J. Parasitol., 90(1), 2004, pp. 128–136

TWO NEW SPECIES OF *CARDICOLA* (DIGENEA: SANGUINICOLIDAE) IN DRUMS (SCIAENIDAE) FROM MISSISSIPPI AND LOUISIANA

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ABSTRACT: Two new species of *Cardicola* (Digenea: Sanguinicolidae) are described from the heart of drums (Perciformes: Sciaenidae) in and off Mississippi and Louisiana. *Cardicola palmeri* n. sp. infects the black drum, *Pogonias cromis*, and, in mature individuals, is distinguished from its congeners by the combination of a body 1.9–2.9 times longer than wide, an esophagus 44–52% of the body length, posterior ceca 1.0–1.8 times longer than the anterior ones, a gland encircling the seminal vesicle that is 30–37% of maximum body width in diameter, and a sinistral and nearly medial male pore. *Cardicola currani* n. sp. infects the red drum, *Sciaenops ocellatus*, and is distinguished from its congeners by the combination of posterior ceca 1.8–4.2 times longer than anterior ones, a male pore located well posterior to the ootype, a female pore and transverse metraterm located just anterior to the level of the ootype, and a medial and posttesticular ovary located at the level of the terminal ends of the posterior ceca. No adult blood fluke had been described previously from the northern Gulf of Mexico west of Florida. Each of the 2 flukes infected only 1 host species despite the hosts being sympatric.

Little information exists regarding the taxonomic diversity and host range of fish blood flukes (Sanguinicolidae) in the Gulf of Mexico. Only 5 nominal species of 4 genera are known from 7 fishes in the region (Smith, 1997b; Bullard and Overstreet, 2003). *Paradeontacylix sanguinicoloides* McIntosh, 1934, infects the gill, presumably branchial vessels, of the yellowtail, *Seriola lalandi* Valenciennes, 1833 (Carangidae), in the Atlantic Ocean off Miami, Florida (McIntosh, 1934), and probably ranges into the Gulf of Mexico. The 10 nominal species of *Cardicola* Short, 1953, infect the heart and the blood vessels of the kidney, liver, gill, and coelom of tunas (Scombridae), mullets (Mugilidae), a chub (Sparidae), butterflyfishes (Chaetodontidae), an odacid (Odacidae), and drums (Sciaenidae) (see Smith, 1997a, 1997b). They range from the north Pacific Ocean off Hawaii (Yamaguti, 1970); the Tasman Sea off Wellington, New Zealand (Manter, 1954); the Indian Ocean off the southern coast of Australia (Cribb et al., 2000); the southeast Atlantic Ocean off Brazil (Knoff and Amato, 1992); the Gulf of Tonkin and the South China Sea (Lebedev and Mamaev, 1968); and the Gulf of Mexico off Florida (Manter, 1947; Short, 1952, 1953). In this study, we describe 2 new species of *Cardicola* from drums in and off Mississippi and Louisiana, one from the black drum and the other from the red drum.

MATERIALS AND METHODS

Thirteen species of Sciaenidae were caught using hook and line, trawl, or gill net from the Gulf of Mexico and an inland lake between June 1997 and June 2000 (Table I). Of these, only 2 were infected by blood flukes, even though 2 more have been reported as hosts (Short, 1953). Some of these fish were maintained in a 1,100-L holding tank for 24–48 hr before being killed by spinal severance or by exposure to tricaine methanesulfonate. Immediately after the fish were killed, the heart was extracted, placed in a glass petri dish with 8.5 ppt NaCl solution or an anticoagulant solution of 5.0 g NaCl and 2.0 g NaCl-citrate/L of distilled water, bisected, and sprayed with the same solution from a squirt bottle to dislodge the flukes. Gill filaments were removed, placed on a slide with several drops of seawater, coverslipped, and examined with the aid of a compound microscope equipped with Nomarski optics. These and a few liberated fluke eggs were photographed with a digital camera. Adult and juvenile flukes were examined live under a dissecting microscope, compound microscope, or both before killing them under slight coverslip pressure with heat from an ethanol-burner flame and were transferred to a vial containing 5 or 10% neutral buffered formalin. Whole mounts were stained in Van Cleave's hematoxylin, with several additional drops of Ehrlich's hematoxylin, made basic at 70% ethanol with lithium carbonate and butyl amine, dehydrated, cleared in clove oil, and mounted in Canada balsam. Lateral tegumental spines were measured by crushing a formalin-fixed specimen of each species beneath a coverslip. A specimen of each species also was embedded in paraffin, sectioned at 4 μm, and stained with Gill's hematoxylin and eosin. Three specimens of each species to be used for scanning electron microscopy were dehydrated, immersed in hexamethyldisilazane for 15 min, dried under a vacuum for 10 min, and sputter coated with gold–palladium. Drawings of mounted specimens were made with the aid of a drawing tube. Measurements are reported in micrometers and given as ranges followed by the sample size in parentheses. Specimens were deposited in the U.S. National Parasite Collection (USNPC) at Beltsville, Maryland.

Received 11 March 2003; revised 30 April 2003; accepted 13 June 2003.

DESCRIPTIONS

Cardicola palmeri n. sp.

(Figs. 1–17)

Adult (based on 12 specimens): Body flat, ventrally concave, ovoid, 1,449–2,357 (12) long, 867–1,105 (12) wide, 1.9–2.9 times longer than wide, with anterior tip recessed slightly at midline and tapered slightly more than posterior end of body (Figs. 1, 6, 7, 14); body margin either straight (Figs. 8, 9) or crimped ventrally (Fig. 10), spined; tegumental body spines in ventrolateral transverse rows, with recurved distal tips, 33–38 (20) long, 5–6 (20) wide at base (Figs. 4, 5, 11), protruding 5 (5) or 14–20% of spine total length from tegument, with lateral most spine in each row 10–20 (40) from body margin (Figs. 1, 4, 5, 8–11). Tegumental spine rows extending along ventrolateral margins for entire body length, confluent anteriorly and posteriorly or nearly so, with 164–193 rows per side or total of 343–379 (11) rows; each row 32–40 (40) long in middle portion of body (Figs. 8–10), with number of spines per row increasing from anterior end of body mediad, decreasing posteriorly, with typical pattern of 3–4–3 spines per row (3 of 12 specimens with medial rows consisting of 5 spines) (Figs. 1, 8–10, 14). Fused or rosethorn-shaped spines lacking. Nervous system with ventrolateral and dorsolateral nerve cords and commissure; ventrolateral nerve cord 1,350–2,234 (12) long, 12–25 (12) wide near midbody at widest level, 99–198 (12) from body margin, connected anteriorly and posteriorly, joining paired cord 74–122 (10) or 4–6% of body length from posterior end of body, with secondary branches extending laterad and mediad; dorso-

