viewed using substage lighting. Removing all the soft tissue and viewing just the exoskeleton may make the pulvillus easier to see. Removal can be accomplished by placing the severed head in a 10% solution of a commercial sodium hypochlorite bleach such as Clorox®.

16(15a) **a.** Basal segment of antenna with a large, conspicuous, spiny bulge near center of medial side, and a small, round pulvillus near proximal end on anteromedial surface; older adult males with an apophysis located posteromedially on basal segment of antenna; apophysis not present in young adult males (Fig. 7.15A)
Branchinecta coloradensis **Packard, 1874**

b. Basal segment of antenna without a large, conspicuous, spiny bulge; males never have an apophysis near proximal end of basal segment of antenna **18**

17(15b) **a.** Antennules of female longer than her antennae; brood pouch lacks outpocketings. Compare end of antenna of male with Fig. 7.16A
Branchinecta mackini **Dexter, 1956**

b. Antennules of female equal to or shorter than her antennae; brood pouch with conical outpocketings in midlateral position (Fig. 7.17); these outpocketings not found in any other branchinectid. Compare end of antenna of male with Fig. 7.16B
Branchinecta campestris **Lynch, 1960**

Note: Males of these two species are morphologically very similar; compare the distal ends of their antennae for specific differences using Fig. 7.16A,B.

18(16b) **a.** Many prominent spines covering more than half of medial surface of basal segment of antenna (Fig. 7.19A,B) **19**

b. Few to no spines on medial surface of basal segment of antenna (Figs. 7.15B, 7.23, 7.24, 7.25, 7.26) **20**

19(18a) **a.** Antennae long enough to reach genital segments; basal segment with an oval pulvillus near proximal end, a band of prominent spines along medial surface from pulvillus to near distal end, and a large patch of low wart-like mounds covering medial surface at distal end (Fig. 7.19A)
Branchinecta longiantenna **Eng, Belk, & Eriksen, 1990**

b. Antennae not long enough to reach genital segments; basal segment with a small pulvillus near proximal end, a band of spines from near center of medial surface to distal end (Fig. 7.19B), and no wart-like mounds
Branchinecta dissimilis **Lynch, 1972**

20(18b) **a.** Basal segment of antenna with a small elongate pulvillus located near proximal end, a small ridge-like outgrowth located near anterior edge of medial surface just distal to pulvillus, and a small, variably developed, mound-like bulge on anteromedial side of basal segment just distal to middle (Fig. 7.15B). Female with dorsolateral processes on thoracic segment 3 (Fig. 7.18B), unlike similar looking female in 23a
Branchinecta lynchi **Eng, Belk, & Eriksen, 1990**

b. Basal segment of antenna with a large, elongate, oval pulvillus near proximal end; the only other outgrowths being small spines which occasionally develop near middle of medial surface, these usually absent (Figs. 7.23, 7.24, 7.25, 7.26). **USE CAUTION AS THE NEXT FOUR SPECIES CAN BE CONFUSED WITH EACH OTHER UNLESS SPECIAL CARE IS EXERCISED** **21**

21(20b) **a.** Distal segment of antenna with only one hump extending above half the total height of its medially bent end (Fig. 7.21A,B) **22**

b. Distal segment of antenna with two unequal humps extending above half the total height of its medially bent end (Fig. 7.21C,D) **23**

22(21a) **a.** Distal segment of antenna increases in width up to level at which end bends medially (Figs. 7.21A, 7.23); female with two dorsolateral conical processes on each side of thoracic segments 3 and 5-8 (Fig. 7.22A)
Branchinecta sandiegonensis **Fugate, 1993**

b. Distal segment of antenna constricted near level at which end bends medially (Figs. 7.21B, 7.24); female with only one dorsolateral conical process on each side of a variable number of thoracic segments (Fig. 7.22B)
Branchinecta lindahli **Packard, 1883**

23(21b) **a.** Distal segment of antenna with a large anterior hump and a small posterior hump on distal edge of its medially turned end (Figs. 7.21C, 7.25). Female lacks dorsolateral processes on thoracic segment 3 (Fig. 7.18A), unlike similar looking female in 20a
midvalley fairy shrimp (Belk & Fugate in review)

b. Distal segment of antenna with a small anterior hump and a large posterior hump on distal edge of its medially turned end (Figs. 7.21D, 7.26).
Branchinecta conservatio **Eng, Belk, & Eriksen, 1990**

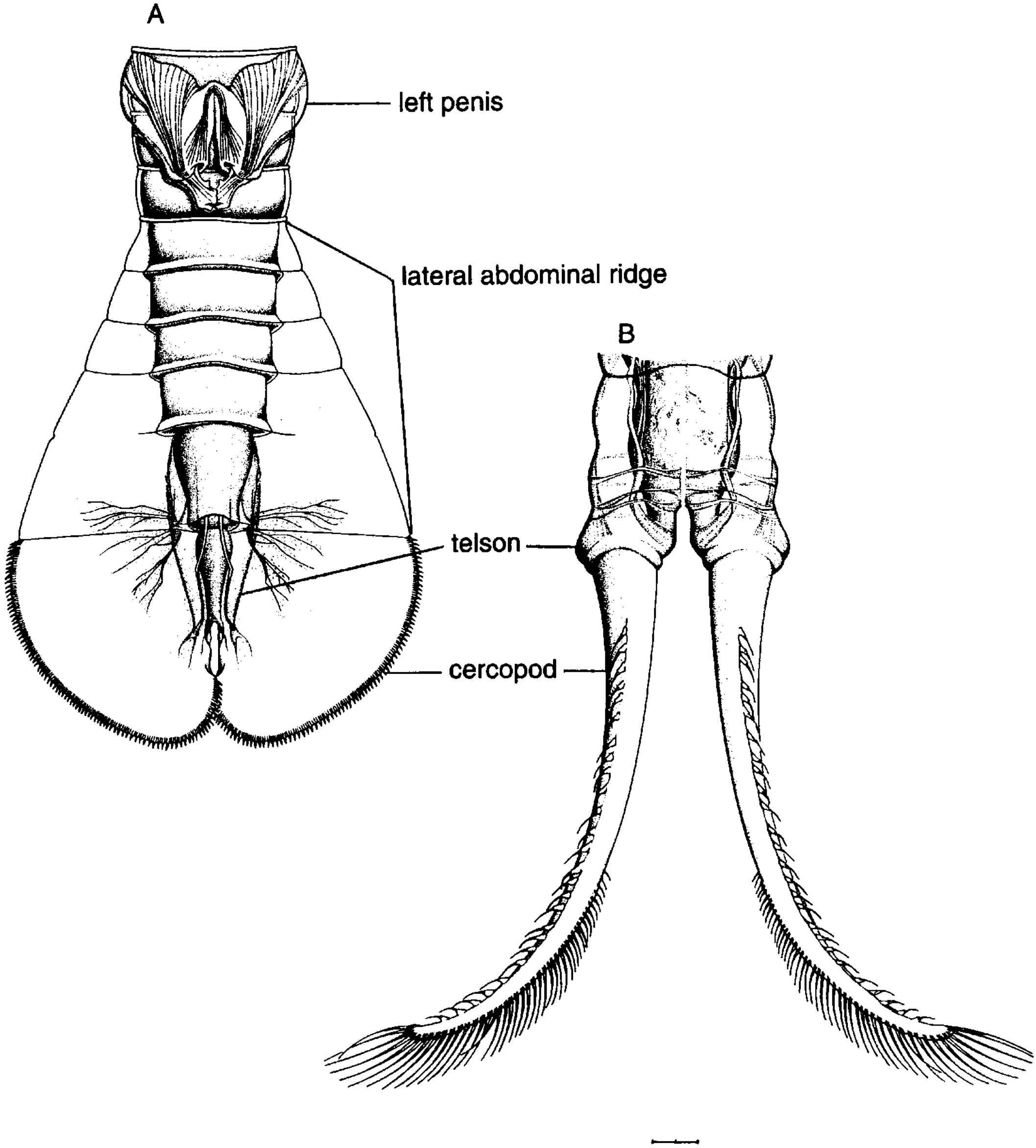


Fig. 7.1. **A.** *Thamnocephalus platyurus*, ventral view of genital segments, abdomen, and cercopods of a male. **B.** *Branchinecta gigas*, ventral view of telson and cercopods. Enlarged view of setae in Fig. 7.27 p. 166. Scale = 1 mm.

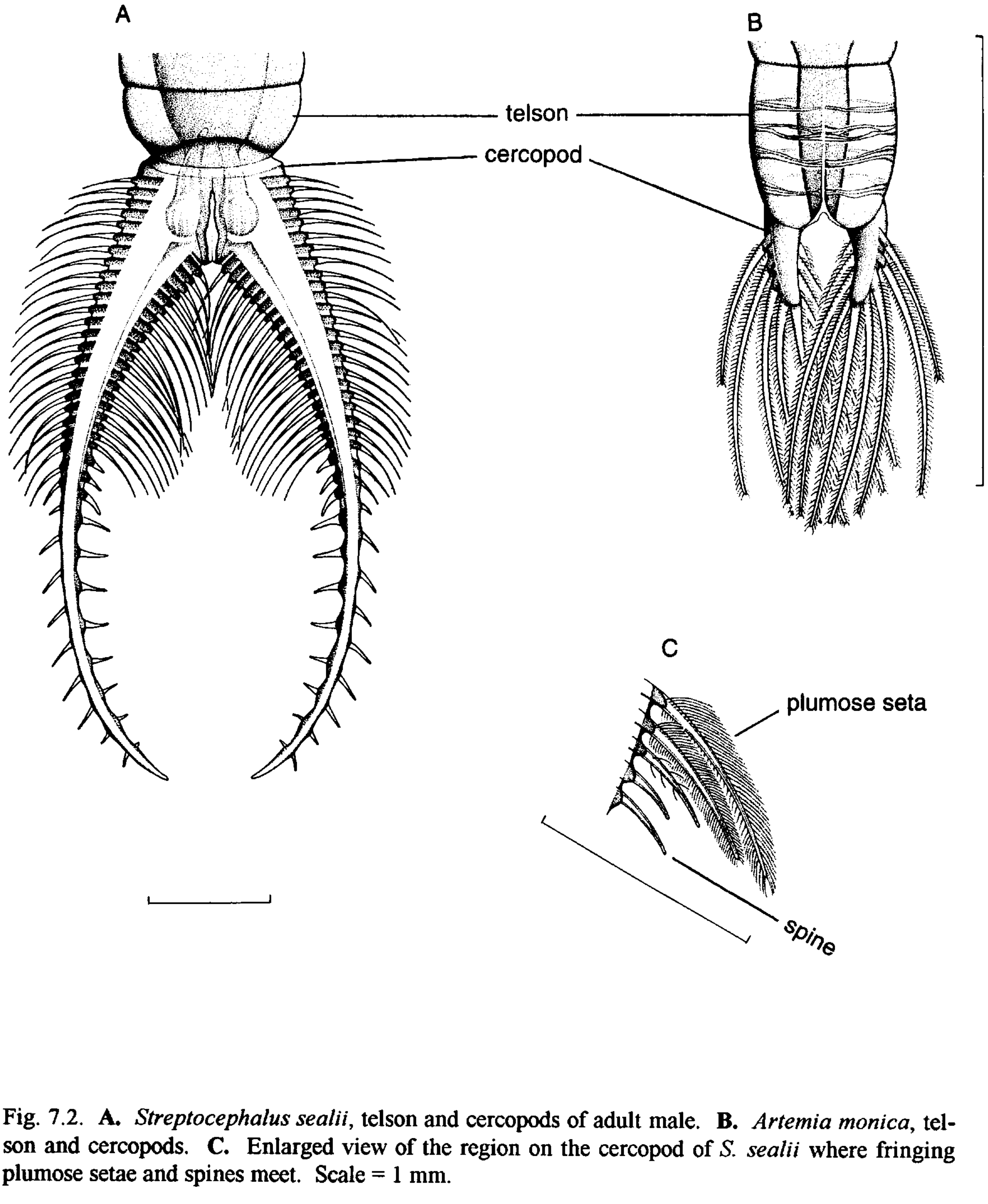


Fig. 7.2. **A.** *Streptocephalus sealii*, telson and cercopods of adult male. **B.** *Artemia monica*, telson and cercopods. **C.** Enlarged view of the region on the cercopod of *S. sealii* where fringing plumose setae and spines meet. Scale = 1 mm.

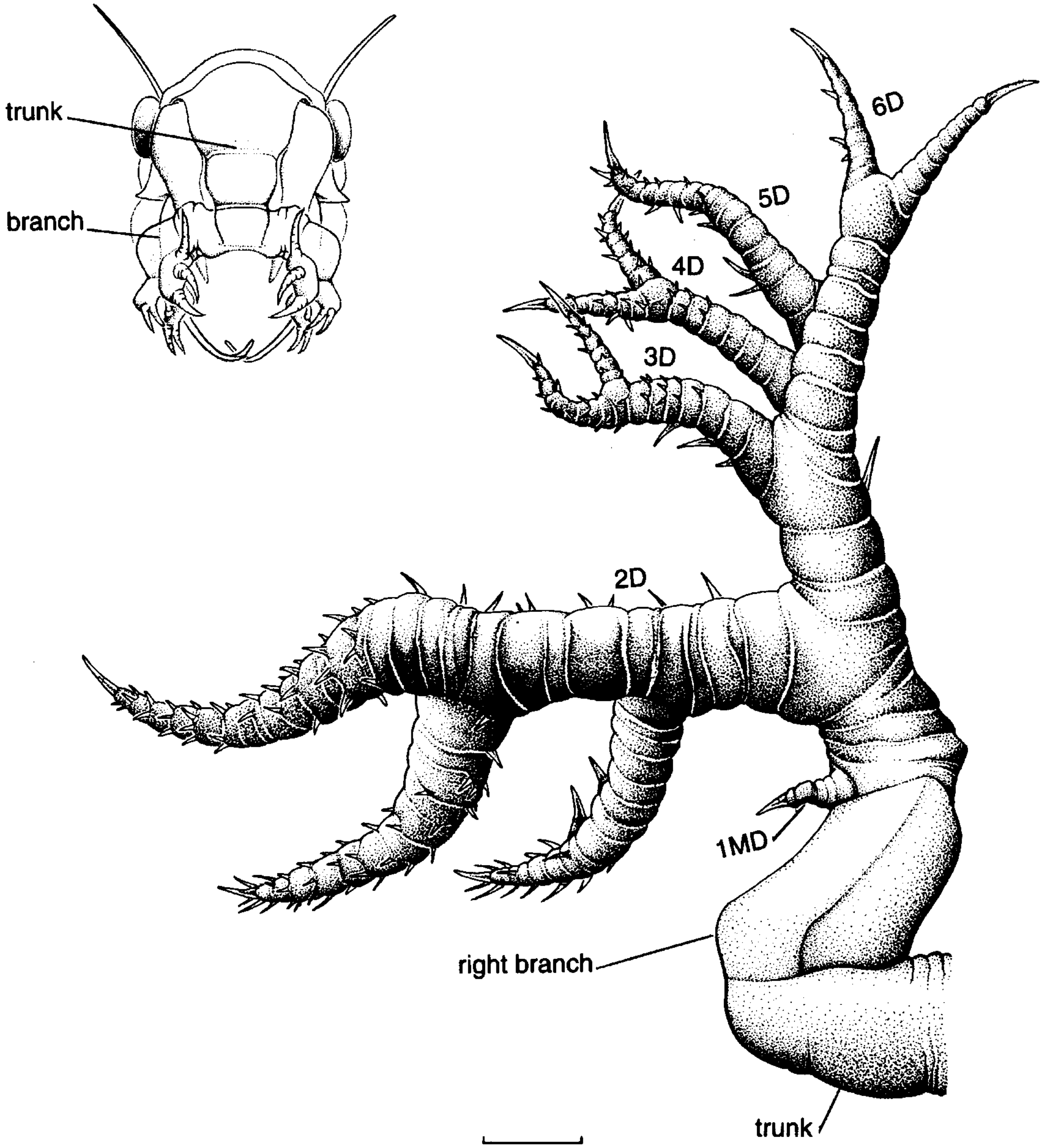


Fig. 7.3. *Thamnocephalus platyurus*, lateral view of the trunk and right main branch of the frontal appendage, branches extend from dorsal surface. The insert shows how the frontal appendage is situated on the male's head. Scale = 1 mm.

