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Special Issue: Fossil and Modern Clam Shrimp (Branchiopoda: Spinicaudata, Laevicaudata) Open Access

A New *Eulimnadia* (Branchiopoda: Spinicaudata: Limnadiidae) from the US Virgin Islands

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We describe a new species of *Eulimnadia* from the Caribbean using fresh material from the island of St Thomas. Originally reported in 2003 as a *Eulimnadia* cf. *texana* (Packard, 1871) based on egg morphology, this species egg distinctly differs from *E. texana* by the number of lateral grooves and by the single domed end.

Key words: Spiny clam shrimp, Diplostraca, Caribbean Islands.

BACKGROUND

The clam shrimp of the Caribbean Islands, as for most areas, have been in confusion for some time (Rogers et al. 2020). Only one Cyzicid clam shrimp has been reported from the Caribbean. Baird (1849) described *Cyzicus jonesi* from Cuba, however Daday (1914) suggested that the material actually came from the southern USA or Central America.

Limnadiid clam shrimp from the Caribbean have been even more confused, especially since modern species morphological definitions for *Eulimnadia* were not available until 1989. *Eulimnadia antillarum* (Baird, 1852) *nomen dubium* was described from the Dominican Republic, with subsequent reports from Brazil (Lilljeborg 1889), and México (Daday 1926; Tasch and Scaffer 1964). *Eulimnadia* species can only reliably be identified morphologically by the form of the egg (Belk 1989; Rabet 2010; Rogers et al. 2012). However, none of the descriptions above included egg morphology, and all the descriptions were inconsistent with each other (Rogers et al. 2020). Martin (1989) and Rabet (2010) reported that all specimens ascribed to this species, which Baird had examined in the British Museum, the Hungarian Museum, and the Paris Museum, either lacked eggs or had eggs from multiple species present. Baird (1852) did not mention the egg in the original description and Belk (1989) stated "no useful information is available on the egg morphology of *E. antillarum*", leading Rogers et al. (2020) to treat this species as a *nomen dubium*.

Muchmore (1993) reported *Eulimnadia diversa* Mattox, 1937 from a "temporary pond at Great Lameshur Bay", St John, in the US Virgin Islands, and claimed to have sent material to several institutions. Muchmore (1993) did not provide any basis for his determination, nor state where any of his material was deposited. Smith and Little (2003) were unable to locate any of his specimens. Smith and Wier (1999) collected *Eulimnadia* from numerous pools on Mona Island, Puerto Rico and reported one additional collection from Jamaica (at Harvard University, which may be the same as Gurney's (1931) allusion to an undescribed *Eulimnadia* from Jamaica), both populations with a cylindrical egg. The Mona Island population egg was figured (Smith and Wier 1999: figs. 3 and 4) and the authors ascribed the populations to *E. texana* Packard, 1871 but with reservations. Later, Smith and Little (2003) reared *Eulimnadia* from soil samples collected from the pool visited by Muchmore (1993) and reported

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that the egg was cylindrical (unlike *E. diversa*, which has spherical eggs (Belk 1989)). These authors referred the St. John material to *E.* cf. *texana*, based on a comparison with the literature.

We collected fresh material of a Caribbean *Eulimnadia*, from new localities in St. Thomas during several surveys in 2019. We describe this species based on field-collected live specimens and eggs extracted from these animals, as well as museum collections from Mona Island and Jamaica.

MATERIALS AND METHODS

Adults were collected using dip nets from ponds ("water hazards") of the Herman E. Moore Golf Course at the University of the Virgin Islands in St. Thomas (18.3381°N, 64.8941°W). Most individuals were collected in association with a green freshwater alga (*Cladophora* sp.). Only females were found in the collection. Specimens were preserved in 70% ethanol, transferred to 90% ethanol after 24 hours, and examined using a Wild M8 stereomicroscope.

Acronyms: MCZ = Harvard Museum of Comparative Zoology. DCR = collections of D.C. Rogers.

RESULTS

SYSTEMATICS

Limnadiidae Baird, 1849

Eulimnadia insularis sp. nov.