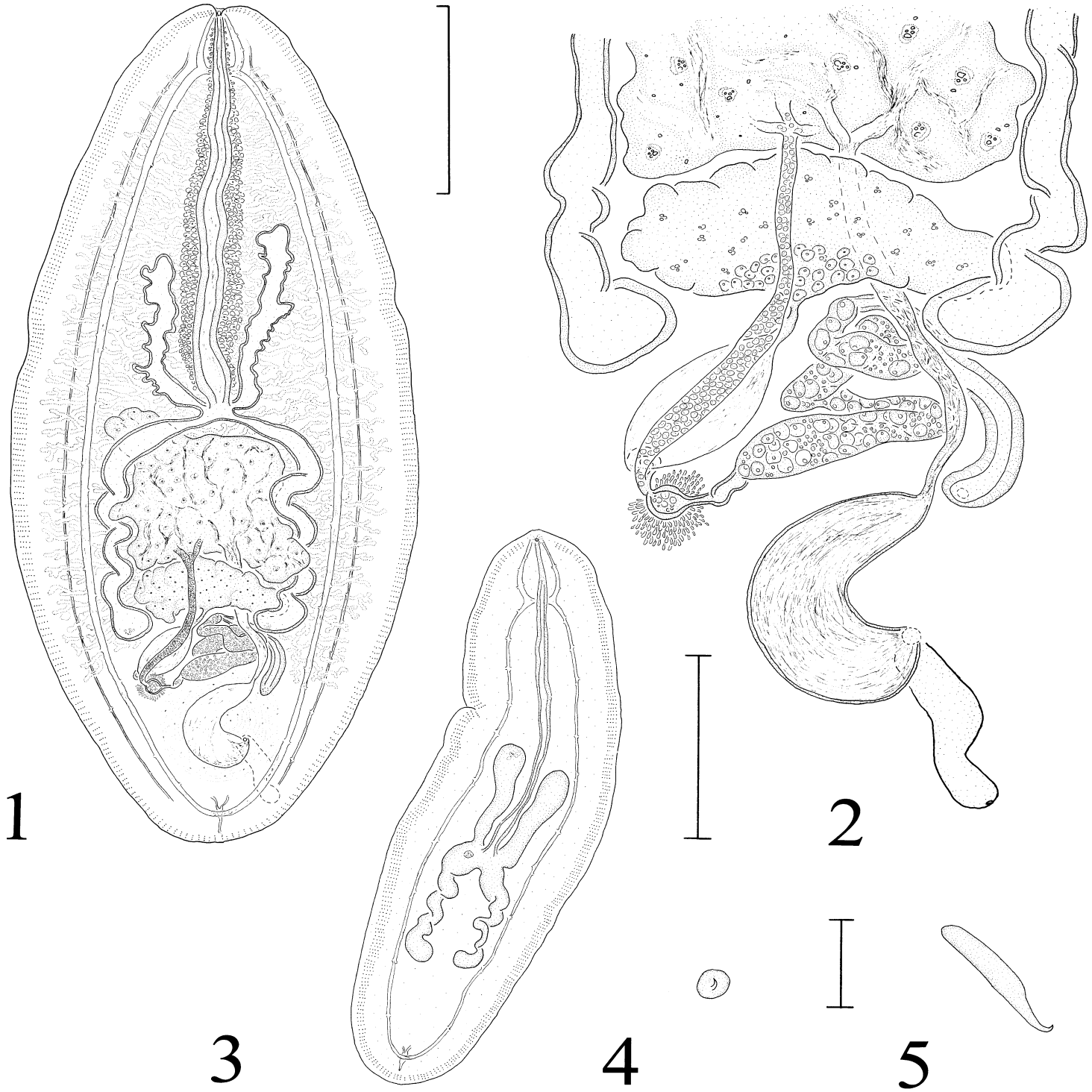
TABLE I. Drums and seatrouts (Sciaenidae) examined for sanguinicolids.

Species examined	No. infected/ no. examined	Locality
Sciaenops ocellatus (red drum)	3/10	Gulf of Mexico, Louisiana
	35/81	Gulf of Mexico, Mississippi
Micropogonias undulatus (Atlantic croaker)	0/22	Gulf of Mexico, Mississippi
Pogonias cromis (black drum)	28/92	Gulf of Mexico, Mississippi
Aplodinotus grunniens (freshwater drum)	0/3	Lake Chotard, Mississippi
Leiostomus xanthurus (spot)	0/1	Gulf of Mexico, Mississippi
Cynoscion nebulosus (spotted seatrout)	0/3	Gulf of Mexico, Louisiana
	0/11	Gulf of Mexico, Mississippi
C. arenarius (sand seatrout)	0/12	Gulf of Mexico, Mississippi
Bairdiella chrysoura (silver perch)	0/5	Gulf of Mexico, Mississippi
Menticirrhus americanus (southern kingfish)	0/16	Gulf of Mexico, Mississippi
M. littoralis (gulf kingfish)	0/2	Gulf of Mexico, Mississippi
M. saxatilis, northern kingfish	0/8	Gulf of Mexico, Mississippi
Equetus umbrosus (cubbyu)	0/1	Gulf of Mexico, Texas
Larimus fasciatus (banded drum)	0/11	Gulf of Mexico, Texas

lateral nerve cord paired, extending parallel with ventrolateral nerve cord between ventrolateral nerve cord and body margin, approximately 10 wide, indistinct in region anterior to nerve commissure, with secondary branches extending laterad and mediad, not connected with counterpart; commissure perpendicular to midline of body 131–164 (11) or 7–10% of body length from anterior end of body, 62–99 (10) across width of worm, 10–25 (11) in diameter (Fig. 1). Dorsal and ventral tegumental sensory papillae abundant; dorsal papillae loosely arranged in dorsolateral bands (Figs. 6, 12); bands overlying approximate track of lateral nerve cords, extending parallel with lateral body margins (Fig. 6); ventral papillae internal and external to spine rows, 3–5 in number between spine rows (Figs. 8–10), dispersed ventrolaterally (Fig. 8), scarce or absent along ventral midline (Fig. 13).

Oral sucker and pharynx lacking (Figs. 1, 6, 7, 14). Mouth 5–7 (11) in diameter, medioventral, subterminal, with flanking spine rows (Figs. 1, 14). Esophagus 752–1,089 (12) long or 44–52% of body length, 50–104 (12) in maximum width, extending straight or sinuously posteriad along midline, with up to 6 (12) curves, widening posteriorly, lined with cilia; esophageal wall thickening from 3–5 (12) near mouth to 10–30 (12) in medial and posterior portions or 2–6 times thickness of wall in anterior portion, slightly expanding posteriorly (Fig. 1); cilia dense, directed posteriorly, slightly refractive. Esophageal gland enveloping esophagus, concentrating in an area 445–940 (12) long or 55–100% of esophageal length and 85–208 (12) wide or 1.6–2.3 times width of esophagus, consisting of spherical cells and refractive dorsoventral rodlike processes (Fig. 1); each cell approximately 8 long and 4 wide, subspherical or spherical. Alimentary tract H-shaped, with paired anterior and posterior ceca, with ceca connecting with esophagus anteroventrally; intersection of anterior and posterior ceca 44–52% of body length from anterior end; anterior ceca 338–547 (12) long or 19–26% of body length, unequal in length (dextral cecum longest in 6 of 12 specimens), 15–104 (12) wide, with each cecum extending slightly anterolaterally and between esophageal gland and ventrolateral nerve cord, with wall approximately 8 thick, with uneven borders and diverticula, containing granular material within lumen of some individuals; granular material dense, brownish-yellow in both live and mounted individuals, evenly filling lumen of ceca; posterior ceca 373–805 (12) long or 26–35% of body length and 1.0–1.8 times length of anterior ceca, unequal in length (dextral cecum longest in 9 of 12 specimens), 25–75 (12) wide, with neither cecum extending beyond ventrolateral nerve cord, with each cecum extending sinuously posteriad approximately parallel with ventrolateral nerve cord, sinuous in some regions, lacking diverticula, expanding laterally at terminal end in 11 of 12 specimens; expanded terminal end 55–139 (11) wide or 1.5–3.4 (width of posterior ceca), often containing same granular material as in anterior ceca.

