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FIRST RECORD OF FAIRY SHRIMP FROM BELIZE, AND A COMPARISON OF CYST-SHELL MORPHOLOGY IN THE NEW WORLD MEMBERS OF THE *STREPTOCEPHALUS SEALII* SPECIES GROUP (ANOSTRACA: STREPTOCEPHALIDAE)

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ABSTRACT

Anostraca are recorded for the first time from Belize, and for the second time from Central America. The Belizean *Streptocephalus similis* occupies a thermal refuge from insect predators. Cyst-shell morphologies in the New World members of the *Streptocephalus sealii* species group are described. They indicate a closer relationship between *S. sealii* and *S. woottoni* than between either species and *S. similis*.

While conducting stream surveys in Belize, I found a roadside pond containing a small population of the fairy shrimp *Streptocephalus similis* Baird. The pond was in a forested area of the Rio Bravo Preserve in northern Belize, an area of karst topography having much in common with the Yucatan peninsula of Mexico. The collection was made by W. D. Shepard in Belize; Orange Walk District, Rio Bravo Preserve, in a roadside pond 1 mi (1.61 km) south of the headquarters on the east side of the road, 2 January 1996. This collection extends the known continental range of *S. similis* approximately 1,200 km to the southeast (from southern Tamaulipas, Mexico). The closest known population is on Jamaica, approximately 1,000 km to the east (Moore, 1958; Belk, personal communication). The only other collection of anostracans from Central America (excluding Mexico) is from Costa Rica (Pereira and Belk, 1987). I collected 14 individuals (6 males, 8 females) all of which are deposited in the collection of Denton Belk (collection number DB 1272).

The anostracans were inhabiting a pond (Fig. 1) filled with potential insect predators (notonectids, nepids, belostomids, and various odonate nymphs). Individuals of *Streptocephalus similis* were restricted to the deepest part of the pond, and inside extensive beds of charophycean algae. The deepest water, and that inside the algal beds, was cool (25°C) compared to the rest of the pond (30°C). The insects were in the warmer surface waters and on the periphery of the algal beds. Thus, the algal beds and the cool water may have offered a refuge from predation, affirming the important influence of physical environmental factors upon predation (Woodard and Kiesecker, 1994). While the pond was beside the road, it appeared to be natural and not to be a borrow-ditch resulting from road construction. This observation is supported by the fact that roads in this area are built up by adding crushed limestone to the existing surface, not by using the roadside soil as a base.

Six of the females had shelled resting-eggs, or cysts, in their brood pouches. Of the two that lacked cysts, one had well-developed shell glands while the other did not. All males had readily visible penes. Thus, the population was evidently reproducing. The total lengths in mm were: males –13.0, 15.5, 17.0, 17.5, 19.2, and 19.5; females –14.0, 15.8, 16.0, 16.2, 16.2, 17.0, 17.1, and 17.6.

Taxonomy of Streptocephalus.—Early reviews of New World *Streptocephalus* are by Creaser (1930) and Moore (1966). All species known in *Streptocephalus* as of 1993 were listed by Belk and Brtek (1995). Three additional species have been described (Belk and Brtek, 1997). Maeda-Martinez *et al.* (1995a, b) reviewed the systematics of the Streptocephalidae and split *Streptocephalus* into nine species groups, three of which occur in the New World. Their work was based on adult morphology; cyst characteristics were not used in their analysis. Most of the past descriptive work has involved adult morphology. Increasingly, however, attention is being given to cysts (Brendonck, 1989; De

Fig. 1. Roadside pond with charophycean algal beds occupied by *Streptocephalus similis*.

Walsche *et al.*, 1991; Mura, 1992a, b). Cyst morphology has been used to make identification keys for regional groups of *Streptocephalus* spp. (Brendonck and Coomans, 1994a, b). It has become important in descriptions of new taxa to include descriptions of cysts (Brendonck *et al.*, 1992; Brendonck and Belk, 1993; Hamer and Brendonck, 1993). Most cyst illustrations and/or descriptions have dealt only with cyst exteriors. Only recently has there been examination of the interior of cyst shells. Cyst-shell cross sections have been illustrated for *S. dichotomous* (Baird) (see De Walsche *et al.*, 1991) and *S. texanus* Packard (see Hill and Shepard, 1997).