(Fig. 1)
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= *Eulimnadia diversa* Mattox, 1937 in Muchmore, 1993
= *Eulimnadia texana* Packard, 1871 in Smith & Wier, 1999
= *Eulimnadia* cf. *texana* Packard, 1871 in Smith & Little 2003

Type locality: University of the Virgin Islands, Herman E. Moore Golf Course, St. Thomas, US Virgin Islands.

Etymology: From the Latin "*insulum*" (an island) and the suffix"-*aris*", forming a third declension, two termination adjective "*insularis*", literally; "from an island". The gender is neuter.

Material examined: JAMAICA: Trelawny Parish: Jackson Town, Baron Hill, 18.415253°, -77.487415/1930°; May 1930; Perkens; MCZ 43811; identified as *Eulimnadia antillarum*. U.S.: PUERTO RICO: Mona Island: temporary pools off Camino Los Cerezos, from 0.5 mi to 1 mi from origin; 17 March 1996; D.G. Smith; MCZ 58808; identified as *Eulimnadia* cf. *texana*. VIRGIN ISLANDS: St. Thomas: University of the Virgin Islands Herman E. Moore Golf Course water hazards; 19 August 2019; 12 females/hermaphrodites; D.C. Rogers, E. Cruz-Rivera; DCR-1152.

Diagnosis: Mature egg (Fig. 1D) overall form a slightly expanding subcylinder with the larger end slightly domed and occasionally with an oblique ridge. Each end of the cylinder with a projecting margin. Narrower end with margin not projecting laterally (~0.1–0.5x) as far as larger end margin. Cylinder wall with numerous, subparallel grooves, either in line with the cylinder (Smith and Wier 1999: fig. 4; Smith and Little 2003: fig. 3) or oblique (Smith and Wier 1999: fig. 3). Cylinder wall grooves numerous, separated by narrow, angular ridges, sloping steeply into the grooves. Cylinder end marginal ridge line following cylinder circumference, subangular to rounded in cross section, and projecting slightly beyond cylinder wall ridges. Egg narrow end with three to six subparallel angular ridges, some may be joined at centre. Egg broad end with several parallel or oblique groups of subparallel angular ridges, some joined at random intervals into a narrow transverse ridge. Eggs 150–190 μm in diameter.

Description: Egg as for diagnosis, above. Ocular tubercle prominent (Fig. 1A), projecting dorsally further than rostrum projects anteriorly. Head broadly rectangular, broader than ocular tubercle. Contiguous compound eyes large, subspherical, ~0.80x ocular tubercle width. Naupliar ocellus subtriangular, lying just posterior to and within, or slightly above and posterior to rostrum. Ocular face abruptly angulate to rostrum. Head front in lateral view straight, distance from rostral base to ocular tubercle base subequal to or slightly greater than length of ocular tubercle. Rostrum reduced, broadly rounded to truncate or acute, apex slightly upturned, 0.8x ocular tubercle width. Angle between rostrum and frons 100° to 90°. Rostrum subeven with head ventral surface. Pedunculate frontal organ length approximately 0.9x to 1.2x distance of organ from ocular tubercle. Dorsal organ prominent, pedunculate, directed anteriorly, and elongate ovate to subtriangular. First antennae well below and posterior to rostrum, pedunculate, and 0.6x as long as second antennal peduncle. Second antennae 2 to 2.5x head length. Second antennal peduncle subcylindrical, subequal in length to head, slightly geniculate, and bearing dorsal transverse rows of spiniform setae.