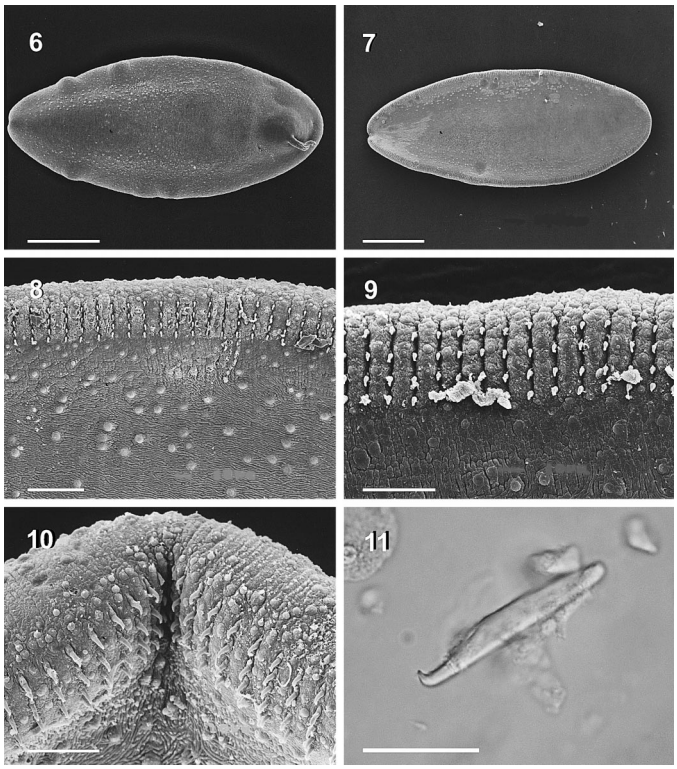
Testis approximately square, 249–349 (11) long or 14–21% of body length, 298–597 (11) wide or 42–61% of body width, entirely between posterior ceca in 8 of 12 specimens, extending laterally just beyond posterior ceca in remaining 4, entirely posterior to level of cecal intersection or extending anteriad to level immediately beyond cecal intersection, with lobed border, enclosing refractive processes; processes indistinct, clustered; each cluster 10–17 (10) in diameter, with 2–5 processes (Figs. 1, 2). Posttesticular space 425–933 (11) long or 28–39% of body length (Fig. 1). Vasa efferentia difficult to trace in fixed specimens, an interconnecting meshwork of fine ducts entwining throughout testicular tissue, containing spermatozoa in all specimens, 10–25 (8) in diameter, extending primarily dorsoventrally and along ventral surface of testis, uniting in posterior region of testis (Figs. 1, 2); vas deferens 223–447 (11) long, 20–37 (11) wide, slightly sinistral, extending dorsomedially from testis and posteriad to near terminal end of sinistral posterior cecum, not extending beyond sinistral ventrolateral nerve cord or cecum, narrowing distally, containing sperm in all specimens (Figs. 1, 2). Seminal vesicle acutely arcuate, 161–423 (12) long, 32–114 (12) wide, medial, postcecal, postgonadal, orienting toward sinistral body margin, containing sperm in 8 of 12 specimens, with wall 3–12 (11) thick (Figs. 1, 2), with surrounding gland; gland a loose aggregation of cells and associated fine ducts, 214–373 (10) in diameter or 30–37% of maximum body width, 99–221 (9) or 6–13% of body length from posterior end, not extending beyond lateral nerve cords (Fig. 1); each cell approximately 6 long and 3 wide. Auxiliary seminal vesicle lacking. Cirrus large, fingerlike when extruded,



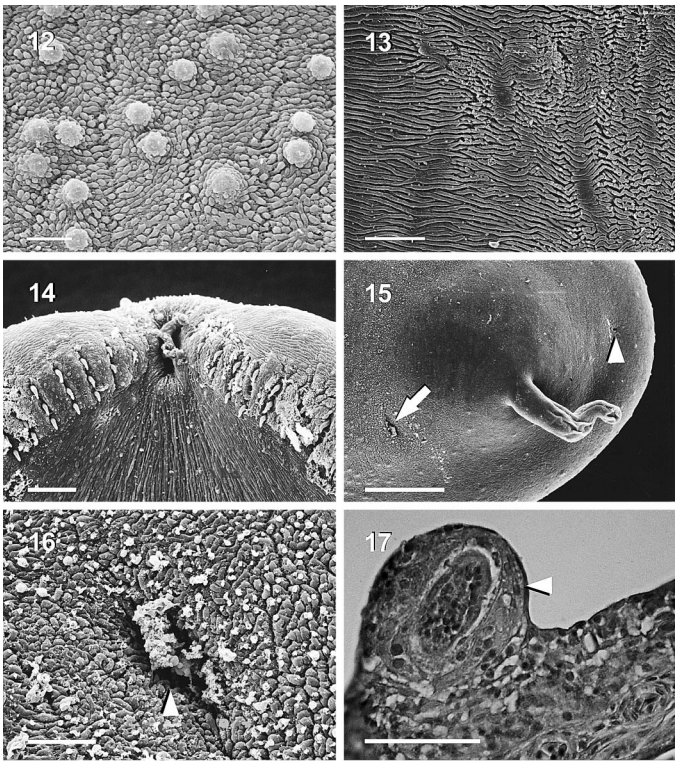
FIGURES 1–5. *Cardicola palmeri* n. sp. from heart of *Pogonias cromis*. **1.** Holotype, body of adult, ventral view; vitelline network is both dorsal and ventral to gonads and alimentary tract. Bar = 500 μm. **2.** Holotype, enlarged view of genitalia shown in Fig. 1, ventral view. Bar = 200 μm. **3.** Body of juvenile from heart of a black drum that was 29 cm in total length and caught in Mississippi Sound on 15 December 1999, ventral view. Bar = 200 μm. **4.** Lateral tegumental spine, adult specimen, frontal view, showing thickness of spine. Bar = 20 μm. **5.** Lateral tegumental spine showing recurved distal tip and wide main portion, adult specimen, ventral view. Bar = 20 μm.

unarmed, 141–253 (5) long up to 157% of seminal vesicle length when extruded (5 of 12 specimens), 50–75 (5) wide or 51–156% of seminal vesicle width, 2.3–3.7 times longer than wide, extruding posterosinistrad and dorsally at approximately 45° angle to midline of body. Male pore 10–22 (7) wide, 161–234 (9) from sinistral lateral body margin, 179–348 (10) or 10–15% of body length from posterior end of body (Figs. 1, 6, 15).

Ovary medial, irregular with occasional lobe, 90–179 (11)



FIGURES 6–11. *Cardicola palmeri* n. sp. from heart of *Pogonias cromis*. **6.** Adult dorsal view, anterior end at left. Bar = 300 μm. **7.** Adult ventral view, anterior end at left. Bar = 300 μm. **8.** Ventrolateral tegumental spine rows and papillae, near midbody, ventral view. Bar = 30 μm. **9.** Enlarged view of lateral tegumental spine rows shown in Fig. 8, ventral view. Bar = 35 μm. **10.** Naturally crimped body margin with rows of lateral tegumental spines in apposition to each other as if to grip host tissue, ventrolateral view. Bar = 20 μm. **11.** Spine isolated from formalin-fixed, crushed specimen. Bar = 20 μm.