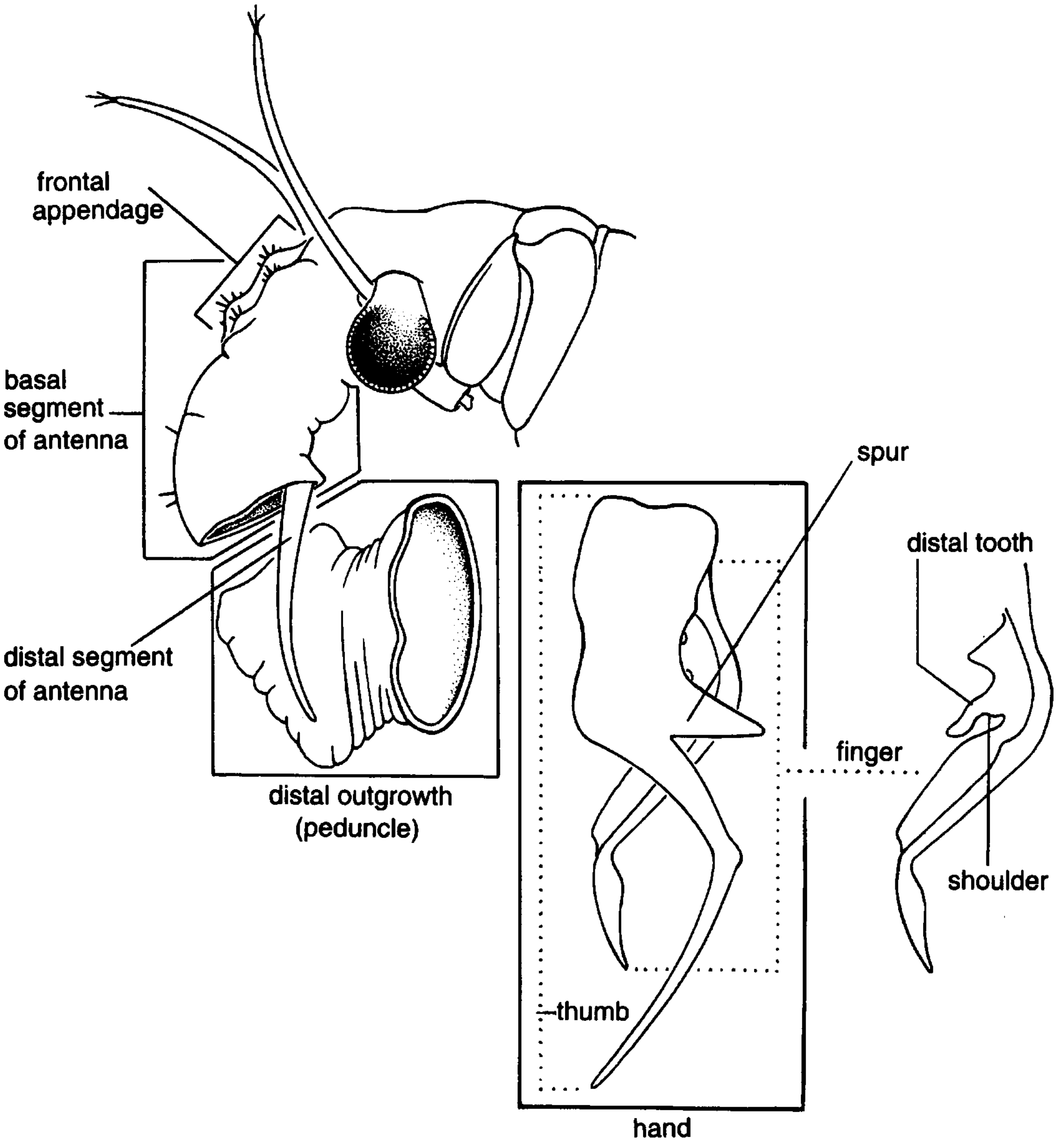


Fig. 7.4. Schematic of *Streptocephalus sealii* showing head and antennal structures of males in the genus *Streptocephalus*; drawn in lateral view. For the intact view, see Fig. 7.7 p. 146.

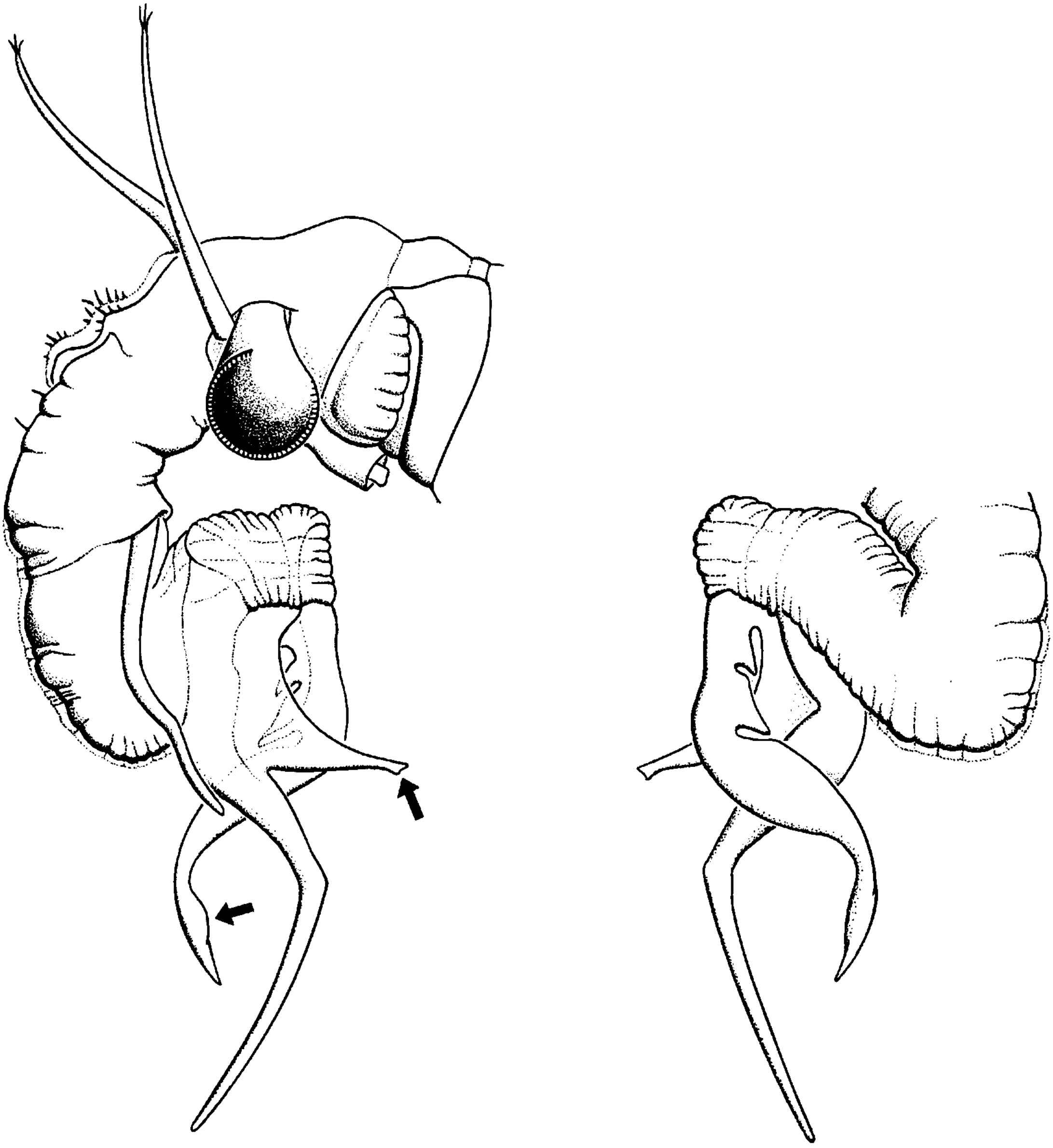


Fig. 7.5. *Streptocephalus dorothae*, lateral view of male's head, and medial view of distal outgrowth and hand. Check Fig. 7.4 for names of structures.

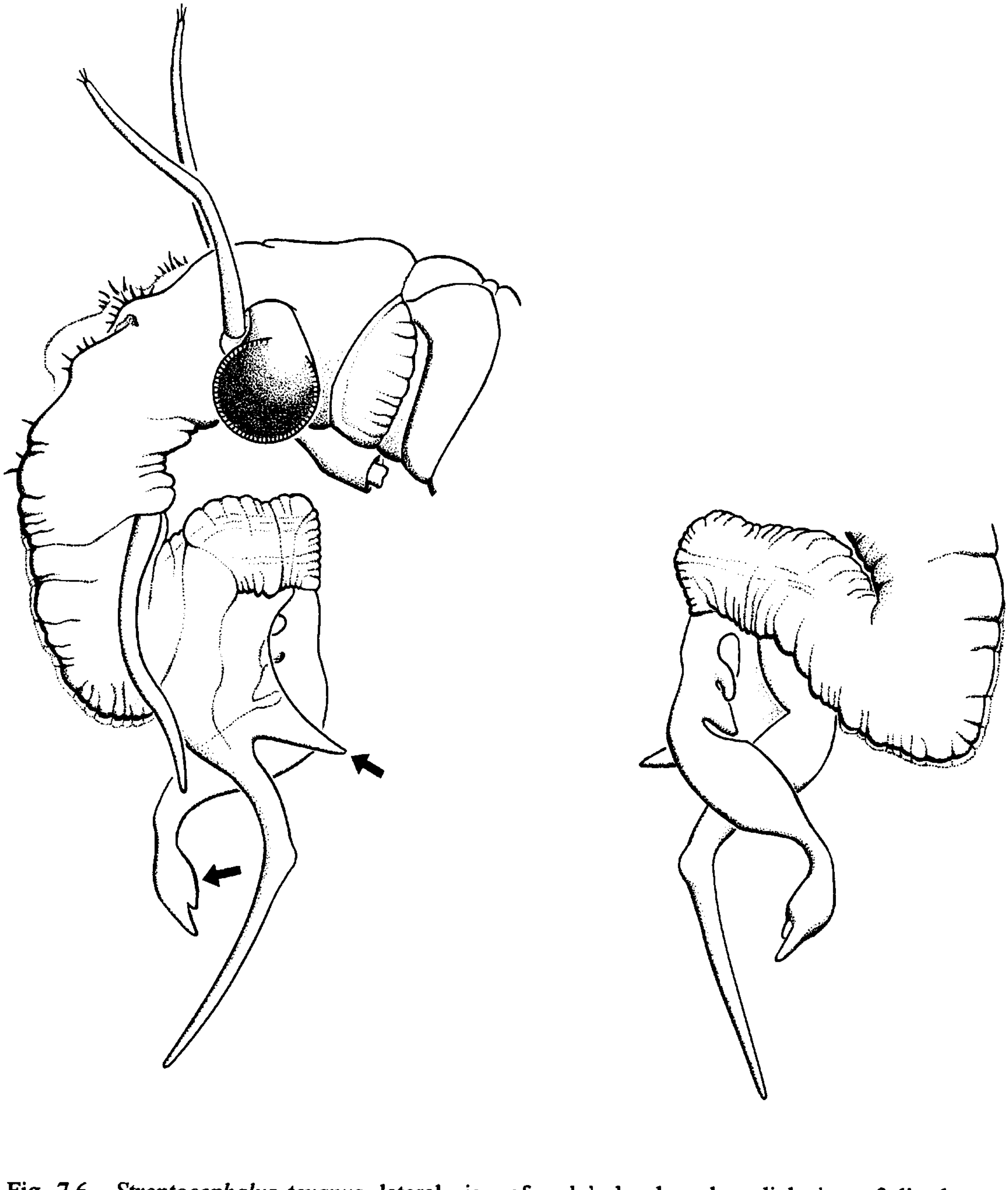


Fig. 7.6. *Streptocephalus texanus*, lateral view of male's head, and medial view of distal outgrowth and hand. Check Fig. 7.4 for names of structures.