Second antennal anterior flagellum (exopod) with six or seven annulations, each dorsally with a transverse row of setae. Posterior flagellum (endopod) with eight or nine such annulations, and subequal in length to anterior flagellum. Both flagellae with a ventral, longitudinal row of long plumose natatory setae, about 0.7x peduncle length. Carapace typical for the genus; broadly oval, with growth lines obscure. Carapace intervals smooth. Umbone absent. Adductor muscle scar broad, oblong, length ~2x width. Fourteen to sixteen pairs of thoracopods, with ninth and tenth or tenth and eleventh pairs bearing dorsally elongated flabellae for carrying eggs. Abdomen segments posterior to eleventh thoracopod pair dorsally with transverse row of spiniform setae or spines, diminishing in length serially in posterior abdominal segments, each spine apically with spinulae. Telson (Fig. 1B) with 13 to 22 pairs of posterior spines borne on the posteriolateral ridges. Anterior most spine pair directed dorsally or subdorsally, smaller than second pair, which is often

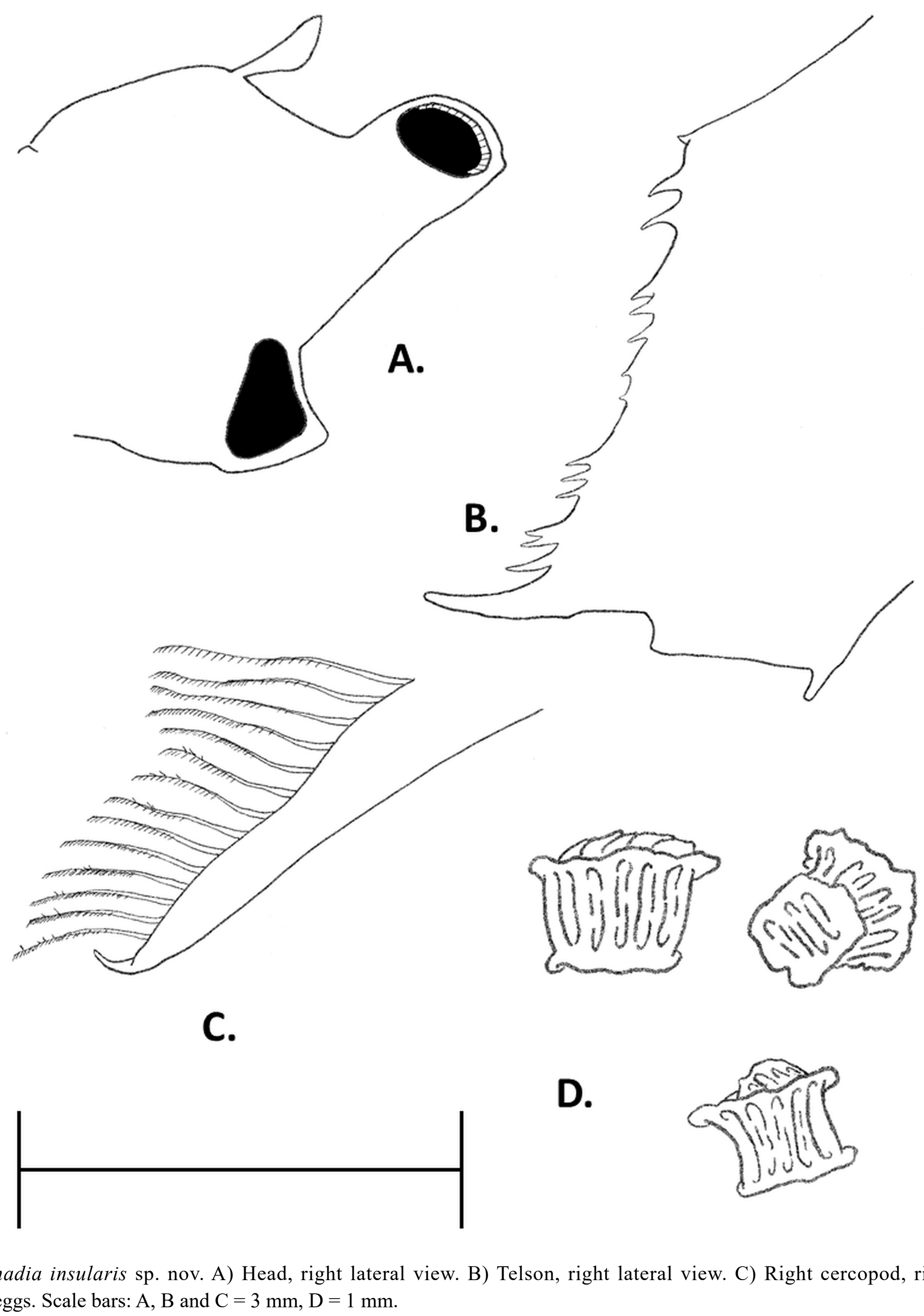

Fig. 1. *Eulimnadia insularis* sp. nov. A) Head, right lateral view. B) Telson, right lateral view. C) Right cercopod, right lateral view. D) Representative eggs. Scale bars: A, B and C = 3 mm, D = 1 mm.