FIGURES 12–17. *Cardicola palmeri* n. sp. from heart of *Pogonias cromis*. **12.** Dorsal tegumental papillae. Bar = 10 μm. **13.** Ventral surface of tegument lacking tegumental papillae at the level of the midbody. Bar = 10 μm. **14.** Mouth flanked by spine rows and partially obstructed by debris, ventral view. Note that a preoral lobe is lacking. Bar = 20 μm. **15.** Posterior end of adult showing everted cirrus, female genital pore (arrow), and excretory pore (arrowhead), dorsal view. Bar = 100 μm. **16.** Female genital pore, dorsal view. Bar = 10 μm. **17.** Histological section of egg embedded within gill epithelium containing well-developed miracidium (arrowhead). Bar = 40 μm.

long, 224–447 (11) wide or 33–44% of body width, 1.8–3.4 times wider than long, occupying space immediately posterior to testis or overlapping slightly with posterior testicular margin, ventral to vas deferens, mostly between terminal ends of posterior ceca, overlapping slightly dorsal to posterior ceca in some specimens, containing refractive dorsoventral rodlike processes similar to those in testis; processes occurring singly or clustered. Postovarian space 482–791 (9) long or 24–35% of body length (Figs. 1, 2). Oviduct 186–348 (12) long, near middle, 47–109 (12) wide, extending posteriad and slightly dextrad, leaving ovary medioventrally, conspicuously crooked at distal end; end recurving and arching dorsally toward midline of body before turning posteriad, with oviducal seminal receptacle (Figs. 1, 2); oviducal seminal receptacle 136–249 (12) long or 64–94% of oviduct length, 47–109 (12) wide, containing sperm in all individuals and single ovum in 1 of 12 individuals; ovum 7 in diameter; female duct distal to oviducal seminal receptacle relatively short before confluence of vitelline duct with ootype; ootype 25–50 (12) long, 22–50 (12) wide, ovoid, dextral, located at level of junction of vas deferens and seminal vesicle (Figs. 1, 2). Vitellarium consisting of extensive network of narrow interconnecting branching bands, filling space both dorsal and ventral to gonads and alimentary tract, extending laterad slightly beyond nerve cords (Fig. 1); secondary collecting ducts at least 2 in number (Figs. 1, 2); common collecting duct extending sinuously posteriad 249–457 (9) from testis before becoming 12–35 (9) wide, often indistinct in region immediately anterior to ovary, passing ventral to ovary before curving slightly dextrad and extending beneath oviducal seminal receptacle, meeting distal portion of oviduct ventrally, with distal portion containing separated and primarily fully developed vitelline cells (Fig. 2). Mehlis' gland 50–100 (10) long, 50–124 (10) wide (Fig. 2). Uterus sinuous, 25–75 (12) in maximum width, entirely postgonadal, medial and anterior to seminal vesicle, with prominent metraterm; metraterm 62–186 (11) long, 25–45 (12) wide, 1.8–5.2 times longer than wide, with wall 5–12 (12) thick, sinistral, extending posteriorly from immediately posterior to ovary to level of junction of vas deferens and seminal vesicle, not extending lateral to sinistral ventrolateral nerve cord. Uterine eggs with thin membrane, lacking thickened shell, 5–22 (9) in diameter, spheroid or nearly so, filling uterus in most specimens (Fig. 2); released eggs in branchial arteriole or gill epithelium, typically thin-shelled and pliable, oblong or ovoid, 40–65 (10) long, 23–40 (10) wide, 1.4–2.5 times longer than wide (Fig. 17), nearly transparent in fresh preparations of gill, within host fibrotic encapsulation or not. Female pore dorsal, 7–47 (11) wide, sinistral, at level of or just anterior to

ootype, 99–223 (12) in straight-line-distance from male pore (Figs. 1, 2, 15, 16).

Excretory system often indistinct; vesicle Y-shaped; stem 15–65 (10) long, 17–35 (10) wide, dorsal to posterior nerve confluence, with wall 3–5 (10) thick; arms straight or sinuous, extending approximately parallel with nerve cords in posterior region of body, with anterior extent indistinct; excretory pore subterminal, dorsal, 42–67 (2) from posterior end of body (Figs. 1, 15).

Juvenile (based on 2 specimens): Body flat, ventrally concave, ovoid, 603–633 long, 187–188 wide, 3 times longer than wide, with anterior and posterior ends tapering equally, spined (Fig. 3); tegumental body spines in ventrolateral transverse rows, spikelike, with slightly recurved distal tips about 9 long and 2 wide at base, protruding 1 or 11% of its total length from tegument, with lateral most spine in each row 5 (5) from body margin (Fig. 3). Tegumental spine rows extending along ventrolateral margins for entire body length, rows confluent anteriorly and posteriorly, with 175–187 rows per side of body or a total of 355–367; each row 10 (5) long, with 4 (10) spines per row. Fused or rosethorn-shaped spines lacking. Nervous system not distinct, with ventrolateral nerve cord and commissure; ventrolateral nerve cord 554–584 long, 5 (4) wide near midbody at widest level, 40 (4) from body margin, joining paired cord anteriorly and posteriorly, with posterior connection 31–32 or 5% of body length from posterior end of body, with numerous secondary branches extending laterad and mediad; commissure perpendicular to midline of body 74–87 or 12–14% of body length from anterior end of body, 26–28 across width of worm, 5–10 in diameter (Fig. 3). Dorsolateral nerve cord not evident. Dorsal and ventral tegumental sensory papillae not evident.

Oral sucker and pharynx lacking. Mouth 2 (2) in diameter, medioventral, subterminal, with flanking spine rows (Fig. 3). Esophagus 343 (2) long or 54–57% of body length, 17 (2) wide, extending straight or sinuously posteriad along midline, widening medially and posteriorly; esophageal wall thickening from 1 (2) near mouth to 3–4 in medial and posterior portions or 3–4 times thickness of wall in anterior portion (Fig. 3). Esophageal cilia not evident. Esophageal gland not evident. Alimentary tract H-shaped, with paired anterior and posterior ceca connecting with esophagus anteroventrally; intersection of anterior and posterior ceca 54–57% of body length from anterior end; anterior ceca 93–124 long or 15–20% of body length, 20–25 wide, with each cecum extending anteriorly between esophagus and ventrolateral nerve cord, approximately equal in length, lacking diverticula; posterior ceca 106–149 long or 18–24% of body length and 1.1–1.2 times length of anterior ceca, approximately equal in length, 9–19 wide, not extending beyond ventrolateral nerve cord, with each cecum extending sinuously posteriad approximately parallel with ventrolateral nerve cord, lacking diverticula, expanding laterally at terminal end; expanded terminal end 23–41 wide or 1.6–3.1 times width of posterior ceca, a blind ending sac (Fig. 3); granular material not observed.

Terminal genitalia and gonads not developed; anlagen to seminal vesicle and ovary evident in a single specimen; seminal vesicle anlage 35 long, 25 wide, medial; uterine anlage 124 long, 8 wide, medial, occupying space between terminal ends of posterior ceca.