The *S. sealii* species group is comprised of three New World species (*S. sealii* Ryder, *S. similis* Baird, *S. woottoni* Eng, Belk and Eriksen; see Appendix for collection records) and three Old World species (*S. bourguinii* Hamer and Appleton, *S. distinctus* Thiele, *S. spinosus* Daday) (Maeda-Martinez *et al.*, 1995a). Brendonck and Coomans (1994b) have illustrated and systematically described cyst exteriors for the Old World species *S. distinctus* and *S. spinosus*. Mura (1992a) illustrated, but did not systematically describe, cyst exteriors for all three New World *S. sealii* group species. Considerable interspecific variation in cyst size has been found in *S. sealii* (Belk *et al.*, 1990). Some of that variation is related to female size and some to habitat variables. Some may be due to unknown cryptic species. Research into cyst variation in *S. sealii* is being initiated (Richard Hill, personal communication).

The interior and exterior morphology of cysts of *S. sealii* and *S. woottoni* have been studied as part of a study of cysts in California anostracans (Hill and Shepard, 1997). With the collection of cyst-bearing females of *S. similis*, in was possible for me to examine all the New World species in the *S. sealii* species group. In doing so, I hoped to determine whether cyst morphology is as useful as adult morphology (Maeda-Martinez, 1995a) indicating relationships among closely related species.

Materials and Methods

The Belizean fairy shrimp were preserved in 70% isopropyl alcohol in the field and later switched to 70% ethyl alcohol. In the laboratory, cysts were removed from one

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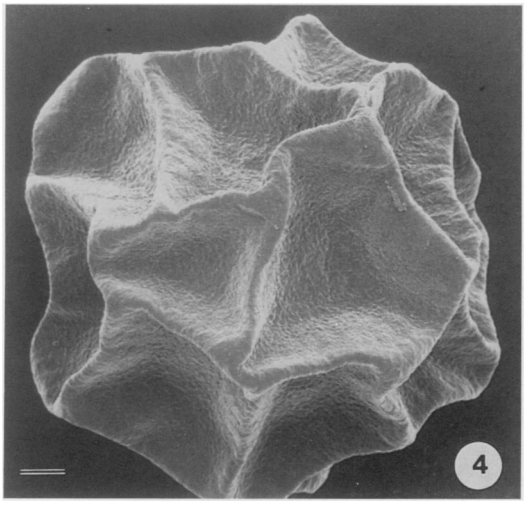
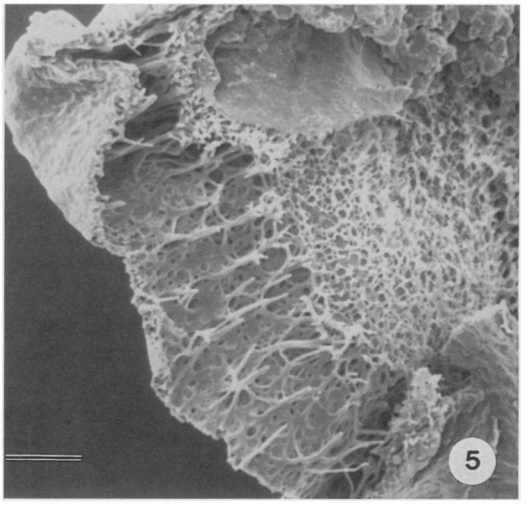
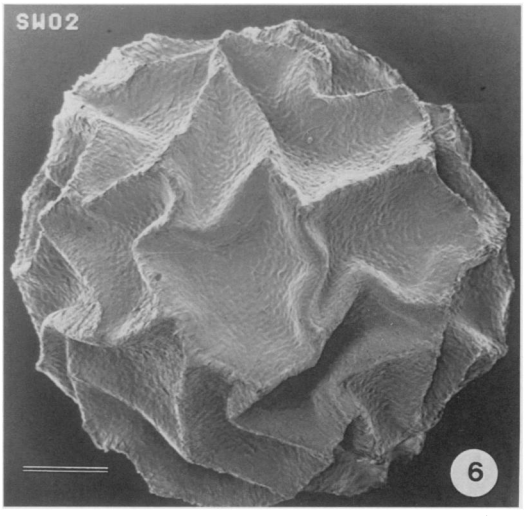
Figs. 2–7. Cysts of *Streptocephalus*. Fig. 2. *Streptocephalus sealii*, whole cyst. Scale bar = 50 μm. Fig. 3. *Streptocephalus sealii*, cyst wall cross section. Scale bar = 10 μm. Fig. 4. *Streptocephalus similis*, whole cyst. Scale bar = 20 μm. Fig. 5. *Streptocephalus similis*, cyst wall cross section. Scale bar = 10 μm. Fig. 6. *Streptocephalus woottoni*, whole cyst. Scale bar = 50 μm. Fig. 7. *Streptocephalus woottoni*, cyst wall cross section. Scale bar = 5 μm.