the largest pair. Spines spaced unevenly, sometimes separated by several times the spine basal width. Occasional small spines slightly out of line. Spines uneven in size, with smaller spines basal width ~0.7x larger spines basal width. Caudal filaments originating on mound on telson posterior surface between the ridges at or about the fourth of fifth pair of spines. Telson posteriolateral ridges each terminating in an elongated spiniform projection, 3.5 to 4.0x nearest spine length. Cercopods (Fig. 1C) projecting posteriorly from the ventral surface of the telson, each subtended by an anteriobasal spiniform projection, directed posteriolaterally over the base of the cercus. Cercopod ~0.9x telson length, margined dorsomedially with a longitudinal row of long plumose setae, extending from base distally to ~90% point. Setal row terminating in a short spine.

Habitat: Two temporary ponds that constitute the "water hazards" in the University of the Virgin Island's Herman E. Moore Golf Course. The ponds inundate during the wet season of August-November (ca. 2 m deep) but are otherwise completely dry. A diverse community of aquatic insects, one species of Cladocera, and tadpoles from two frog species inhabit these ponds. Green filamentous algae (*Cladophora* sp.) occurred in 0.5–1 m mats on the edges of the ponds and several *Eulimnadia* individuals were obtained by collecting these algal mats.

Distribution: Puerto Rico, Jamaica, St. Thomas, St. John.

DISCUSSION

As is typical for the genus, the adult morphology is not reliably distinguishable between *Eulimnadia* species (Belk 1989; Rabet 2010; Rogers et al. 2012). The specific diagnostic characters are limited to the eggs in this genus, and are only visible with scanning electron microscopy. *Eulimnadia insularis* sp. nov. belongs to the *Eulimnadia texana* species group as defined by Rogers (2020), which includes all New World species with cylindrical eggs. Rogers (2020) established this species group based on the tremendous overlap in egg morphology among New World taxa with cylindrical eggs (Brendonck et al. 1990; Rogers et al. 2020). *Eulimnadia insularis* sp. nov. differs from all congeners in the *Eulimnadia texana* species group by having the cylindrical body of the egg expanding slightly in one direction (like a section of a cone), with the wider cylinder end slightly domed. All other new world species with a cylindrical egg, have the cylinder basically parallel sided, with each end subequal in diameter and both ends either flat or depressed. Other differences are as follows:

Eulimnadia texana is widespread in North America and northern South America (Rogers 2020; Rogers et al. 2020). The very similar *E. ovisimilis* Martin & Belk, 1989 occurs from Paraguay to Argentina (Marinone et al. 2016). Both species have a very similar egg morphology and are readily separated from *E. insularis* sp. nov. by bearing fewer cylinder wall grooves between broadly rounded ridges (Belk 1989: figs. 1–6; Marinone et al. 2016: fig. 4G, H), in addition to the characters mentioned above. In *E. insularis* sp. nov., the cylinder wall grooves are more numerous and lie between narrow, angular ridges.

Eulimnadia cylindrova Belk, 1989, is reported from the deserts of southern USA and northern México, south to the Caribbean (Weeks et al. 2009; Rabet et al. 2014; Bellec and Rabet 2016; Rogers et al. 2020). This species has the circumferential ridges angular with crenulate margins, whereas in *E. insularis* sp. nov. the circumferential ridges are rounded and sinuate to smooth (Belk 1989; figs. 23, 24). *Eulimnadia belki* Martin, 1989 ranges from southern México south to northern South America. This species has the circumferential ridges broken into large, rounded lobes, projecting well beyond the cylinder walls, four to six times the height of the cylinder wall ridges (Martin 1989; Fig. 4A, B). In *E. insularis* sp. nov. the circumferential ridges are entire, and only projecting approximately twice the height of the cylinder wall ridges.