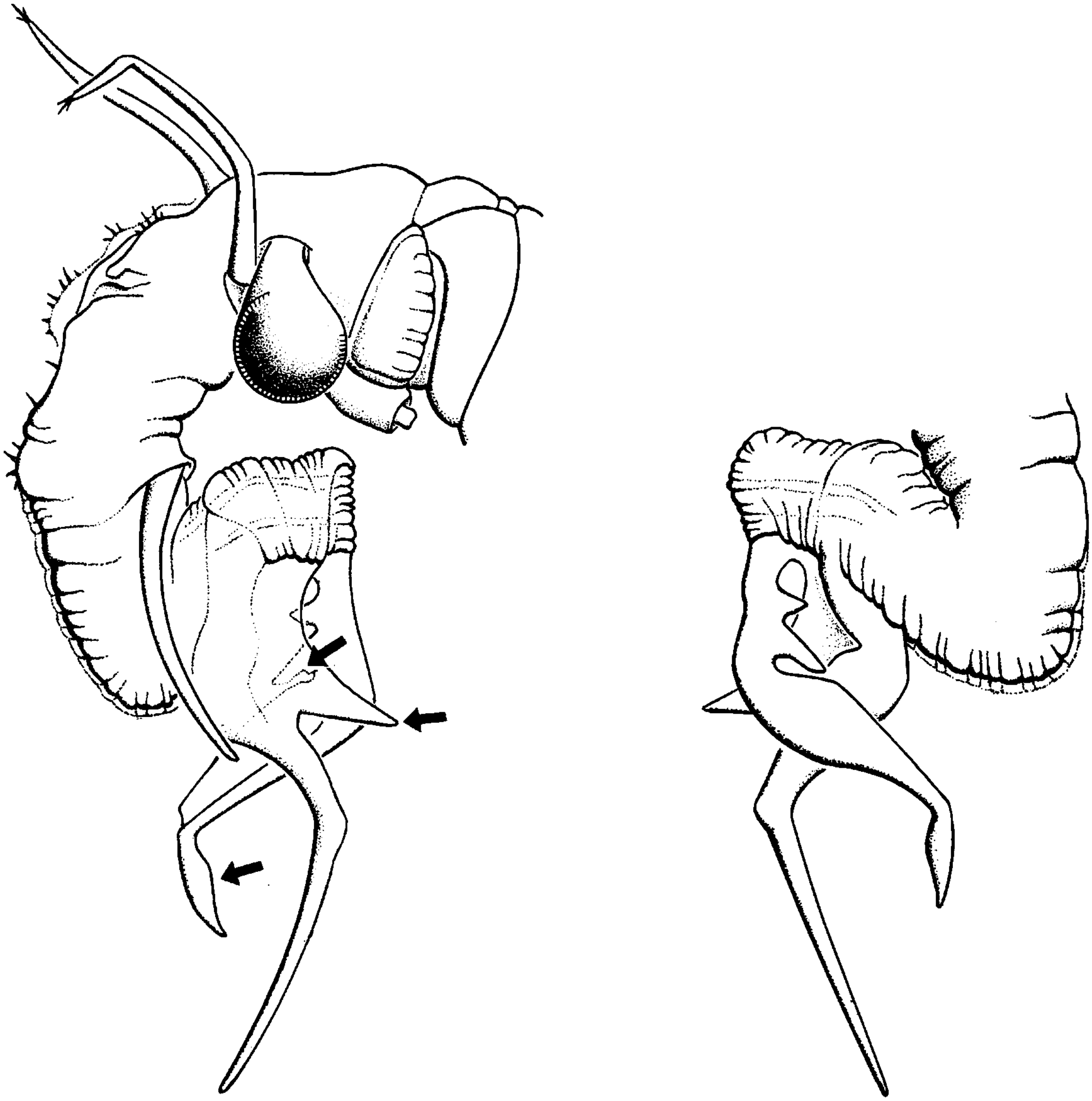


Fig. 7.7. *Streptocephalus sealii*, lateral view of male's head, and medial view of distal outgrowth. Check Fig. 7.4 for names of structures.

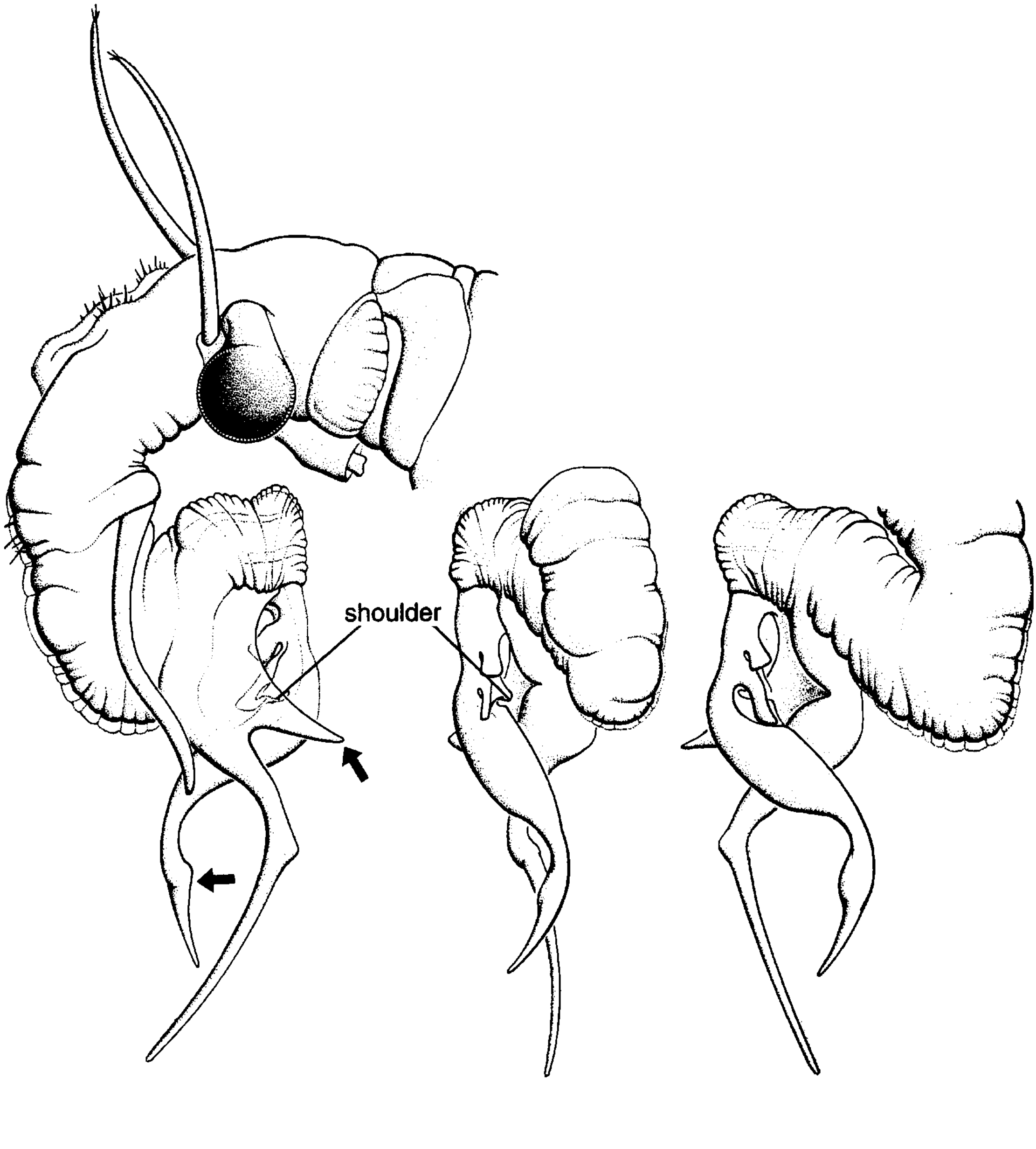


Fig. 7.8. *Streptocephalus woottoni*, lateral view of male's head, and dorsomedial and medial views of distal outgrowth and hand. Check Fig. 7.4 for names of structures.

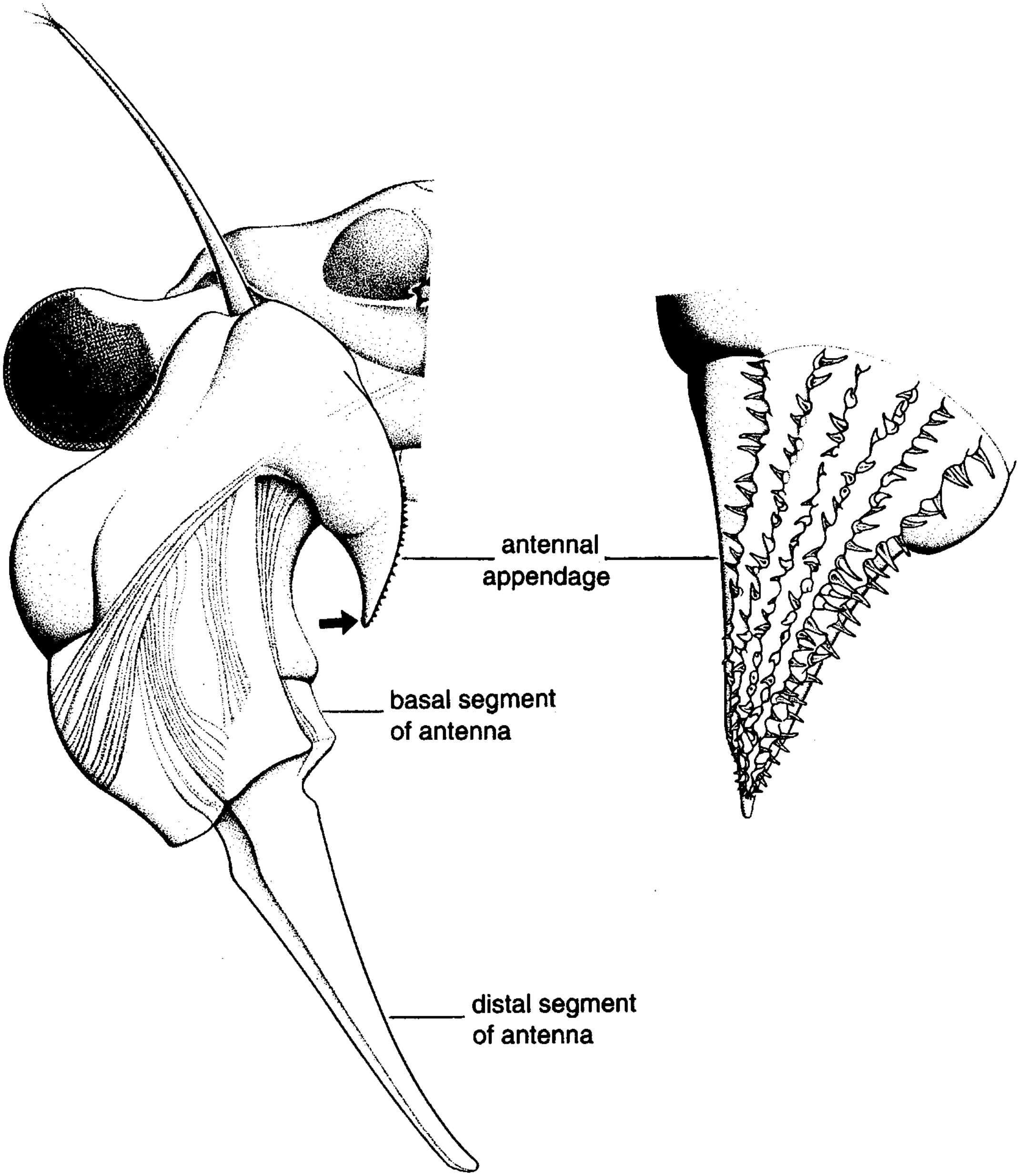


Fig. 7.9. *Linderiella occidentalis*, frontal view of male's head (right half, for view of intact head see next page), and enlarged view of medial surface of the antennal appendage.

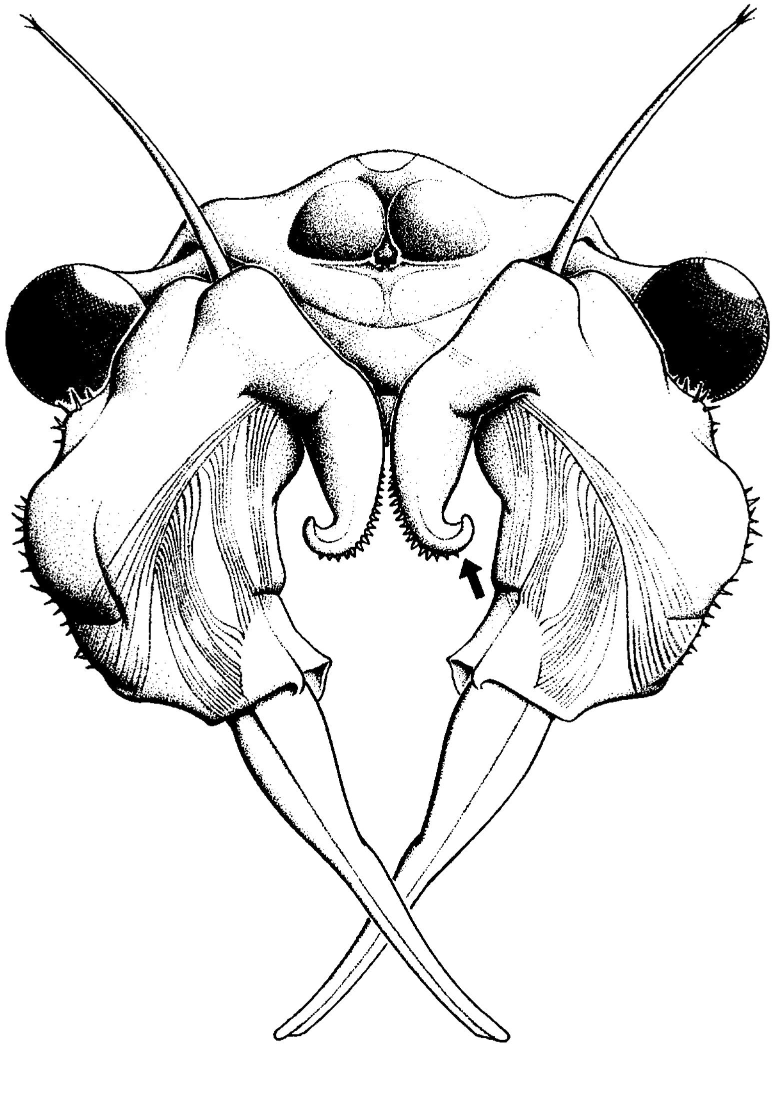


Fig. 7.10. *Linderiella santarosae*, frontal view of male's head.

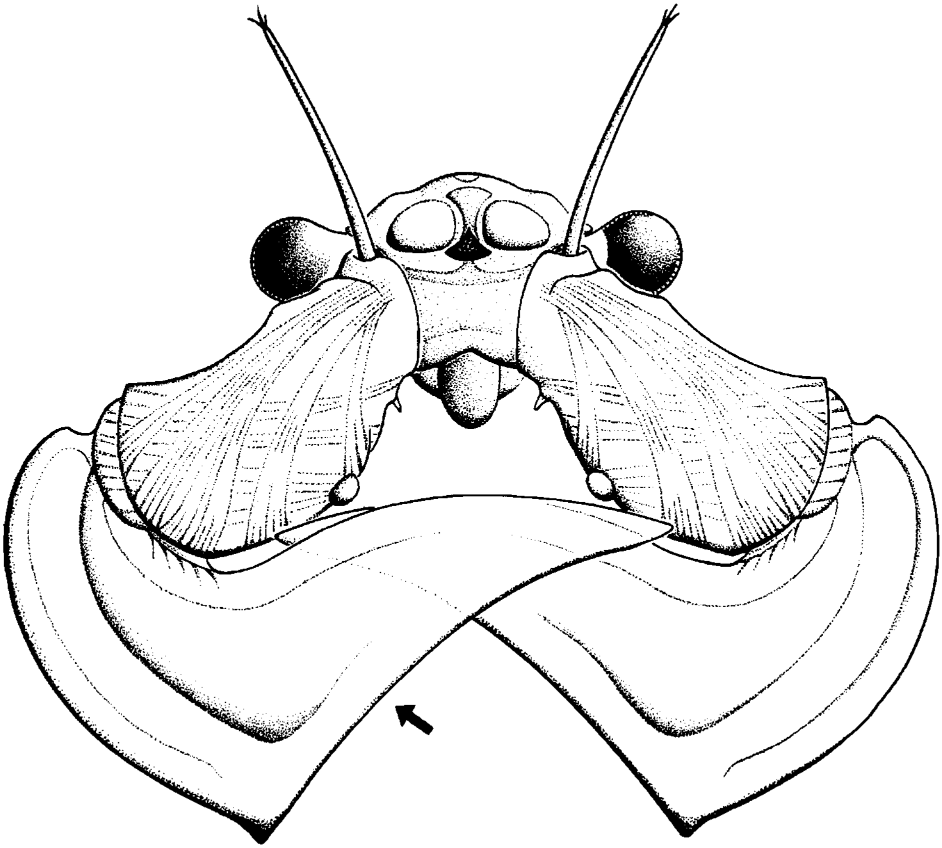


Fig. 7.11. *Artemia monica*, frontal view of male's head showing the triangular medial extension of the distal segment of the antennae common to all members of the genus *Artemia*.

