A NEW SPECIES OF *CARDICOLA* SHORT, 1953 (DIGENEA: APOROCOTYLIDAE) FROM THE HEART AND BRANCHIAL VESSELS OF TWO SURFPERCHES (PERCIFORMES: EMBIOTOCIDAE) IN THE EASTERN PACIFIC OCEAN OFF CALIFORNIA

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ABSTRACT: *Cardicola nonamo* n. sp. (Digenea: Aporocotylidae) infects the heart of white seaperch, *Phanerodon furcatus* Girard, 1854 (Perciformes: Embiotocidae) (type host), in Monterey Bay, California, and the branchial vessels of rubberlip seaperch, *Rhacochilus toxotes* Agassiz, 1854 (Embiotocidae), from Naples Reef, Santa Barbara Channel, off Santa Barbara, California. It is most easily distinguished from other species of *Cardicola* Short, 1953 by the combination of having (1) rows of minute tegumental spines distributing along the entire ventrolateral body margin; (2) an aspinous anterior sucker comprising a nearly indistinct spheroid structure centering on the mouth; (3) an esophagus 17–21% of the total body length; (4) convoluted posterior ceca 51–65% of the total body length and 9–18× length of the anterior ceca; (5) a rectangular, intercecal testis not extending posteriad beyond the posterior ceca; (6) a post-testicular and post-cecal ovary; (7) an oviduct emanating from the posterodextral margin of the ovary; (8) a post-ovarian uterus coiling twice just posterior to the ovary; and (9) male and female genital pores opening dorsomedially and posterior to the uterus and ootype. The new species most closely resembles *Cardicola ambrosioi* Braicovich, Etchegoin, Timi, and Sardella, 2006, which infects the blood vessels of the gill and liver of Brazilian flathead, *Percophis brasiliensis* Quoy and Gaimard, 1825 (Perciformes: Percophidae), in the southwestern Atlantic Ocean off Argentina; however, *C. ambrosioi* differs morphologically from the new species at least by lacking post-ovarian spine rows and by having posterior ceca that are 4× length of the anterior ceca. This is the first published record of an aporocotylid from a surfperch (Embiotocidae) as well as that of a species of *Cardicola* from the Pacific Ocean east of the Hawaiian Islands.

Cardicola Short, 1953 presently accommodates many of the nominal marine and estuarine fish blood flukes (Digenea: Aporocotylidae) that have a single testis and an ''H-shaped'' gut, i.e., an anterior and posterior pair of approximately equal-length ceca intersecting at the body midline. *Cardicola* spp. infect the blood vascular system of marine percomorphs (Percomorpha) (see Manter, 1947, 1954; Short, 1953; Lebedev and Mamaev, 1968; Yamaguti, 1970; Parukhin, 1976; Speare, 1995, 1999; Cribb et al., 2000; Bullard and Overstreet, 2004, 2006; Bullard et al., 2004; Braicovich et al., 2006; Nolan and Cribb, 2006; Holzer et al., 2008) and 2 euryhaline mullets (*Mugil* spp., Mugiliformes: Mugilidae) (Yamaguti, 1970; Knoff and Amato, 1992), with all of these host records deriving from fishes of superorder Acanthopterygii (see Nelson, 2006).

Much remains to be documented regarding the geographic distribution, host range, general biology, life history, and taxonomy of the collection of aporocotylids presently included within *Cardicola*. The ecological breadth and geographic range of definitive hosts used by *Cardicola* spp. comprises estuarine, coastal, and pelagic fishes occupying a wide band of latitude worldwide; however, noteworthy is that none have been reported previously from the eastern Pacific Ocean. Although generally regarded as a strictly marine group with species that mature in oceanic fishes (Smith, 2002), no life cycle has been published for any member of *Cardicola*, and those nominal species of *Cardicola* infecting euryhaline mullets, i.e., *Cardicola mugilis* Yamaguti, 1970 from flathead mullet, *Mugil cephalus* Linnaeus, 1758 in the Pacific Ocean and *Cardicola brasiliensis* Knoff and Amato, 1992 from the mullet, *Mugil platanus* Günther, 1880 in the southwestern Atlantic Ocean, for example, could involve a brackish water or freshwater molluscan or polychaete intermediate host. Hence, it is indeterminate whether *Cardicola* can accurately be characterized as holding ''strictly marine'' aporocotylids.