Excretory system primarily indistinct in 1 specimen; vesicle 14 long, 7 wide, with wall 1 thick (Fig. 3).

Taxonomic summary

Type and only known host: Pogonias cromis (Linnaeus, 1766), black drum (Perciformes: Sciaenidae).

Sites: Adult in atrium, ventricle, and bulbus arteriosus of heart; juvenile in atrium and ventricle; eggs in afferent branchial vessels and lodged within branchial epithelium (Fig. 17).

Type locality: Mississippi Sound off Point Cadet, Biloxi, Mississippi (30°23.7′N, 88°51.4′W).

Other localities: Back Bay of Biloxi, Biloxi, Mississippi (30°25.5′N, 88°58.7′W); Davis Bayou, Ocean Springs, Mississippi (30°23.5′N, 88°47.8′W).

Specimens deposited: Holotype USNPC No. 93198, Paratype USNPC No. 93199.

Prevalence and intensity of infection: Twenty-eight of 92 fish (30%): 1–2 specimens in 11 fish, 3–4 in 8, 6–10 in 4, 12–14 in 3, and 17 and 32 in 2.

Etymology: The specific name *palmeri* honors our friend and laboratory mate Ronnie Glenn Palmer of the Gulf Coast Research Laboratory (GCRL) for his many contributions to parasitology, as demonstrated by his masterful expertise in caring for, collecting, and preparing parasites over the past 34 yr.

Remarks

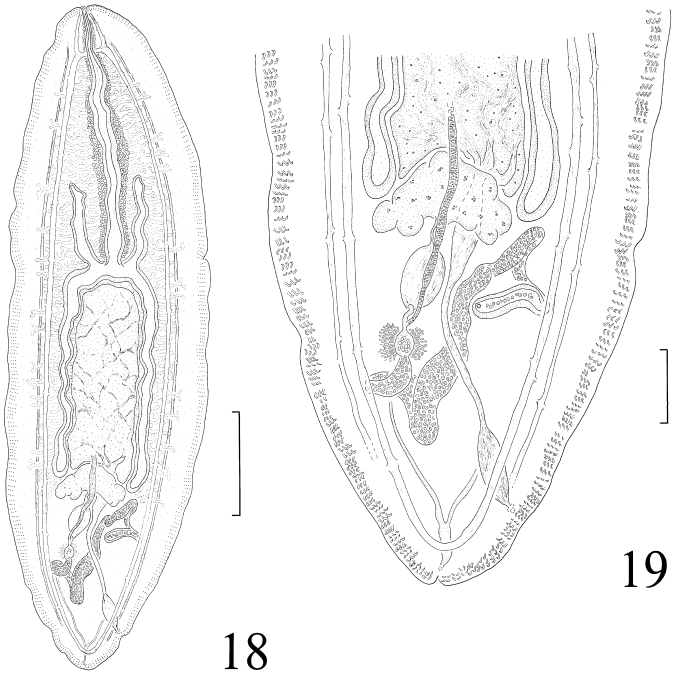
Cardicola palmeri is distinguished from congeneric species by the combination of having a body that is 1.9–2.9 times longer than wide, an esophagus that is 44–52% of the body length, posterior ceca 1–1.8 times longer than the anterior ceca, a gland encircling the seminal vesicle that is 30–37% of maximum body width in diameter, and a male pore that is more medial than the female pore. The new species is most similar to *Cardicola laruei* Short, 1953, from the heart of seatrouts (Sciaenidae: *Cynoscion* spp.) off Florida by the combination of having an esophagus that is about half the total body length, anterior and posterior ceca that are nearly equal in length to each other, and anterior ceca that lack diverticula, and it also infects the heart of sciaenid fishes in the Gulf of Mexico. However, *C. laruei* most notably differs from *C. palmeri* by possessing a male pore that is more lateral than the female pore and that is located at the level of the ootype and overlying the sinistral ventrolateral nerve cord; *C. palmeri* possesses a nearly medial male pore that is located between the ventrolateral nerve cords.

Specimens of *C. palmeri* remained alive long enough (approximately 1 hr) in the salt solution to observe their behavior. They attached to smooth glass surfaces by cupping the ventral surface of the body and to the luminal wall of the heart by pinching trabeculae between adjacent spine rows. Detached flukes that were flipped with a probe so that the dorsum touched the glass dish could seldom right themselves and reattach. Specimens of *C. palmeri* readily attached to each other, to coagulated blood, and to tissue debris.

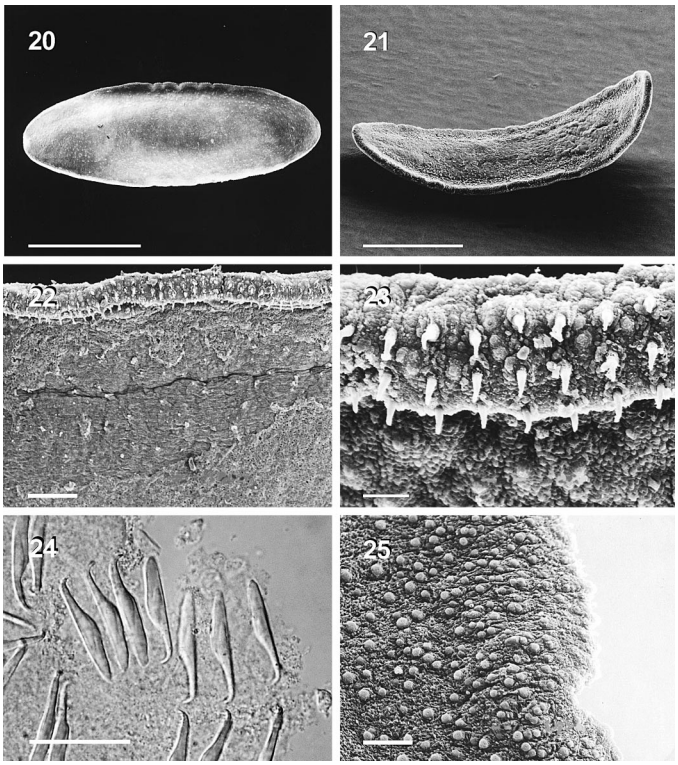
Cardicola currani n. sp.

(Figs. 18–31)

Adult (based on 20 specimens): Body flat, ventrally concave, elongate oval, 1,375–2,853 (20) long, 442–663 (20) wide or



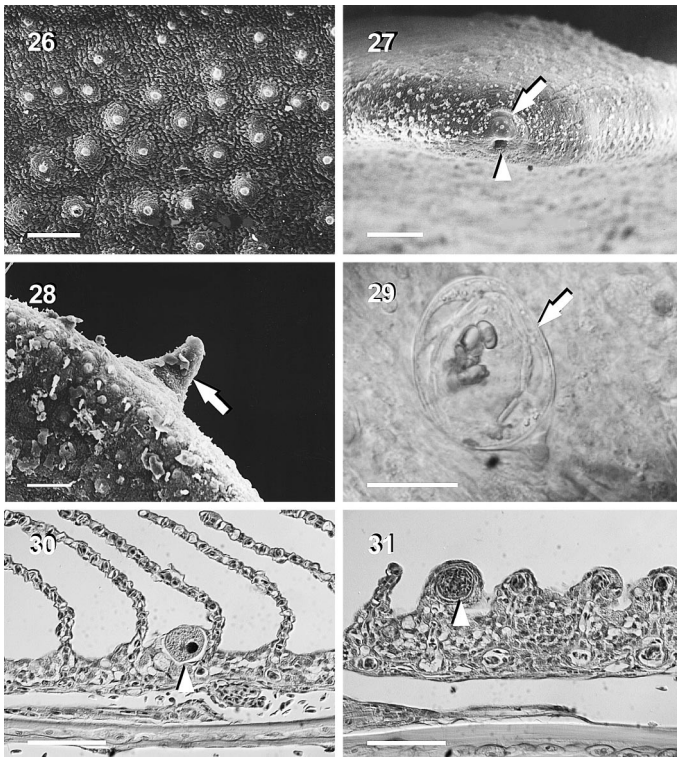
FIGURES 18–19. *Cardicola currani* n. sp. from heart of *Sciaenops ocellatus*. **18.** Holotype, ventral view. Note that vitelline network is actually both dorsal and ventral to gonads and alimentary tract. Bar = 300 μm. **19.** Holotype, enlarged view of posterior end shown in Fig. 18, ventral view. Bar = 100 μm.