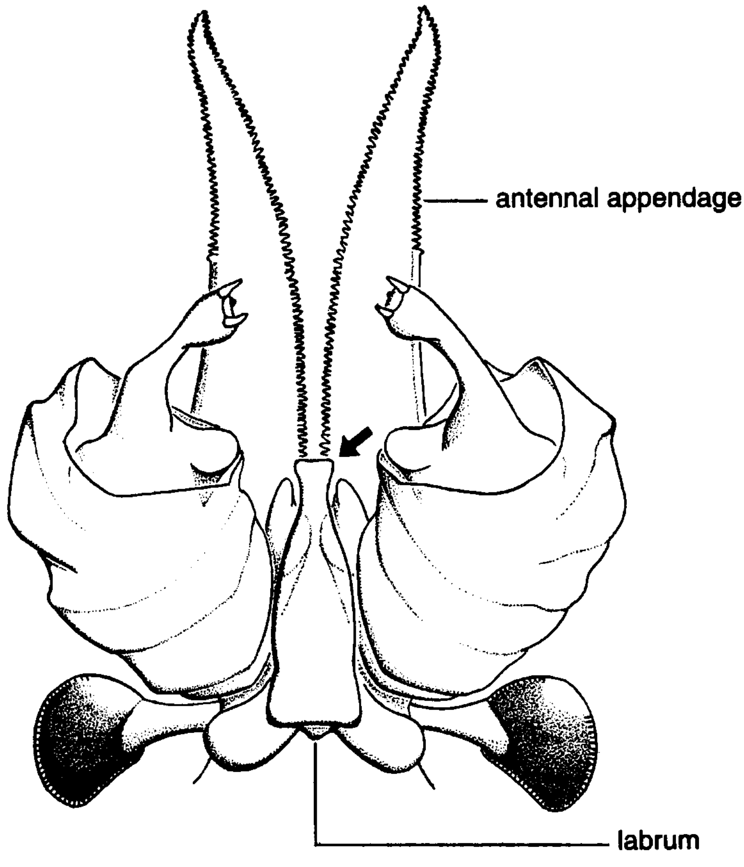


Fig. 7.12. *Eubranchipus bundyi*, ventral view of male's head with antennal appendages unrolled and extended, and view of labrum showing its unique anteriorly placed knob-like extension.

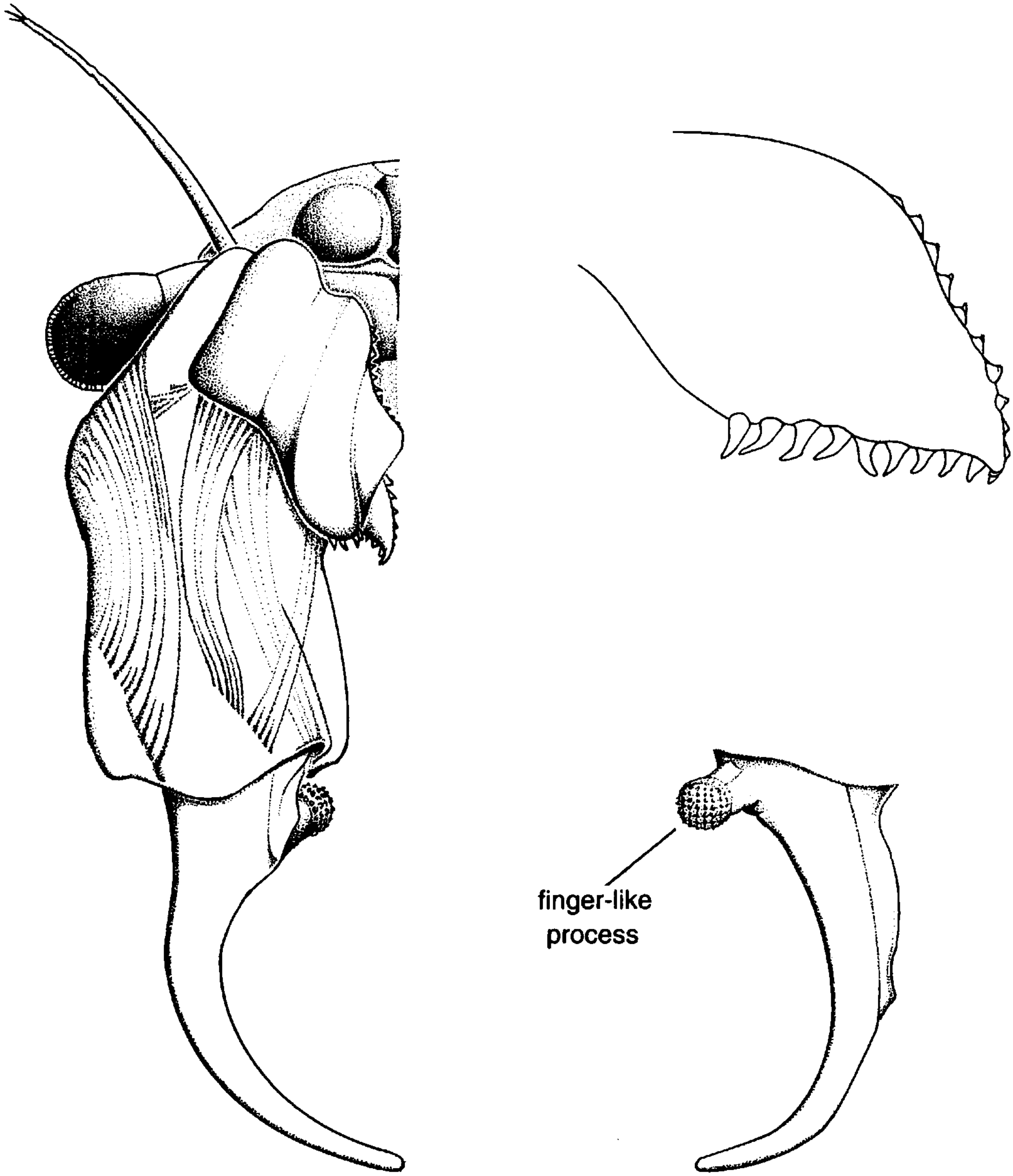


Fig. 7.13. *Eubranchipus oregonus*, frontal view of male's head (right half) with antennal appendage partially folded, posterior view of distal segment of antenna, and dorsal view of right antennal appendage unrolled and extended.

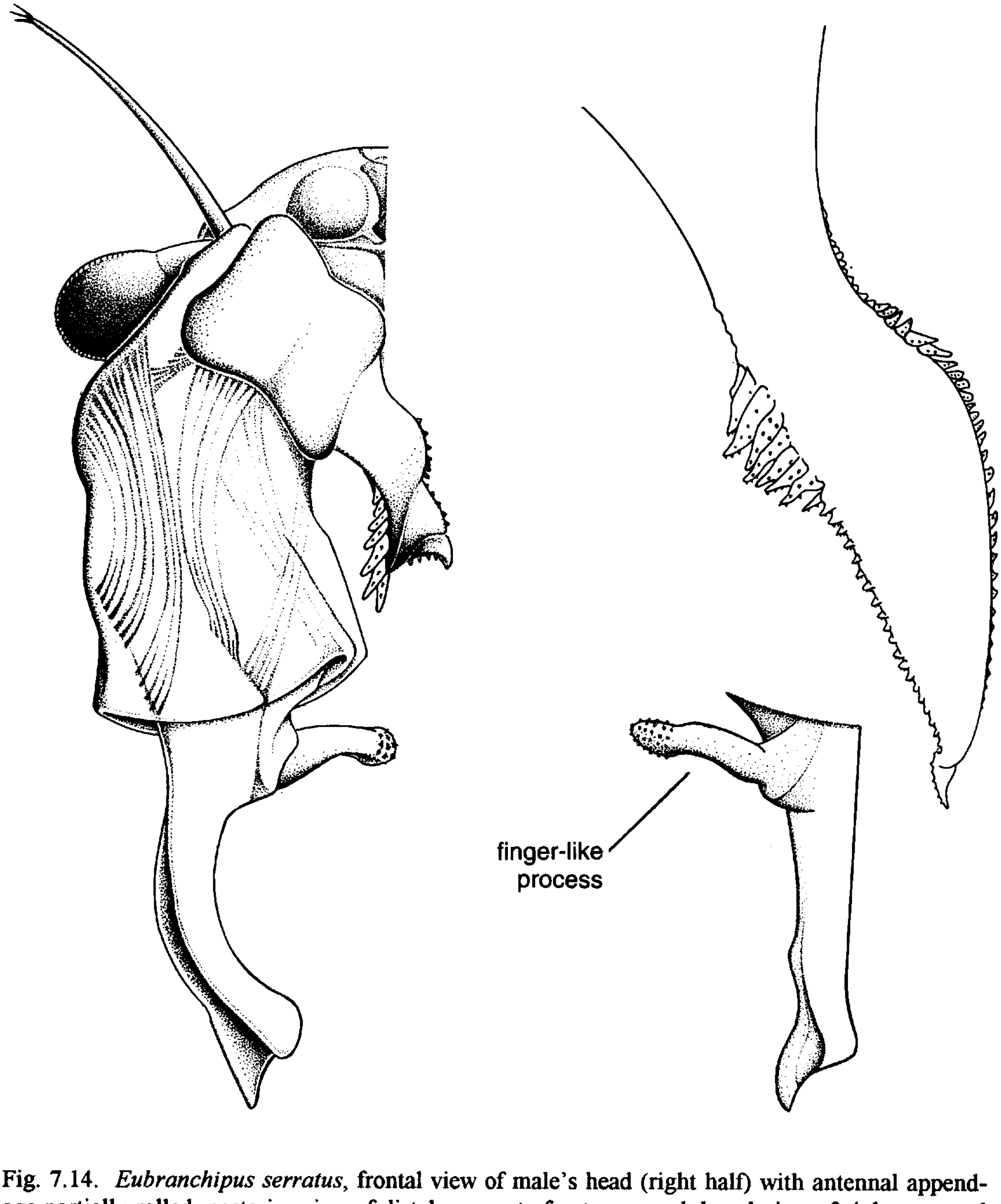


Fig. 7.14. *Eubranchipus serratus*, frontal view of male's head (right half) with antennal appendage partially rolled, posterior view of distal segment of antenna, and dorsal view of right antennal appendage unrolled and extended.

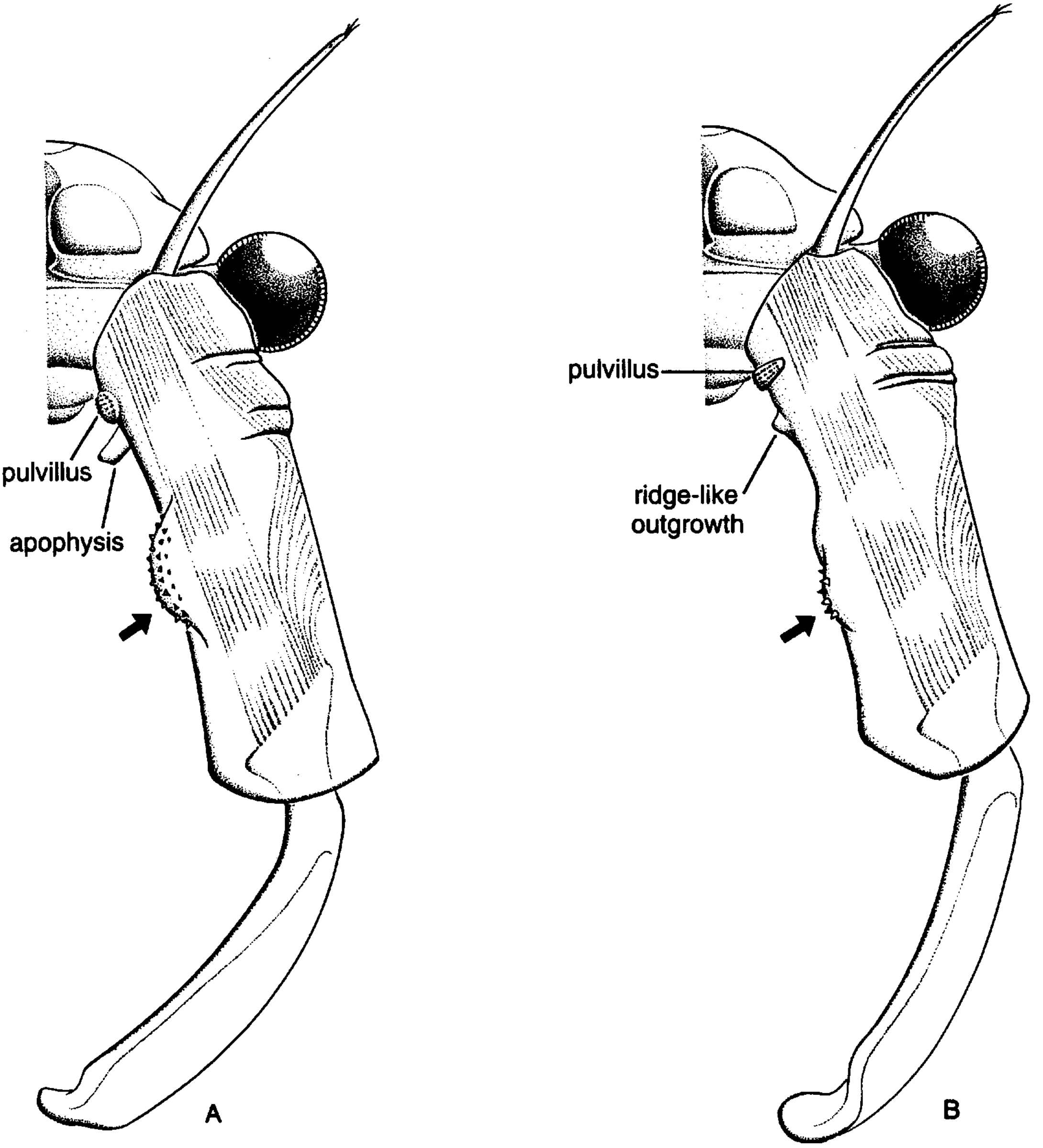


Fig. 7.15. **A.** *Branchinecta coloradensis*, frontal view of male's head (left half). **B.** *Branchinecta lynchi*, frontal view of male's head (left half).