Some adult aporocotylids seem specific to the heart (Smith, 1972, 1997a, 1997b, 2002; Bullard and Overstreet, 2002, 2004, 2006), but tissue and organ site specificities within the definitive fish host reportedly have not been studied for any species of *Cardicola*. Reported sites of infection for adults of *Cardicola* spp., in addition to heart, include ''washings of gut'' (Short, 1953), ''gills and coelom, probably blood vessels'' (Manter, 1954), ''blood vessels and gills'' (Lebedev and Mamaev, 1968), ''intestine wall'' (Lebedev and Mamaev, 1968), and ''blood vessels of the heart, kidney, liver, and gill'' (Knoff and Amato, 1992). Complicating the matter of site specificity in the definitive host is that at least some aporocotylids are motile and may relocate within the fish's vascular system. This relocation could relate to potential seasonality of their life cycles (Avendaño de MacIntosh and Ostrowski de Núñez, 1998; Bullard and Overstreet, 2002, 2008) and/or to deposition of eggs nearest the gill or perhaps intestine to increase the likelihood that the miracidium can escape the host when the appropriate intermediate hosts are seasonally abundant in the system.

Monophyly of *Cardicola* has not been demonstrated by a phylogenetic analysis including morphological data or molecular data derived from the type species *Cardicola cardiocolum* (Manter, 1947) Short, 1953 (synonyms of this species are *Psettarium cardiocolum* of Manter [1947] and Short [1953]; and *Cardicola cardicola* of Short [1953], Smith [1997], and Cribb et al. [2000]) or the majority of aporocotylid species described before 2006. In fact, like many nominal species of the genus, reportedly no specimen of *C. cardiocolum* has been collected since its original description, which is based on specimens excised from the heart of jolthead porgy, *Calamus bajonado* (Bloch and Schneider, 1801) (Perciformes: Sparidae) captured off Tortugas, Florida. In addition, and like many deposited type and voucher specimens of species of *Cardicola*, the holotype of *C. cardiocolum* (United States National Parasite Collection [USNPC] 37035) is in generally poor condition, i.e., lightly stained and folded. Furthermore, Manter's (1947) original description of the fluke was incomplete and overly stylized. That, coupled with the poor condition of the holotype and the lack of other deposited

vouchers available for study, creates a situation wherein, quite simply, it is unclear what morphological features are present or absent in the type species. This has led to understandable confusion, with some authors assigning species to *Cardicola* that possess the diagnostic features of *Elaphrobates* Bullard and Overstreet, 2003, recognized herein as distinct from *Cardicola* (see Nolan and Cribb, 2006; Holzer et al., 2008). In addition to the type species, several species incertae sedis should be the focus of new collection efforts and subsequent descriptive work because their original descriptions are incomplete, and type materials are either lost, not available for loan, or in generally poor overall condition: *Cardicola congruenta* Lebedev and Mamaev, 1968; *Cardicola grandis* Lebedev and Mamaev, 1968 (see Bullard and Overstreet, 2006); *Cardicola ahi* Yamaguti, 1970; *Cardicola mugilis* Yamaguti, 1970; and *Cardicola kurochkini* (Parukhin, 1976) Bullard and Overstreet, 2006.

Despite the need for taxonomic clarification, species discovery among related aporocotylids and within *Cardicola* will nevertheless contribute to an eventual systematic revision of the group. Herein, a new species of Aporocotylidae Odhner, 1912 is described based on 1 and 4 whole-mounted specimens collected during 1936 and 1980, respectively, from 2 species of surfperch (Perciformes: Embiotocidae) captured in the eastern Pacific Ocean off the coast of southern California. The new species is provisionally assigned to *Cardicola*, pending a revision of the genus that includes morphological and molecular data derived from *C. cardiocolum* and related species.

MATERIALS AND METHODS

In 2000, the whole-mounted specimen designated as the holotype of the new species was given to SAB by Fuad Michael Nahhas (deceased, Department of Biological Sciences, University of the Pacific, Stockton, California), who probably obtained it directly from his departmental colleague Alden Earl Nobel (deceased, University of the Pacific), who either collected it himself or was given the specimen and subsequently informed that it was collected on 20 July 1936 from Monterey Bay, California. The 4 paratypes (on 1 slide, USNPC 82424.02, M1593-1) of the new species were collected by Mike Moser (University of California, Berkley, California), who speared the host during summer 1980 on Naples Reef (Santa Barbara Channel) off Santa Barbara, California. Moser's aporocotylid specimens were identified later as *Cardicola* sp. by John C. Holmes (University of Alberta, Edmonton, Alberta, Canada) and Cameron P. Goater (University of Lethbridge, Lethbridge, Alberta, Canada). That slide was borrowed from the USNPC by SAB in July 2009, with the newer specimens being regarded herein as conspecific with Nobel's 1936 specimen. Illustrations were made with the aid of a Leica DM-2500 (Leica Microsystems, Inc., Deerfield, Illinois) equipped with differential interference contrast optical components and a drawing tube. Measurements were obtained by using a calibrated ocular micrometer and are herein reported in micrometers followed by the number of specimens measured in parentheses. Common and scientific names for fishes follow FishBase (Froese and Pauly, 2009). Higher-level fish classification and nomenclature follow Nelson (2006). Nomenclature for Aporocotylidae follows Bullard et al. (2009). Specimens of *Cardicola* spp. were borrowed from the USNPC; The South Australian Museum (SAM), Adelaide, South Australia; and the Parasite Collection of the H. W. Manter Laboratory of Parasitology (HWML), Lincoln, Nebraska.