Eulimnadia geayi Daday, 1913 has been reported from Mexico to Colombia and Venezuela (Pereira and García 2001; Reed et al. 2015). The egg is depicted by Martin (1989) and Pereira and García (2001). The egg is subcylindrical, as in *Eulimnadia insularis* sp. nov., with the larger end of the cylinder domed, but lacks the circumferential ridges.

This species was specifically associated with green algal mats. *Eulimnadia* are largely considered detritivores or microvores (Brendonck et al. 2008; Rogers 2009; Wang et al. 2012; Liu et al. 2020) and tend to occur in more open areas or areas with anthophytes as dense filamentous algal mats may entangle and trap them. It is doubtful that the filamentous algae were being used as food (Wang et al. 2012; Liu et al. 2020). The peculiar occurrence and particular habitat of this species in a golf course at a university campus suggests a relatively recent colonization event. No previous samplings of this habitat exist to determine the age of the population with accuracy, but the golf course was constructed by the American Virgin Islands government in the early 1950s (Murray 1951) from an area that was originally part of the Bourne Field airport's alternative runway, which was operated by the US Marine Corps until the end of WWII (Murray 1951; Work 1970).

No fish were stocked as the ponds are seasonally astatic. Thus, the most logical route of introduction appears to be transport via aquatic birds (*sensu* Rogers 2014), which are commonly observed foraging in the area. During our surveys Spotted Sandpiper (*Actitis macularius* Linnaeus, 1767) were observed feeding in all the water hazards on the golf course, with at least four birds present per pond.

Bass and de Silva (2010) report an unidentified clam shrimp from Saint Vincent and the Grenadines as "*Eocyzius*? sp.", as "*Spinicaudata eocyzinus*", and finally as "genus *Eocyizius*", stating that it belongs to the Cyzicidae, and picturing the animal (figures un-numbered in the paper). We assume that they are referring to the genus *Eocyzicus* Daday, 1914. However, the photograph clearly depicts a *Eulimnadia* (Limnadiidae) with visible eggs. These eggs are obviously cylindrical, but there is insufficient resolution to identify the species.

As an aid to identification of clam shrimp from the Caribbean Islands, we provide a key to the known Spinicaudata species of this region.

Key to Caribbean Spinicaudata

This key is of limited use, in that three species are not readily separable at this time, and further study is needed to determine if they are conspecific or not.

1. Head with pedunculate frontal organ; carapace thin, generally translucent (unless covered with algal growth), growth lines obscure; telson with a ventral subcercopodal spine; Limnadiidae 2
- Head with frontal organ sessile; carapace thicker, never translucent, growth lines well developed; telson without a ventral subcercopodal spine (one vague report from Cuba, not collected since, identity unclear) .... Cyzicidae

2(1) Egg cylindrical, sides of cylinder parallel 3
- Egg subcylindrical, one end wider than the other, with projecting margin; cylinder sides slightly diverging towards one end; larger end slightly domed or with a transverse ridge .... *Eulimnadia insularis* sp. nov.

[Puerto Rico, Virgin Islands, Jamaica]

3(2) Egg cylinder ends with a circumferential ridge; cylinder wall ridges angulate 4
- Egg cylinder ends without a circumferential ridge; cylinder wall ridges broadly rounded .... *Eulimnadia texana*/ *ovisimilis*/ *geayi*

[Americas, Galapagos Islands]

4(3) Egg cylinder circumferential ridges angular with crenulate margins, projecting ~2x cylinder wall ridge height .... *Eulimnadia cylindrova*

[USA, México, Martinique, La Désirade]
- Egg cylinder circumferential ridges rounded discontinuous lobes, projecting well beyond the cylinder walls, 4–6x the height of the cylinder wall ridges .... *Eulimnadia belki*

[México (Island of Cozumel)]

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