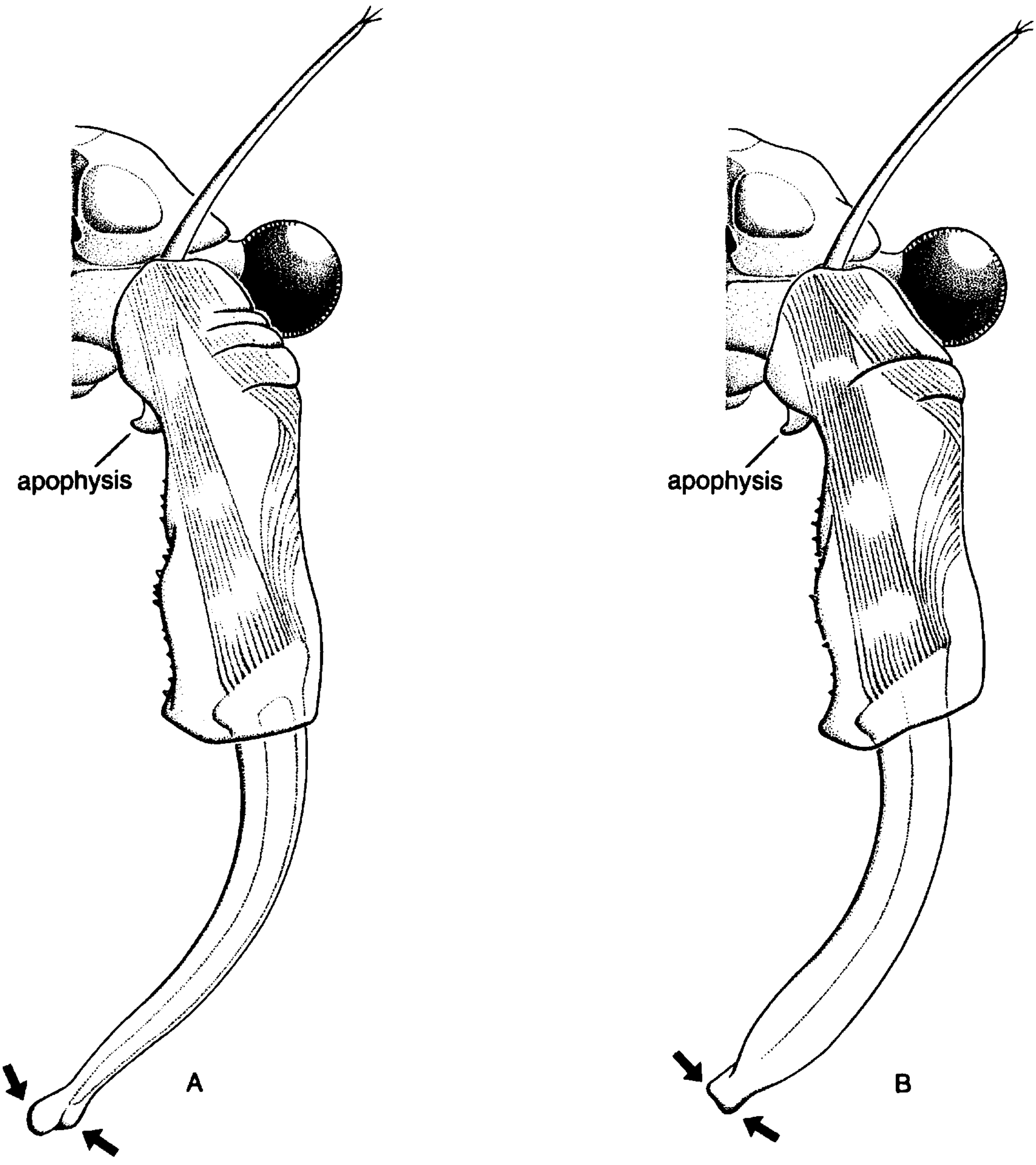


Fig. 7.16. **A.** *Branchinecta mackini*, frontal view of male's head (left half). **B.** *Branchinecta campestris*, frontal view of male's head (left half).

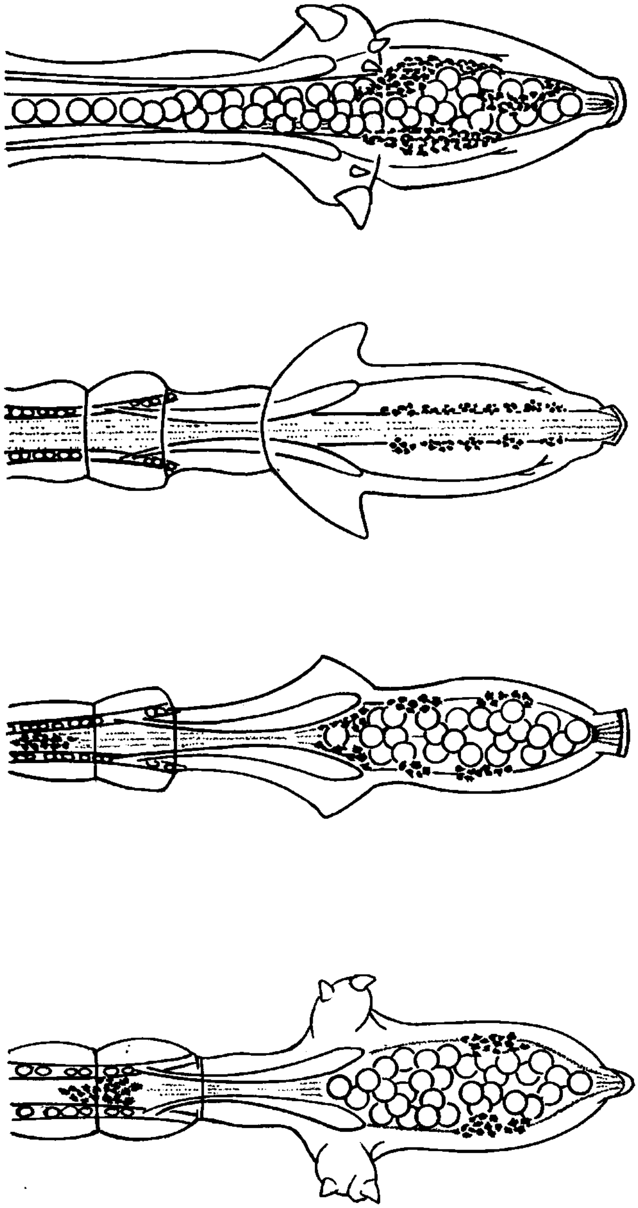


Fig. 7.17. Ventral views of brood pouches of *Branchinecta campestris* showing some of the variety of conical outpocketings found uniquely in females of this species; redrawn from Lynch (1960).

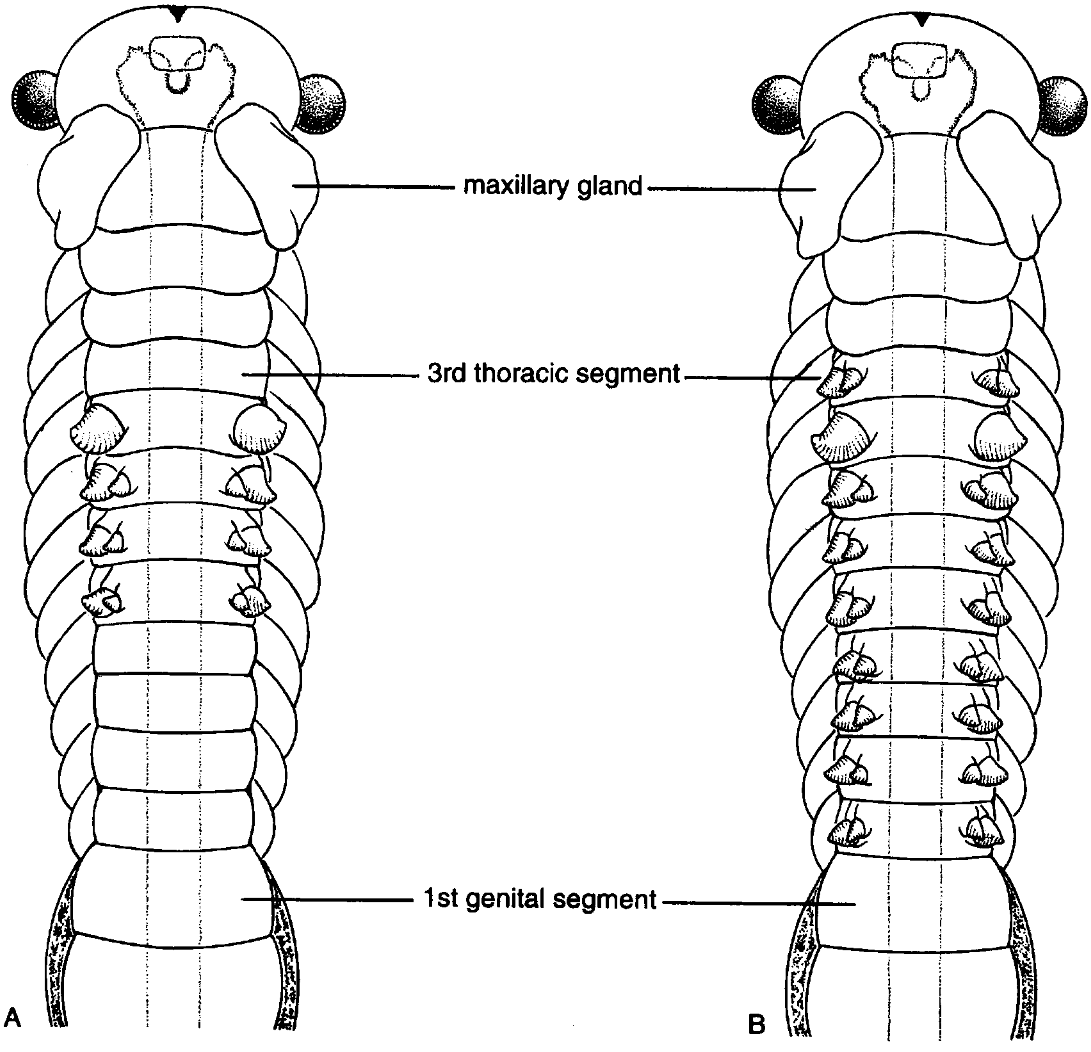


Fig. 7.18. Dorsolateral processes on the backs of females of: **A.** *Branchinecta* sp. (midvalley fairy shrimp); **B.** *Branchinecta lynchi*. The number of segments with processes beyond the 4th thoracic segment is variable in both species.

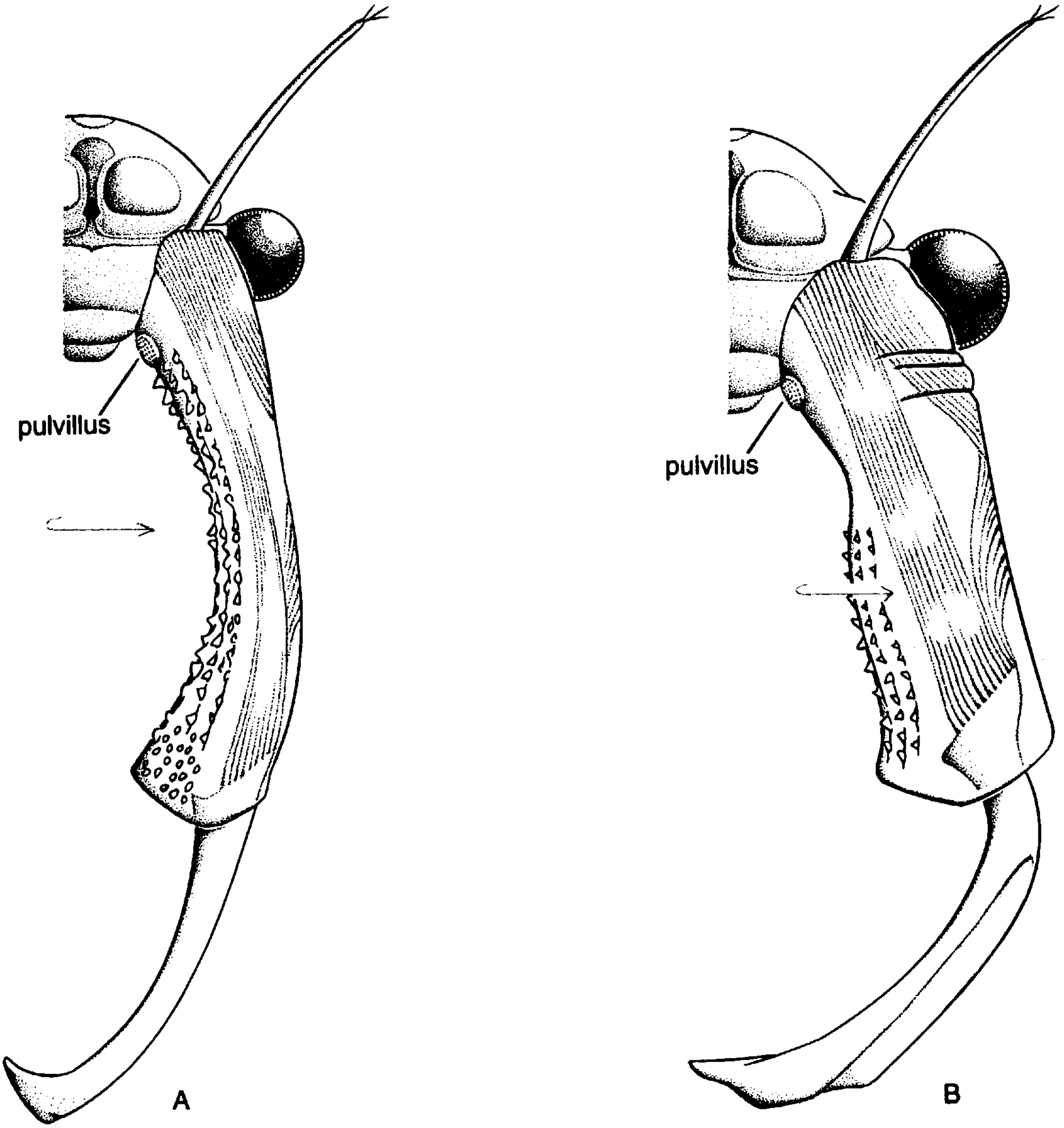


Fig. 7.19. **A.** *Branchinecta longiantenna*, frontal view of male's head (left half).
B. *Branchinecta dissimilis*, frontal view of male's head (left half). Antennae slightly rotated to expose more of the medial surface as indicated by arrows with a curled shaft.