FIGURES 20–25. *Cardicola currani* n. sp. from heart of *Sciaenops ocellatus*. **20.** Adult, dorsal view, anterior end at left. Bar = 500 μm. **21.** Adult, ventral view, anterior end at left. Bar = 500 μm. **22.** Rows of lateral tegumental spines, midbody, ventral view. Bar = 50 μm. **23.** Enlarged view of spine rows shown in Fig. 22, midbody, ventral view. Bar = 10 μm. **24.** Spines isolated from formalin-fixed, crushed specimen. Bar = 20 μm. **25.** Dorsolateral surface of body showing papillae, dorsal view, midbody. Bar = 10 μm.

2.6–5.0 times longer than wide, with ends tapering equally (Figs. 18, 20, 21); body margin either crimped ventrally or straight (Figs. 20–23), spined; tegumental body spines in ventrolateral transverse rows, with recurved distal tips, 19–25 (20) long, 3–4 (20) wide at base (Fig. 24), protruding 5–7 (8) or 23–33% of spine length from tegument, with lateral-most spine in each row 5–22 (17) from body margin or slightly wrapping around lateral body margin (Figs. 18, 22, 23). Tegumental spine rows extending along ventrolateral margins for entire body length, confluent anteriorly and posteriorly or nearly so, with 189–224 rows per side of body or total of 379–482 (16) rows; each row 15–25 (18) long in middle portion of body (Figs. 22–24), with 2–4 spines per row, with most rows possessing 4 spines (Figs. 18, 22, 23). Fused or rosethorn-shaped spines lacking. Nervous system with ventrolateral and dorsolateral nerve cords and commissure; ventrolateral nerve cord 1,301–2,771 (17) long, 10–15 (17) wide near midbody at widest level, 69–139 (17) from body margin, connected anteriorly and posteriorly, joining paired cord 40–59 (16) or 2–4% of body length from posterior end of body, with numerous secondary branches extending laterad and mediad (Fig. 18); dorsolateral nerve cord extending parallel with ventrolateral nerve cord between ventrolateral nerve cord and body margin, approximately 7 wide, indistinct in anterior and posterior regions of body, with numerous secondary branches extending laterad and mediad, not connected with counterpart; commissure perpendicular to midline of body 74–189 (18) or 3–8% of body length from anterior end of body, 52–82 (18) across width of worm, 10–32 (18) in diameter (Fig. 18). Dorsal (Fig. 25) and ventral (Figs. 22, 23, 26) tegumental sensory papillae abundant; dorsal papillae dispersed laterally (Fig. 25); ventral papillae internal (Figs. 22, 23) and external (Fig. 26) to spine rows.

Oral sucker and pharynx lacking. Preoral lobe terminal, hemispherical, minute, with central papilla surrounded by ring of 4 papillae (Fig. 27). Mouth 3–10 (18) in diameter, medioventral, subterminal (Fig. 27). Esophagus 514–989 (19) long or 31–40% of body length, 25–60 (18) in maximum width, slightly sinuous, widening medially or posteriorly, lined with cilia; esophageal wall thickening from 3–5 (15) near mouth to 5–17 (15) in medial and posterior portions or 1–4 times thickness of wall in anterior portion; cilia dense in anterior half of esophagus, directed posteriorly. Esophageal gland enveloping esophagus, concentrating in area 124–348 (15) long or 21–40% of esophageal length and 75–149 (15) wide or 2–4 times width of esophagus, consisting of spherical cells and interspersed refractive dorsoventral rodlike processes; each cell approximately 8 long and 4 wide, subspherical or spherical. Alimentary tract H-shaped, with paired anterior and posterior ceca, with ceca connecting with esophagus anteroventrally; intersection of anterior and posterior ceca 31–40% of body length from anterior end (Fig. 18); anterior ceca 139–418 (18) long or 9–18% of body length, equal or slightly unequal in length (sinistral cecum longest in 8 of 18 specimens), 12–82 (18) wide, with each cecum extending anteriorly and between esophageal gland and ventrolateral nerve cord, with wall approximately 5 thick, lacking di-



FIGURES 26–31. *Cardicola currani* n. sp. from heart of *Sciaenops ocellatus*. **26.** Ventral papillae, midbody. Bar = 10 μm. **27.** Mouth (arrowhead) and terminal preoral lobe with central papilla surrounded by ring of 4 papillae (arrow), frontal view. Bar = 50 μm. **28.** Everted cirrus on dorsal surface (arrow), ventrolateral view. Bar = 10 μm. **29.** Egg (arrow) within gill epithelium containing developing miracidium. Bar = 20 μm. **30.** Egg (arrowhead) within gill epithelium containing well-developed, ciliated miracidium. Bar = 50 μm. **31.** Egg (arrowhead) within gill epithelium containing developing miracidium. Bar = 40 μm.

verticula, containing granular material within lumen of some individuals; granular material dense, brownish-yellow in both live and mounted individuals, evenly filling lumen of ceca; posterior ceca 398–1,007 (18) long or 28–40% of body length and 1.8–4.2 times length of anterior ceca, equal or slightly unequal in length (sinistral cecum longest in 9 of 18 specimens), 7–50 (17) wide, with neither cecum extending beyond ventrolateral nerve cord, with each cecum extending directly posteriad and approximately parallel to ventrolateral nerve cord, lacking diverticula, expanding laterally at terminal end in some specimens; terminal end often expanded, 27–89 (15) wide or 1.0–5.5 times width of posterior ceca, often containing same granular material as in anterior ceca.