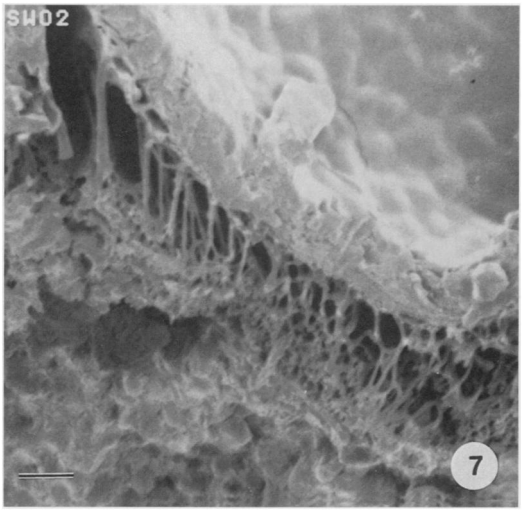

SSEL4
2


SSEL2
3


4


5


SW02
6


SW02
7

female for examination by scanning electron microscopy (SEM). Egg preparation followed that of Hill and Shepard (1997). Terminology for internal structures follows that of Lee *et al.* (1994) and Hill and Shepard (1997).

Eggs of *S. sealii* Ryder and *S. woottoni* Eng, Belk, and Eriksen were obtained from alcohol-preserved museum specimens. Eggs from four populations each of *S. sealii* and *S. woottoni* were examined. Specific collection data are listed in the Appendix.

With the use of SEM, the entire cysts were photographed and a cross section of the cyst shell, together with any unusual surface structures (Hill and Shepard, 1997). The diameter of several cysts per population was measured using an in-scope micrometer.

Results

For the populations examined, I found consistent differences in cyst morphology among members of the *S. sealii* species group. Individual cyst diameters per female are listed in the Appendix. Composite descriptions from the populations examined are as follows.

Externally, cysts from all known members of the *S. sealii* group are spherical with large rugosities defining polygonal depressions (Figs. 2, 4, 6).

Streptocephalus sealii (Figs. 2, 3).—Cyst diameter 236–307 μm ($\bar{x}$ = 274, N = 19, 3 populations). Cortex relatively thick (≈5 μm) and solid, with few pores. Alveolar layer composed of short anastomosing branches defining numerous small vesicular hollows. Tertiary base relatively thin.

Streptocephalus similis (Figs. 4, 5).—Cyst diameter 190–200 μm ($\bar{x}$ = 196; N = 10; 1 population). Cortex relatively thin (≈2.5 μm), with pores numerous on flat ridge tops. Alveolar layer composed of inner sublayer of numerous short anastomosing branches defining small vesicular hollows, and outer sublayer of columnar supports in predominately open space. Tertiary base relatively thin.

Streptocephalus woottoni (Figs. 6, 7).—Cyst diameter 240–310 μm ($\bar{x}$ = 268, N = 30; 3 populations). Cortex relatively thick (≈5 μm) and solid, with few pores. Alveolar layer with mixed areas of short anastomosing branches defining small vesicular hollows, and columnar supports defining large hollows. Tertiary base relatively thin.