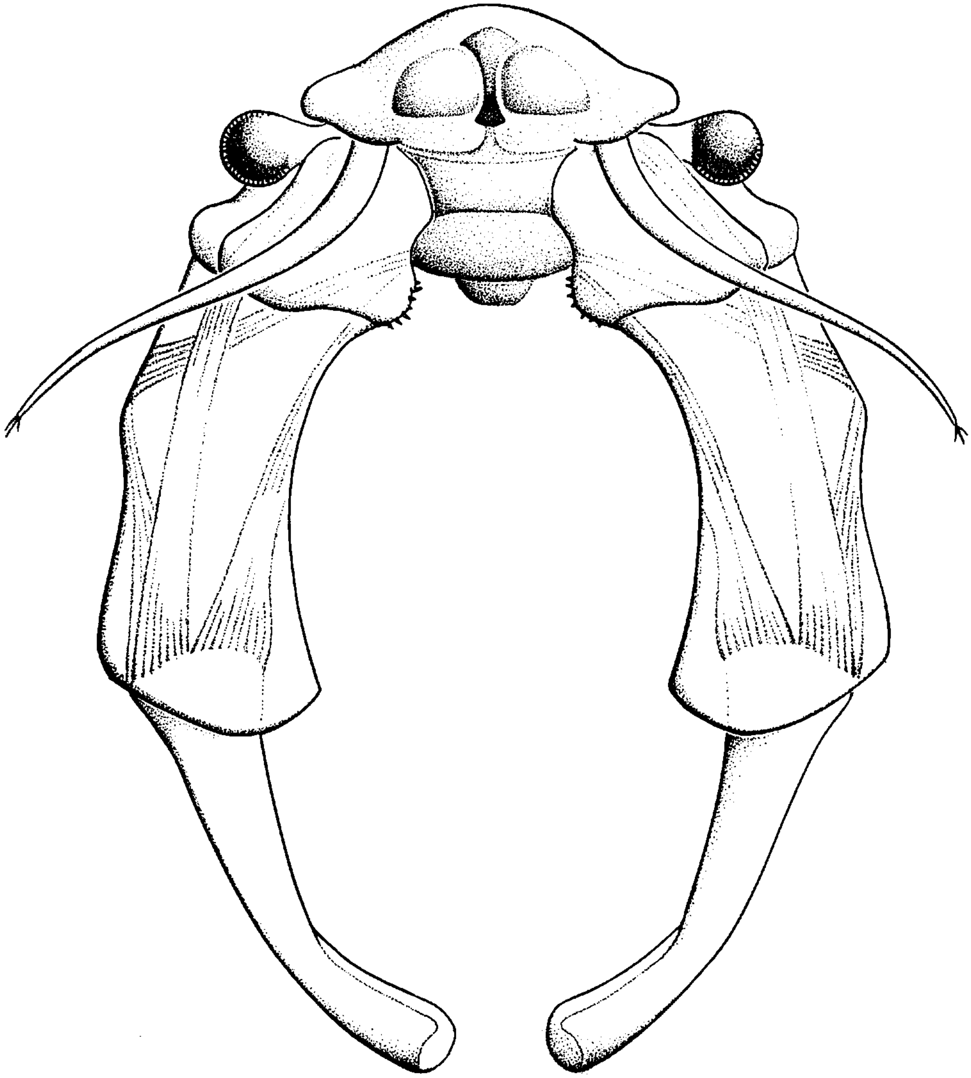


Fig. 7.20. *Branchinecta gigas*, frontal view of male's head. For side views of the whole body of both sexes, see Fig. 4.1 p. 73.

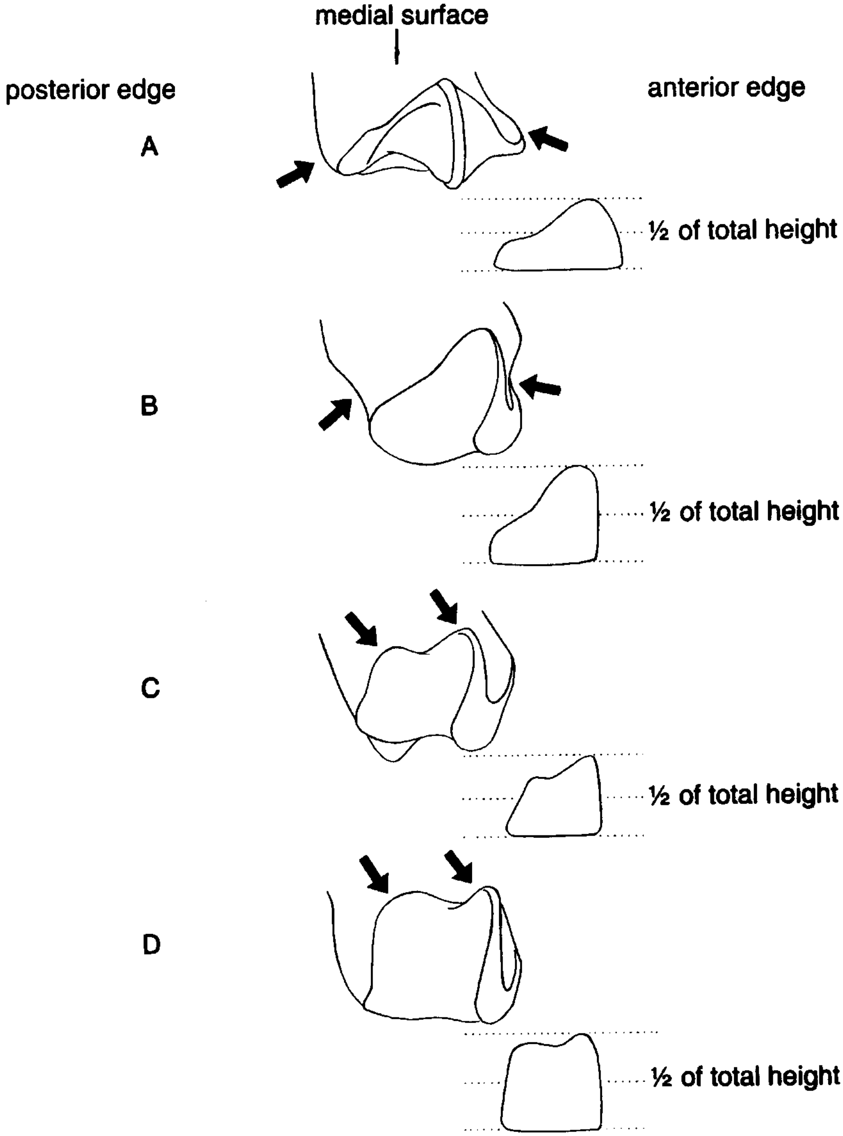


Fig. 7.21. Schematic comparing features at the distal ends of the second antennae of four species of *Branchinecta*. Outline drawings at right show which species have one or two humps above half the total height of the medially bent end. **A.** *Branchinecta sandiegonensis*, **B.** *B. lindahli*, **C.** *B.* sp. midvalley fairy shrimp, and **D.** *B. conservatio*.

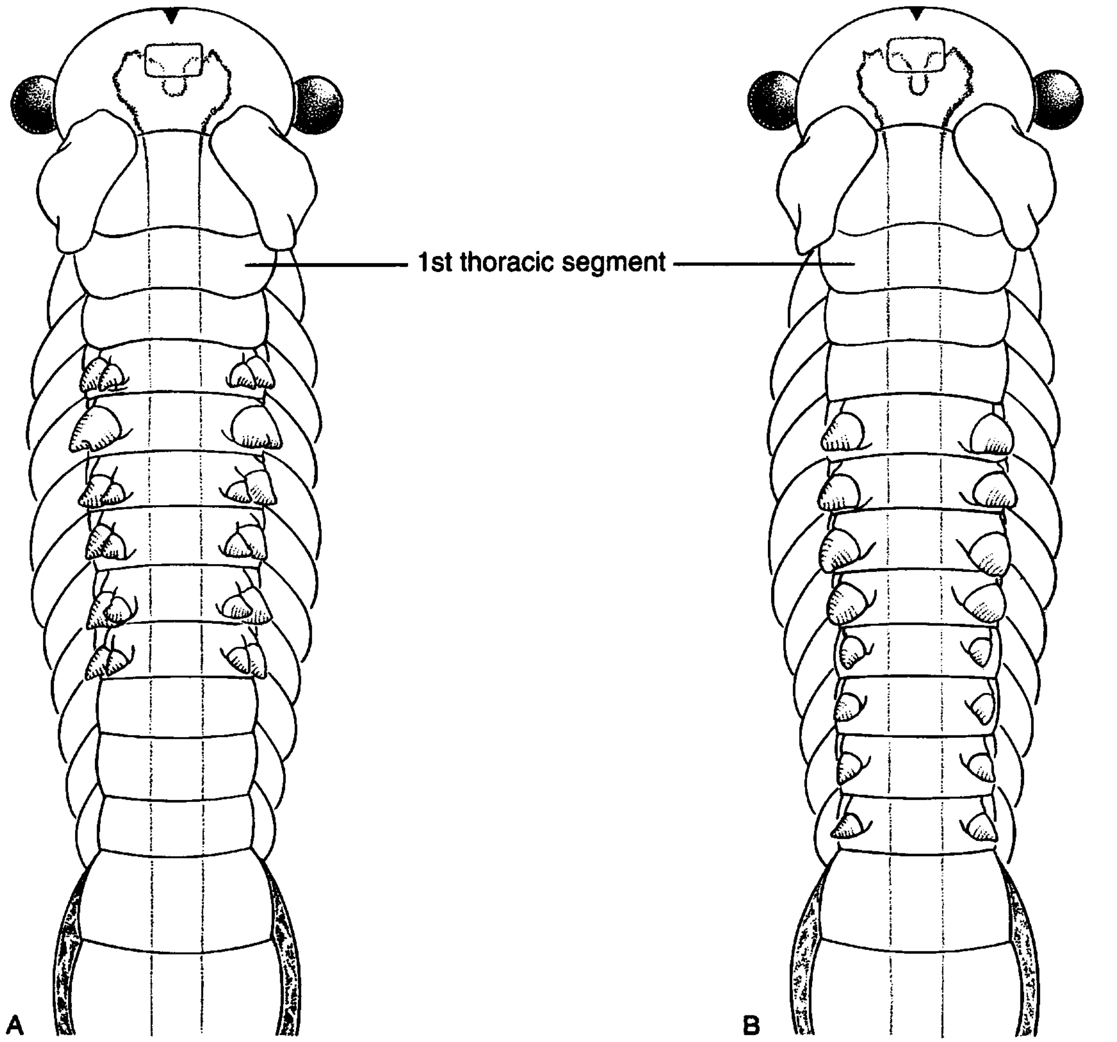


Fig. 7.22. Dorsolateral processes on the thorax of females of: **A.** *Branchinecta sandiegonensis*, and **B.** *Branchinecta lindahli*. The number of segments with processes is variable in both species.

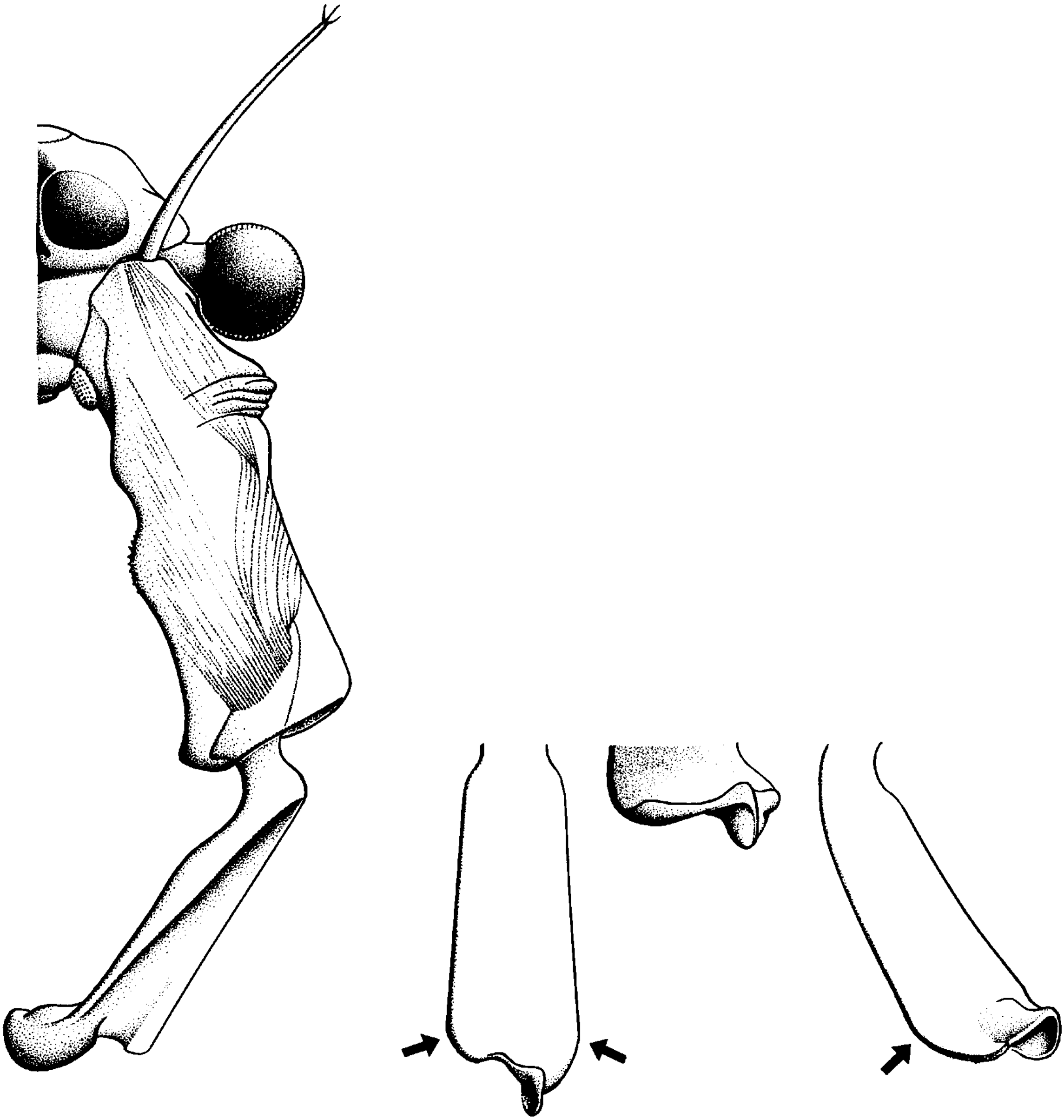


Fig. 7.23. *Branchinecta sandiegonensis*, frontal view of male's head (left half). Views of distal segment of second antenna from left to right: medial, tip in medioventral view, and posteromedial.