Testis approximately rectangular, 358–742 (17) long or 24–37% of body length, 124–348 (18) wide or 25–59% of body width, entirely between posterior ceca in 13 of 16 specimens, extending laterally just beyond posterior ceca in remaining 3, between cecal intersection and distal tips of posterior ceca, with border slightly irregular or occasionally lobed, but not branched, enclosing refractive processes; processes clustered; each cluster 5–12 (10) in diameter (Fig. 18). Posttesticular space 445–821 (18) long or 27–36% of body length. Vasa efferentia difficult to trace in fixed specimens, an interconnecting meshwork of fine ducts entwining throughout testicular tissue, containing spermatozoa in all specimens, 12–22 (2) in diameter, extending primarily dorsoventrally and along ventral surface of testis, uniting in posterior region of testis (Figs. 18, 19); vas deferens 323–621 (18) long, 12–55 (17) wide, sinistral, extending dorsomedially from testis before curving sinistrad, narrowing distally, containing sperm in all specimens (Figs. 18, 19). Seminal vesicle oblong, 45–178 (20) long, 12–35 (20) wide, sinistral, directed posteriad and laterad, narrowing distally at level of sinistral dorsolateral nerve cord, containing sperm in 17 of 18 specimens, with wall 1–3 (17) thick (Figs. 18, 19). Gland surrounding seminal vesicle lacking. Auxiliary seminal vesicle lacking. Cirrus small, nipplelike when extruded, unarmed, 5–25 (13) long or up to 27% of seminal vesicle length when extruded, 5–12 (13) wide, 1–3.6 times longer than wide, extruding posterosinistrad and dorsally between sinistral ventrolateral nerve cord and lateral body margin (Figs. 18, 19, 28). Male pore 69–149 (10) or 3–7% of body length from posterior end of body.

Ovary medial, arcuate, irregular to lobed but not branching, 45–159 (20) long, 99–298 (20) wide or 18–56% of body width, 1.3–4.3 times wider than long, medial, occupying space immediately posterior to testis or contiguous with posterior testicular margin, ventral to vas deferens, not extending laterally beyond level of terminal ends of posterior ceca, containing refractive rodlike dorsoventral processes similar to those in testis; processes occurring singly or clustered. Postovarian space 366–554 (10) long or 24–30% of body length (Fig. 19). Oviduct 94–231 (18) long, 27–74 (20) wide, extending posteriad and slightly dextrad, leaving ovary medioventrally, continuing posteriad in parallel with vas deferens for part of its length, conspicuously crooked at distal end, with end recurving and arching ventrally toward midline of body before turning posteriad, with oviducal seminal receptacle near middle (Fig. 19); oviducal seminal receptacle 55–112 (20) long or 32–76% of oviduct length, 27–74 (20) wide, containing sperm in all individuals and single ovum in 2 of 20 individuals; ovum 5 (2) in diameter; female duct distal to oviducal seminal receptacle, relatively short before confluence of vitelline duct with ootype; ootype 21–52 (17) long, 17–32 (17) wide, ovoid, dextral, located well anterior to junction of vas deferens and seminal vesicle (Figs. 18, 19). Vitellarium consisting of extensive network of narrow interconnecting branching bands, filling space both dorsal and ventral to gonads and alimentary tract, extending laterad slightly beyond nerve cords; secondary collecting ducts indistinct; common collecting duct often indistinct in region anterior to ovary, originating from level of middle region of esophagus, extending sinuously posteriad along midline, passing ventral to alimentary tract and ovary as well as oviducal seminal receptacle, 146–396 (19) in length from level of ovary to distal end, 12–30 (19) in maximum width at level of ovary. Mehlis' gland 37–87 (12) long, 37–79 (12) wide (Figs. 18, 19). Uterus with few turns, 396–933 (17) long, 30–55 (17) wide, not extending laterally far beyond ventrolateral nerve cords, postcecal, posttesticular, mostly anterior to level of seminal vesicle, with prominent metraterm (Fig. 19); metraterm 92–151 (18) long or 14–26% of uterus length, 15–45 (18) wide or 50–100% of uterus width, 2–7 times longer than wide, with wall 3–12 (18) thick, sinistral, extending mediad and perpendicular to long axis of body, at level of oviducal seminal receptacle (Fig. 19). Uterine eggs with thin membrane, lacking thickened shell, 7–10 (13) in diameter, spheroid, filling uterus in most specimens (Figs. 18, 19); re-

TABLE II. Blood fluke infections in Gulf of Mexico fishes.

Host	Parasite	Locality	Reference
Lamniformes			
Carcharhinidae			
Rhizoprionodon terraenovae	*Selachohemecus olsoni*	Alligator Harbor, Florida	Short (1954)
Perciformes			
Lutjanidae			
Lutjanus campechanus	*Elaphrobates euzeti*	Off Ocean Springs, Mississippi	Bullard and Overstreet (2003)
L. griseus	*E. euzeti*	Off Tampa, Florida	Bullard and Overstreet (2003)
Sparidae			
Calamus bajonado	*Cardicola cardiocola*	Off Tortugas, Florida	Manter (1947)
Sciaenidae			
Cynoscion arenarius	*C. laruei*	Alligator Harbor, Florida	Short (1952, 1953)
C. nebulosus	*C. laruei*	Alligator Harbor, Florida	Short (1952, 1953)
Sciaenops ocellatus	*C. currani*	Mississippi Sound, Mississippi	Overstreet (1983), present study
Pogonias cromis	*C. palmeri*	Mississippi Sound, Mississippi	Present study
Kyphosus sectatrix	*Deontacylix ovalis*	Off Tortugas, Florida	Linton (1910)
		Biscayne Bay, Florida	Overstreet (1969)

leased eggs in proximal region of filament within branchial arteriole or gill epithelium, typically thin shelled, and pliable, oblong, 27–50 (10) long, 27–50 (10) wide, possessing conspicuous excretory concretions, nearly transparent in fresh preparations of gill, often within host fibrotic encapsulation. Female pore dorsal, 5–19 (17) wide, sinistral, postovarian, just anterior to ootype, 161–447 (19) in straight-line-distance from male pore, 9–20% of body length from posterior end of body (Figs. 18, 19).

Excretory system often indistinct; vesicle Y-shaped, with stem 17–37 (6) long, 10–17 (6) wide, dorsal to and just anterior to level of posterior nerve confluence, with wall 1–3 (4) thick; arms straight (Figs. 18, 19) or sinuous, extending approximately parallel with nerve cords, with anterior extent indistinct; excretory pore subterminal, dorsal, 25–60 (4) from posterior end of body (Fig. 19).

Taxonomic summary

Type and only known host: Sciaenops ocellatus (Linnaeus, 1766), red drum (Perciformes: Sciaenidae).

Sites: Adult in atrium, ventricle, and bulbus arteriosus of heart; eggs in afferent branchial vessels and lodged within branchial epithelium (Figs. 29–31).

Type locality: Northern Gulf of Mexico, Davis Bayou, Mississippi Sound, Ocean Springs, Mississippi (30°23.5′N, 88°47.8′W).

Other localities: Northern Gulf of Mexico, Mississippi Sound, Biloxi, Mississippi (30°23.7′N, 88°51.4′W); Back Bay of Biloxi, Biloxi, Mississippi (30°25.5′N, 88°58.7′W); off Grande Isle, Louisiana.

Specimens deposited: Holotype USNPC No. 93200, Paratype USNPC No. 93201.

Prevalence and intensity of infection: Thirty-eight of 91 fish (42%): 1–2 specimens in 15 fish, 3–4 in 9, 5–9 in 5, 11–15 in 8, and 38 in 1.

Etymology: The specific name *currani* honors our friend and laboratory mate Stephen Socrates Curran (GCRL) for his contributions to digenean taxonomy and systematics.