Cysts of *S. similis* are readily distinguished from those of *S. sealii* and *S. woottoni* by their smaller size and thinner cortical layer. Cysts of *S. sealii* and *S. woottoni* are generally very similar, but differ in the structure of the alveolar layer. Cysts of *S. sealii* lack the larger columnar supports and thus have none of the large hollows found in the alveolar area of *S. woottoni.*

Discussion

The habitat of the Belizean population suggests that *S. similis* may be located in the Yucatan peninsula of Mexico, although searches there have not found this species. The Belizean population greatly reduces the previously known large disjunction (between Jamaica and Tamaulipas, Mexico) between populations of *S. similis.* No birds are known to migrate between these populations and thereby serve as vectors between the disjunct populations. However, this new population adds to the trajectory that suggests movement of the fairy shrimp via plate tectonics (Maeda-Martinez *et al.,* 1995a).

The external shape of the cysts in the members of the *S. sealii* group is typical for all New World species and some Old World species (excluding the subgenus *Parastreptocephalus* Brendonck, Hamer, and Thiéry, which has tetrahedral cysts). The internal cyst-shell morphology falls within the variability already described for cysts of *Streptocephalus.*

In respect to cyst morphology, *S. sealii* and *S. woottoni* appear to be more closely related to each other than either is to *S. similis.* This fits the proposal by Maeda-Martinez *et al.* (1995a) of "working hypothesis for the phylogeny of New World species." However, neither matches their cladogram for *Streptocephalus* worldwide, which shows *S. woottoni* less closely related to the species pair *S. sealii/S. similis.*

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APPENDIX. COLLECTION DATA FOR THREE SPECIES OF *STREPTOCEPHALUS*.

Streptocephalus sealii, females

SSEL1—California: Tuolumne County, Kole Lake, 8,500 ft. (2,593 m) elevation, 21°C, 31 July 1989, Brian Quelvog, collector. Female = 17.0 mm total length. Cyst diameters measured (in μm): 261, 266, 270, and 307.

SSEL2—California: Tehama County, 40°25′N, 121°35′W, 7,150 ft. (2,972 m) elevation, 23 June 1987, Clyde Eriksen, collector, number A2–134. Female = 13.0 mm total length. Cyst diamters measured (in μm): 236, 240, 247, 257, 261, 268, 268, 278, 282, and 289.

SSEL3—California: Siskiyou County, "Newt Wallow," Klamath Mountains, Dillon Divide near County Line, 10 August 1985, G. Newton, collector. Female = 17.5 mm total length. Cyst diameters measured (in μm): 282, 282, 282, 285, and 285.

SSEL4—California: Lassen County, 26 km north of Susanville, 1 July 1986, Ed. Smith, collector, California Academy of Sciences collection. No cysts measured.

Streptocephalus similis, female

Belize: Orange Walk District, Rio Bravo Preserve, in roadside pond, 1 mile (1.61 km) south of headquarters, east side of road, 2 January 1996, W. D. Shepard, collector. Female = 15.8 mm total length. Cyst diameters measured (in μm): 190, 190, 194, 196, 196, 196, 199, 199, 200, and 200.

Streptocephalus woottoni, females

SWO1—California: Riverside County, Skunk Hollow, south basin, 33°34′N, 117°06′W, 1,340 ft. (409 m) elevation, 19 March 1992, C. Eriksen, collector, number A2–122. Female = 11.2 mm total length. Cyst diameters measured (in μm): 240, 243, 243, 245, 246, 247, 250, 254, 257, and 257.

SWO2—California: Riverside County, Pala Road, 23°C, 19 March 1992, C. Eriksen, collector, number A2–187. Female = 13.3 mm total length. Cyst diameters measured (in μm): 261, 264, 268, 268, 271, 275, 275, 275, 278, and 310.

SWO3—California: Riverside County, across road from Skunk Hollow, 28°C, 19 March 1992, C. Eriksen, collector, number A2–186. Female = 9.5 mm total length. Cyst diameters measured (in μm); 271, 275, 278, 278, 282, 282, 282, 282, 289, and 307.

SWO4—California: San Diego County, bluffs above White Beach, Camp Pendleton, Pool A, 23 March 1993, J. E. Moeur, collector, number M23Mar93–5. Female = 28.0 mm total length. No cyst diameters measured.