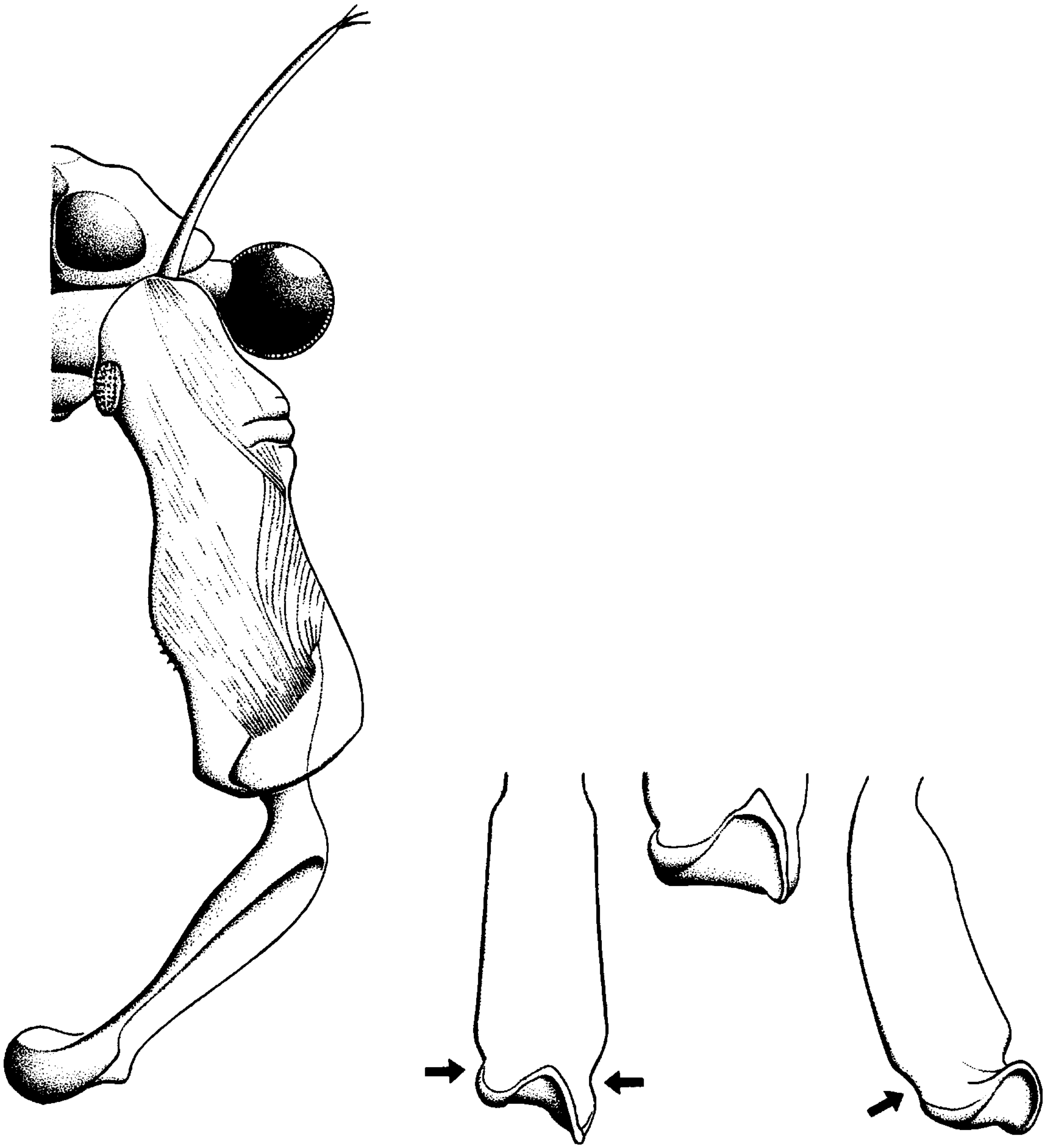


Fig. 7.24. *Branchinecta lindahli*, frontal view of male's head (left half). Views of distal segment of second antenna from left to right: medial, tip in medioventral view, and posteromedial.

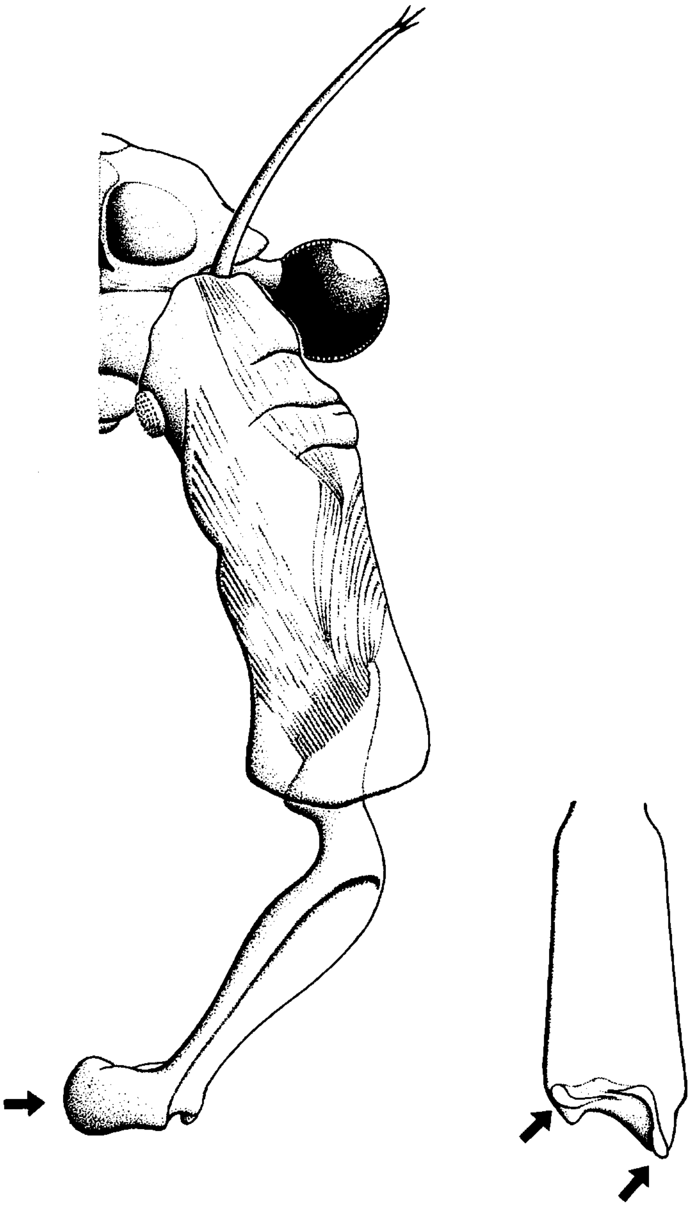


Fig. 7.25. *Branchinecta* sp. (midvalley fairy shrimp), frontal view of male's head (left half) and medial view of distal segment of second antenna. For view of medially bent tip, see Fig. 7.21C p. 160.

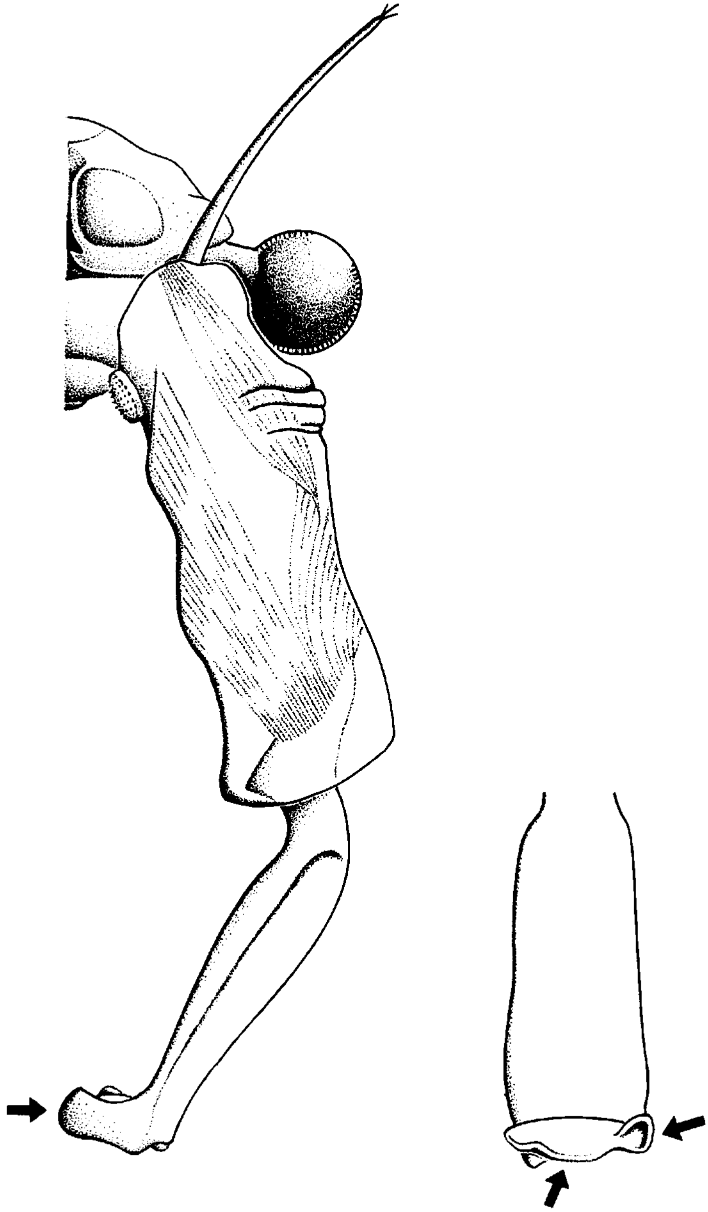


Fig. 7.26. *Branchinecta conservatio*, frontal view of male's head (left half) and medial view of distal segment of second antenna. For view of medially bent tip, see Fig. 7.21D p. 160.

Fig. 7.27. Short seta from the ventral surface and long seta from the medial surface of the cercopod of *Branchinecta gigas* (see Fig. 7.1 p. 140) (scale = 1 mm).

Appendix 1

Glossary

This glossary contains technical terms used in our book. If certain words are not located here, don't fret, they can be found in your favorite dictionary. An excellent source of definitions for terms used in ecology, evolution, and systematics is Lincoln *et al.* (1982).

abdomen: Body region posterior to the two fused genital segments; consists of 7 segments including the telson as the seventh and last segment (Figs. 1.2, 1.3). Many works incorrectly consider the genital segments as part of the abdomen; see Walossek (1993) for discussion.

aestival: Refers to aquatic habitats which, though they contain water all year, freeze completely during winter.

alkalinity: The measure, in ppm (parts per million), of the buffering capacity of water, or the amount of substances in water which can combine with, and therefore neutralize, acids. These materials are usually bicarbonate, carbonate, and hydroxide ions, but may include borates and silicates.

anostracan: A fairy shrimp; a member of the crustacean order Anostraca. Fairy shrimps that live in highly saline waters are often called brine shrimps.

antenna (pl. antennae): One member of the second pair of anterior appendages of the head. In male anostracans, they are typically two-jointed and function as claspers enabling the male to hold onto the female during mating (Figs. 1.2, 1.3). Syn: second antenna.

antennal appendage: A comparatively large outgrowth from the anteromedial surface near the proximal end of the basal joint of the antenna in males of some anostracan species (Figs. 7.9, 7.10, 7.12, 7.13, 7.14).

antennule: One member of the first pair of anterior appendages of the head. They are uniramous structures that are unjointed though they may appear superficially segmented. They may be tipped with sensory setae (Figs. 1.2, 1.3). Syn: first antenna.

anterior: A word denoting relative position, indicating that the structure referred to is placed closer to the front of the animal than another structure, or is situated on or toward the front; the fairy shrimp's head is at the anterior end of its body.

apophysis: In *Branchinecta*, an outgrowth projecting from the surface of the antenna near the proximal end of the basal segment (Figs. 7.15, 7.16).

astatic: As applied to a type of pool, refers to pools with unstable water levels.

biramous: Having two branches; for example, the fairy shrimp's swimming appendage, or phyllopod.

branchiopod: As a structure, a leg having a gill on it. Syn: phyllopod, thoracopod (Figs. 1.2, 1.3, 3.1). As a name, any member of the crustacean class Branchiopoda.

brood pouch: A sack-like structure extending from the ventral surface of the genital segments of female anostracans. It contains the ovisac, lateral pouches, and shell glands. In the past, it was often inappropriately referred to as the ovisac (Fig. 1.3).

cercopod: One of a pair of terminal appendages that articulate with the telson. The cercopods function as stabilizers and enhance the rudder-like function of the abdomen (Figs. 7.1, 7.2). Syn: caudal ramus, furcal ramus.

cheliform: Having a pincer-like shape.

clutch: A batch of cysts contained in the ovisac.

conductivity: A measure of the ability of water to conduct electricity, quantified in µmhos. This measure is directly related to the dissolved material (salinity) in the water.

cyst: A shell-covered dormant embryo. The "resting egg" expelled from the ovisac of a female anostracan. The stage of the life cycle adapted to survive unfavorable environmental conditions and nonaquatic phases of ephemeral pools; it also functions as a dispersal stage. Syn: resting egg, dormant egg (Fig. 3.2).

distal: Situated away from the midline of the body, or along an appendage away from its point of attachment to the body.

dorsal: A word denoting relative position, indicating that the structure referred to is placed on or toward the animal's back; in normal swimming the fairy shrimp is upside-down, its back faces the bottom of the pool.

endemic: Native to, and restricted to, a particular geographic region.

fecundity: Total cyst production during the life of a female.

finger: A term used for the ventral branch of the cheliform part of the distal outgrowth of the antennae on members of the genus *Streptocephalus* (Fig. 7.4)

frontal appendage: Median outgrowth from the front of the head (Fig. 7.3); formed during embryonic development by fusion of the right and left antennal appendages. Belk & Pereira (1982) proposed a method of labeling the branches which we follow in this work. Branches or other outgrowths of each right or left arm (primary branch of the frontal appendage) are assigned consecutive numbers starting with the most proximal branch or outgrowth. In addition to the number, a letter designates the insertion of the outgrowth. For example, if the first branch inserts on the medial side of the arm, it will be designated 1M. If the second is on the dorsal side of the arm, it will be labeled 2D. A third branch on the ventrolateral side would be 3VL.

frontal view: Looking in the face of the fairy shrimp. Syn: anterior view.

genital segments: Two fused body segments from the ventral surface of which arise the penes or brood pouch; they are the last two thoracic segments. In the species found in California, these are post-cephalic body segments 12 and 13 (Figs. 1.2, 1.3). Many works incorrectly consider the genital segments as part of the abdomen; see Walossek (1993) for discussion.

head: Anterior most region of the body (Figs. 1.2, 1.3). The head is formed by coalescence of 5 segments. It is superficially subdivided dorsally by a transverse mandibular groove. The head includes the stalked compound eyes, antennules, antennae, mandibles, maxillules, and maxillae.

hemolymph: Fluid filling body spaces (hemocoel) of arthropods. Analogous to blood and lymph of vertebrates in distributing nutrients etc.

hyperosmotic: Adjective meaning that the concentration of dissolved materials in body fluids is greater than in the surrounding aquatic medium. Syn: hypertonic.

hypo-osmotic: Adjective meaning that the concentration of dissolved materials in body fluids is less than in the surrounding aquatic medium. Syn: hypotonic.

ionic: An atom or group of atoms existing in a charged form (e.g., K^+, $HCO3^-$).

iso-osmotic: Adjective meaning that the concentration of dissolved materials in body fluids is equal to that in the surrounding aquatic medium. Syn: isotonic, isosmotic.

labrum: Upper lip; a large, puffy lobe covering the mouth and mandibles; attached anterior to the mouth (Figs. 1.2, 1.3, 7.12).

lamelliform: Thin and sheet-like in shape.

lateral: A word denoting relative position, indicating that the structure referred to is placed on or toward the side.

lateral abdominal ridge: In *Thamnocephalus*, a thin, plate-like, midlateral projection of the body wall emerging on abdominal segment one and increasing in width until it ends at the posterior edge of abdominal segment 6 (Fig. 7.1).

lateral pouch: A sack-like enlargement of each oviduct just in front of the ovisac. Mature, infertile eggs are stored here before being moved into the ovisac (Fig. 1.3). Passage from the lateral pouch into the ovisac is controlled by a "shutter" which is a mixture of cellular and fibrous components (Criel 1980). Syn: lateral oviducal pouch.