Remarks

Cardicola currani is most easily distinguished from its 11 congeners by the combination of having posterior ceca that are 1.8–4.2 times longer than anterior ones, a male pore located well posterior to the ootype and nearly at the level of the excretory vesicle, a female pore and transversely located metraterm that are both immediately anterior to the level of the ootype, and a medial ovary located at the level of the terminal ends of the posterior ceca and immediately posterior to the testis. The new species is most similar to *C. palmeri* and *C. laruei*, species that infect the related black drum and seatrouts, by the combination of possessing an ovoid body, a testis that is limited to an area between the cecal intersection and the ovary, an ovary that is limited by the terminal ends of posterior ceca, a prominent oviducal seminal receptacle, and a metraterm that is located at the level of the oviducal seminal receptacle. However, *C. currani* most notably differs from *C. laruei* by possessing a relatively short esophagus that is consistently less than half the total body length, anterior ceca that are markedly shorter than the posterior ones, a male pore that is well posterior to the ootype and just anterior to the level of the excretory vesicle, and a short oviduct that extends directly posteriad. *Cardicola laruei* has an esophagus that is about half the total body length, anterior cecal lengths that overlap with posterior ones, a male pore located at the level of the ootype, and a long oviduct that extends anterolaterally before expanding to form the oviducal seminal receptacle. *Cardicola currani* is most easily distinguished from *C. palmeri* by lacking a prominent gland encircling the seminal vesicle and by possessing a tiny, nipplelike cirrus rather than a large robust and elongated cirrus.

An egg was extracted from the gill epithelium of a single red drum that was 44 cm in total length and caught in Mississippi Sound on 22 April 2000. When slight lateral pressure was ap-

plied to the egg, a well-developed, ciliated miracidium emerged. Although slow, the miracidium was mobile and made looping movements in seawater. Other eggs possessed similar miracidia, but none hatched.

DISCUSSION

Cardicola palmeri and *C. currani* increase the number of sanguinicolids in Gulf of Mexico fishes from 5 to 7 (Table II) and the total number of species in *Cardicola* to 12. Each of the 2 new species infected only 1 host species even though the 2 hosts were sympatric and other sciaenids were present. Although *C. currani* was found in more individual fish, the intensity of both digeneans was similar. In other sciaenids, there is only 1 named sanguinicolid: *C. laruei* infects the sand seatrout, *Cynoscion arenarius* Ginsberg, 1929, and the spotted seatrout, *C. nebulosus* (Cuvier, 1830), off Florida (Short, 1953) (Table II). However, an unidentified species of *Sanguinicola* Plehn, 1905, infects the freshwater drum, *Aplodinotus grunniens* Rafinesque, 1819, in Lake Erie (Dechtiar, 1972; Hoffman, 1998).

ACKNOWLEDGMENTS

We thank Andres Soto, Jason Lemus, Jody Peterson, Jason Steckler, Nate Jordan, Alexis Galle, and Stephen Curran (all from GCRL, the University of Southern Mississippi) for providing some of the fish; Ronnie Palmer (GCRL) for providing technical help; and Jeffrey Braswell (Dupont Corporation, Chattanooga, Tennessee) for assisting with scanning electron microscopy. Joyce Shaw, Catherine Schloss, and Marjorie Williams (Gunter Library, GCRL) provided library assistance. Primary funding for this study was provided by United States Department of Commerce, National Marine Fisheries Service, United States Gulf of Mexico Marine Stock Enhancement Program Award NA03NMF4720320, but additional funds were provided by the Mississippi-Alabama Sea Grant Consortium.

LITERATURE CITED

BULLARD, S. A., AND R. M. OVERSTREET. 2003. *Elaphrobates euzeti* gen. and sp. n. (Digenea: Sanguinicolidae) from snappers (Lutjanidae) in the Gulf of Mexico. *In* Taxonomy, ecology and evolution of metazoan parasites—Livre hommage au Professeur Louis Euzet, C. Combes and J. Jourdane (eds.). Les Presses Universitaires de Perpignan, Perpignan, France. p. 97–113.

CRIBB, T. H., M. DAINTITH, AND B. MUNDAY. 2000. A new blood-fluke, *Cardicola forsteri*, (Digenea: Sanguinicolidae) of southern blue-fin tuna (*Thunnus maccoyii*) in aquaculture. Transactions of the Royal Society of South Australia **124:** 117–120.

DECHTIAR, A. O. 1972. New parasite records for Lake Erie fish. Great Lakes Fisheries Commission Technical Report Number 17, 20 p.

HOFFMAN, G. L. 1998. Parasites of North American freshwater fishes, 2nd ed. Comstock Publishing Associates, Cornell University Press, Ithaca, New York, 539 p.

KNOFF, M., AND J. F. R. AMATO. 1992. Nova espécie do gênero *Cardicola* Short, 1953 (Sanguinicolidae: Cardicolinae) parasita de tainhas *Mugil platanus* Günther, 1880 da costa do estado do Rio de Janeiro, Brasil. Revista Brasileira de Biologia **51:** 567–570.

LEBEDEV, B. I., AND YU. L. MAMAEV. 1968. Two new species of *Cardicola* Short, 1953 (Trematoda: Sanguinicolidae) from fishes in the South China Sea. *In* Helminths of animals of the Pacific Ocean, K. I. Skryabin and Yu. L. Mamaev (eds.). Izdat. Nauka, Moscow, Russia, p. 72–75. [In Russian.]

LINTON, E. 1910. Helminth fauna of the Dry Tortugas. II. Trematodes. The Carnegie Institution of Washington **133:** 11–98.

MANTER, H. W. 1947. The digenetic trematodes of marine fishes of Tortugas, Florida. American Midland Naturalist **38:** 257–416.

———. 1954. Some digenetic trematodes from fishes of New Zealand. Transactions of the Royal Society of New Zealand **82:** 475–568.

MCINTOSH, A. 1934. A new blood trematode, *Paradeontacylix sanguinicoloides* n. g., n. sp., from *Seriola lalandi* with a key to the species of the family Aporocotylidae. Parasitology **26:** 463–467.

OVERSTREET, R. M. 1969. Digenetic trematodes of marine teleost fishes from Biscayne Bay, Florida. Tulane Studies in Zoology and Botany **15:** 119–176.

———. 1983. Aspects of the biology of the red drum, *Sciaenops ocellatus*, in Mississippi. Gulf Research Reports, Supplement **1:** 45–68.

SHORT, R. B. 1952. A new species of blood fluke from marine fish (Trematoda: Aporocotylidae). Journal of Parasitology **38:** 36. (Abstract.)

———. 1953. A new blood fluke, *Cardicola laruei* n. g., n. sp. (Aporocotylidae) from marine fishes. Journal of Parasitology **39:** 304–309.

———. 1954. A new blood fluke, *Selachohemecus olsoni*, n. g., n. sp. (Aporocotylidae) from the sharp-nosed shark, *Scoliodon terra-novae*. Proceedings of the Helminthological Society of Washington **21:** 78–82.

SMITH, J. W. 1997a. The blood flukes (Digenea: Sanguinicolidae and Spirorchidae) of cold-blooded vertebrates: Part 1. A review of the published literature since 1971, and bibliography. Helminthological Abstracts **66:** 255–294.

———. 1997b. The blood flukes (Digenea: Sanguinicolidae and Spirorchidae) of cold-blooded vertebrates: Part 2. Appendix I: Comprehensive parasite-host list; Appendix II: Comprehensive host-parasite list. Helminthological Abstracts **66:** 329–344.

YAMAGUTI, S. 1970. Digenetic trematodes of Hawaiian fishes. Keigaku Publishing Company, Limited, Tokyo, Japan, 436 p.