LD/50: A comparative laboratory measure of the conditions (e.g., temperature) at which 50% of the experimental organisms survive and 50% die by the end of a particular period of time (e.g., one hour, one day, etc.). This is a non-ecological measure because such conditions can probably not be tolerated long-term.

life cycle: For an individual, it is the sequence of events from its origin as a zygote to its death. At a more general level, it may be thought of as the stages an organism passes through between the production of gametes by one generation to the production of gametes by the next generation.

longevity: Number of days of life (birth to death).

low critical-level of oxygen: The level of dissolved oxygen in the habitat below which the organism cannot get enough O_2 to maintain metabolism and so dies.

maturity: For an anostracan female, when her first clutch appears in the brood pouch.

maxilla: (pl. maxillae): The second of two pairs of accessory mouth parts posterior to the mandibles. They lie between the maxillules and the first phyllopods (swimming appendages); 5th paired appendage of the head. Syn: second maxilla.

maxillule: First of two pairs of accessory mouth parts that lie between the mandibles and maxillae; 4th paired appendage of the head. Syn: first maxilla.

medial: A word denoting relative position, indicating that the structure referred to is placed closer to, toward, or in the midline of the body.

metanauplius: (pl. metanauplii): Postnaupliar crustacean larva distinguished from a nauplius by increasing addition of body segments and appendages, and more adult-like development of the appendages (Fig. 2.2).

µmho: A unit of measure of conductivity (the ability of water to conduct an electrical current). Because conductance is the inverse of resistance, the measure for which is the ohm, the unit for conductivity is dubbed the mho. A µmho = 0.001 mho.

nauplius: (pl. nauplii): The first larval stage of a crustacean. Its body consists only of a head and the telson. At this stage of development the head possesses only 3 pairs of appendages (antennules, antennae, and mandibles) and a single median eye called the nauplius eye (Fig. 2.2).

osmoconformer: An organism which is unable to regulate the dissolved material content of its blood and thus conforms to the osmotic concentration of its aquatic medium.

osmotic concentration: Concentration of dissolved materials in a solution (e.g., blood, water).

oviparous: Adjective for reproduction involving fertilized eggs that complete their development and hatch outside the body of the parent; egg-laying. This is the typical method used by fairy shrimps.

ovisac: A single, expandable, sack-like structure located centrally within the brood pouch (Fig. 1.3). Left and right lateral pouches and ducts of the shell glands attach to it. The ovisac receives semen during copulation. It functions as the site of fertilization, site of early embryonic development (in *Artemia*, some fertilized eggs may develop all the way to the nauplius larval stage), and site for application of shells to fertilized eggs thus completing their transformation into cysts. Cysts are expelled from the ovisac through a posterior gonopore. In *Artemia*, nauplii also leave via the posterior gonopore during ovoviviparous reproduction.

ovoviviparous: Adjective for reproduction involving fertilized eggs that complete development and hatch within the mother in a specialized parental structure such as the ovisac of anostracans. Members of the genus *Artemia* are the only anostracans able to use this method of reproduction.

phyllopod: As a structure, one of a pair of basically biramous and flattened, leaf-like, swimming appendages on the ventral surface of a thoracic segment. Syn: branchiopod, thoracopod (Figs. 1.2, 1.3, 3.1). As a common name, used for members of the three large branchiopod orders: Anostraca, Conchostraca, and Notostraca. This use derives from the formal grouping of these three taxa into a single taxon, Phyllopoda, by the 19th century biologist G. O. Sars, a grouping no longer considered taxonomically valid.

posterior: A word denoting relative position, indicating that the structure referred to is placed closer to, or is situated on or toward the rear of the animal; the cercopods are at the posterior end of the fairy shrimp's body.

proximal: A word denoting relative position, indicating that the structure referred to is situated toward the point of attachment.

pulvillus (pl. pulvilli): In some species of *Branchinecta*, a mound-like area covered with minute cuticular (exoskeletal) spinules, and found near the proximal end of the basal segment of the antennae (Figs. 7.15, 7.19, 7.23, 7.24, 7.25, 7.26, and couplet 15 p. 137). A scanning electron micrograph may be seen in Fugate (1993; fig. 10a).

saltern: An artificial diked basin where salt water is evaporated by the sun leaving only the minerals.

subterminal lateral lamella: In *Streptocephalus*, a ventrally directed sheet-like expansion of the ventrolateral surface of the finger (Fig. 7.6). The anterior edge of the lateral lamella terminates just back of the tip of the finger, thus subterminal. A scanning electron micrograph may be seen in Maeda-Martinez *et al.* 1995a; fig. 13c).

TDS (total dissolved solids): A measure, in ppm, of the amount of dissolved material in water.

telson: Last body segment; its anterior region is the growth zone which buds off the postcephalic segments during development from nauplius larva to adult. A terminal pair of cercopods extends posteriorly from this segment in adults (Figs. 1.2, 1.3, 7.1, 7.2).

thorax: The postcephalic region of the body composed of the leg-bearing segments, 11 in California species, and the two fused genital segments (Figs. 1.2, 1.3). Many works incorrectly consider the genital segments as part of the abdomen; see Walossek (1993) for discussion.

trunk: Region of body posterior to the head. The adult anostracan trunk consists of two main divisions, thorax and abdomen (Figs. 1.2, 1.3).

turbidity: A measure of the amount of suspended particles (e.g., clay) in water. When these are abundant, the water is opaque and said to be "muddy" or highly turbid.

ventral: A word denoting relative position, indicating that the structure referred to is placed closer to, or is situated on or toward, the leg-bearing surface of the fairy shrimp's body; in normal swimming the legs are directed upward toward the surface of the pool.

Fig. Ap. 1.1. Clyde collecting fairy shrimps.

Appendix 2

Collecting, Preservation, and Storage

If you were to see Denton and Clyde collecting fairy shrimps, you would note they carry dip nets while wading around in pools, playas, or muddy stock tanks. That's about all there is to it folks; so get yourself a net, perhaps some hip boots (no problem if you are also a fly fisherperson), wade on in, and net away! Well, OK, that description is a bit oversimplified, but you get the idea.

Certainly **dip-netting** is the most common means of collecting fairy shrimps. The standard instrument has a wooden handle about 1.3 m long. To this is anchored a metal ring, usually 25 cm in diameter, that supports a bag about 25 cm deep. The bag's cotton or nylon fabric has a 1-2 mm mesh size. Of course dimensions of any of these features can be altered to satisfy specific collecting needs. For example, a much finer netting must be utilized when collecting larvae; a longer handle can be employed for reaching to greater distances, and when "mucking up" a pool by wading is undesirable. If the site is a puddle, a small aquarium net is probably best. Once entrapped, shrimps can be lifted out with fingers, though this is best done with blunt forceps, or the contained materials can be emptied into a pan or jar of water for observation.

Seldom can you stride up to a pool, spot an anostracan or two, and casually reach out and dip them up, for fairy shrimps, like other animals, utilize escape movements when threatened, including by you. Those escape movements may have already removed them from the immediate vicinity by the time you reach pool's edge, for they probably see you before you see them. Admittedly, some species are less flighty than others, so you may dip in and come up satisfied, but at other times you may go wanting. If that's the case, don't leave yet, for "over there" similar actions could result in a passel of wriggling shrimps in your net.

After spending some time with anostracans, you will become more familiar with their habits, and will be better able to judge where in their habitat individuals have gone to escape, or where they are more likely to spend their time.

For example, a number of species do not just cruise the pool, at least in daytime. Rather, they may "hang out" around vegetation where shade offers cooler water, the plants provide protection, and where concentration of small animal foods (e.g., protozoans and rotifers) will undoubtedly be greater. If the habitat is not homogeneous in temperature, then the cooler water lies deeper; so at the warmer times of day, fairy shrimps may congregate in bottom waters. Of course bottom water would also be the favored place for those which include scraping in their feeding activities. Additionally, remember that fertilized females of some species retreat to the depths of the pool, while the males cruise nearer the surface. The point is, to be fully successful in your collecting activities, you must sample the various portions of the habitat, particularly near the bottom and near and amongst vegetation.

Merely dipping a net into a pool is usually not a very effective way to catch fairy shrimps. Typically, the net is "swept" back and forth through the water at any desired depth, an action which entraps whatever does not or has not removed itself from harm's way. Sweeping back and forth several times very close to a particular piece of the bottom will stir up some of the bottom materials and possibly some fairy shrimps, thus the return sweeps will capture those individuals that were rousted out. Of course, if you sweep too close to a detritus-covered bottom, a massive amount of debris may appear in your net and you will never find the organisms that are included amongst it.

As in driving a nail or playing the violin, practice is the key to developing a successful netting technique! And though you might say "don't make a simple procedure more complex than it is", we suspect you will find our comments pretty close to the mark. We illustrate this truth with a real-life drama described by Richard Hill. Richard's first sweeps in a pool on the Modoc Plateau were unsuccessful, so he began gazing into the water to see what could be seen. After awhile, individuals of what turned out to be *Branchinecta coloradensis* began emerging from among mats of vegetation covering the bottom. When he tried to net them, they darted downward and disappeared once more. After a good deal of patience, and practice, Richard became a rather adept fairy shrimp stalker! During his next outing, he directed several colleagues to rest their nets on the bottom of the pool and sweep rapidly upward when the shrimps made their debut. After awhile, Richard had collected a number of individuals, while his friends, lacking practice, and thus technique, had few amongst them.

A different technique, possibly also useful for collecting anostracans with *B. coloradensis*-like behaviors, was sometimes practiced by Clyde in Mojave Desert playa lakes. Playas are so muddy that you and the fairy shrimps will not see each other. However, sweeping a net back and forth through these milk-shake-like universes may result in amassing fewer shrimps than hoped. Why? Perhaps the species living in such places sense you coming via the waves sent out from your advancing legs and net, and take advantage of the official fairy shrimp escape behavior. Clyde often had greater success by walking in reverse while sweeping the net back and forth over the path just traversed, for his passage scared up the animals that the sweeping net then sieved out. Once collected, fairy shrimps may be transported in a bucket of habitat water if the animals are not too crowded, or placed in small containers with tight-fitting lids and preserved in 70-95% alcohol.

A collecting technique that has rather recently come into favor is **dry sampling**. The method involves taking soil from a dry pool bed, and sorting out any anostracan cysts that might be present. The amassed cysts are then either identified from their surface ornamentations (a job for specialists), or hatched, with the hatchlings being raised until maturity allows identification. This method offers several advantages. One is that a particular pool does not have to be sampled within the narrow time frame when animals are large enough for the collector to note their presence, and mature enough to distinguish the species. Also, because the pool is dry and the aquatic vegetation dead, the habitat will not be torn up by a collector moving through it. A disadvantage is that cysts have been found even where no pools exist; that is, their agents of distribution have been successful, but the habitat is inhospitable. Also, just because a cyst is found in a pool basin does not mean that the larval or adult organism can actually survive there.

How does one sample dry soil? Employing a hand trowel to remove the top inch or so of sediment will do the trick, but it is not at all quantitative. Clyde and his students designed a simple device that covers a certain surface area and takes a known volume of the top inch of compact sediments. Hardware stores sell various sizes of hole saws for use with hand drills and drill presses. We merely welded a T-shaped, foot-long handle made from water pipe to the back of the cup of a hole saw. The handle allowed us to rotate the saw into sediments near the lowest portion of the basin and lift out a 25-mm-thick core. Volume of the sample is determined by the diameter of the hole saw used. Our collections were stored in plastic sandwich bags until analyzed. Analysis involves placing a sample in a shallow tray, adding water, waiting for the hard soil to crumble, then washing the material in a sieve with a mesh size (about 0.15 mm) that will catch all cysts. The sieve is then placed in a pan with a water level that barely covers the screen. The items caught by the screen are scanned with the aid of a dissecting microscope, and the cysts amongst them are removed with a pipette. Depending on the information desired, the different types of cysts can be counted and their numbers related to the volume of, or surface area covered by, the sampler.

Keeping in mind some of the pros and cons of the methods we have mentioned, it's now up to you to choose the one that best meets the purpose for sampling your puddle, pool, or playa. By the way, remember, four California species are listed as endangered and one as threatened, and a permit from the USFWS is required to collect or disturb them.

If you do not yet have all the collecting gear you need, the following is an abbreviated list of **sources for supplies:** BioQuip Products, 17803 LaSalle Ave., Gardena, CA 90248; Carolina Biological Supply Co., 2700 York Road, Burlington, NC 27215; The Biology Store, 275 Pauma Place, Escondido, CA 92029; Ward's Natural Science, P.O. Box 5010, San Luis Obispo, CA 93403; your local aquarium shop; your local hardware store.

If you are into making collections of animals for future reference or study, they will require preservation. All that is needed are some bottles with tightly fitting lids and a supply of 70% isopropyl or ethyl alcohol. To avoid having specimens contort into odd shapes when they succumb, it is best to slowly relax them by adding small amounts of alcohol to the water in the collecting bottles. Starting the process with CO_2 is even better for it will anesthetizes your captives. A handy source of this gas is a bottle of club soda; add it slowly and in small amounts. Once the animals are immobile, transfer them to fresh preservative for long-term storage because the body fluids, plus water adhering to their surfaces, may dilute the 70% alcohol to such an extent that the shrimps will soon become "mush".

Careful labeling and record keeping are a very important part of collecting. So write on good quality cotton fiber paper, using alcohol-stable ink or pencil, at least the date, the name of the individual who scooped the creatures from their aquatic world, and, as precisely as possible, the location of your collection. Place this label in the storage bottle with your specimens. The collection will be even more valuable if you are able to describe the pool and its setting (see Chapter 4 for ideas), and make environmental measures (e.g., temperature, TDS)! Such information can be recorded in a notebook coded with a reference number, and this number should be inscribed on the label you place in the collection bottle as well. In addition, Denton typically takes one or more photographs of each collecting site as an acknowledgment that "a picture is worth a thousand words" of habitat description. It also may be a source of information for data not recorded, as well as help in jogging the memory about the place at a later date. Don't forget to record the reference number on the picture(s)!

Store your collections in a safe, cool, place, preferably in the dark. And, remember to check the bottles periodically to guard against having your specimens destroyed by drying. Alcohol, like Houdini, is an escape artist from even the tightest lid.