DESCRIPTION

Cardicola nonamo n. sp.
(Figs. 1–4)

Diagnosis of adult (measurements and illustrations based on 5 whole-mounted adult specimens comprising the holotype and 4 paratypes): Body flat, ventrally concave, elongate oval, 3,750–5,100 (5) long, 640–760 (5) wide or 5.1–6.6× longer than wide, having posterior end slightly more broadly rounded than anterior end, lacking posterolateral body protuberance; body-margin crimped ventrally or straight, spined (Figs. 1, 2); tegumental body spines in ventrolateral transverse rows, not associating with peduncles or protuberances, each spine having recurved distal tip, minute, 5–8 (5) long, 1 (5) wide at base, protruding 1 (5) or 20% of spine length from tegument. Tegumental spine rows distributing along ventrolateral body margin for entire body length from level of mouth to extreme posterior body end, distributing in approximately 400 spine rows per each side of body or a total of approximately 800 rows; spine rows 53–85 (5) long in middle portion of body, with as many as 22 spines per row, with number of spines per row increasing from anterior body end mediad, decreasing from medial part of body posteriad (Figs. 1–4). Fused or rosethorn-shaped spines lacking. Nervous system difficult to trace in most specimens, comprising ventrolateral nerve cords and dorsolateral nerve cords plus associated anterior commissures (Figs. 1, 2). Ventrolateral nerve cords paired; each cord 20 (2) wide near midbody at widest level, 115–130 (2) from body margin at midbody, coursing near or immediately ventral to ceca, contiguous at body ends, becoming confluent with paired cord 50–55 (3) or approximately 1% of body length from posterior body end, having secondary branches 10–25 (5) wide at base and extending both laterad and mediad; commissure of ventrolateral nerve cord 105–169 (3) or 3–5% of body length from anterior body end, 55–115 (3) across width of worm, 25–35 (3) in diameter, perpendicular to long axis of worm, coursing dorsal to esophagus (Figs. 1, 2). Dorsolateral nerve cords paired, each cord approximately equal in length to corresponding ventrolateral nerve cord, 15 (2) wide near midbody at widest level, 80–120 (2) from body margin, coursing in parallel with corresponding ventrolateral nerve cord between ventrolateral nerve cord and body margin for entire length, having secondary branches extending laterad and mediad and equaling 5–20 (5) wide at base (Fig. 2); commissure of dorsolateral nerve cord nearly indistinct, seemingly spanning esophagus ventrally near anterior body end, seemingly becoming confluent with ventrolateral nerve cord in extreme posterior body end (Figs. 1, 2). Tegumental papillae not evident with light microscopy.

Anterior sucker aspinous, comprising a nearly indistinct spheroid structure centering on mouth, 28–35 (2) in diameter, directing ventrally; mouth a circular pore, 3 (3) in diameter, medioventral (Figs. 1, 2). Terminal pre-oral lobe not evident with light microscopy. Pharynx absent. Esophagus 730–950 (5) long or 17–21% of body length, slightly sinuous, 15–23 (3) in maximum width between mouth and commissure of ventrolateral nerve cord, widening posteriorly to 45–60 (5) in maximum width at level anterior to distal tips of anterior ceca; esophageal wall thickening slightly from approximately 5 near mouth to approximately 7 near cecal bifurcation or approximately 1.4 × thickness of wall in anterior portion, with one specimen having yellow granular material filling esophageal lumen for entire length. Esophageal gland not extending lateral to ventrolateral nerve cords, comprising anterior and posterior portions; anterior portion diffuse, weakly stained in all specimens studied, enveloping esophagus from level of ventrolateral nerve commissure to level slightly anterior to distal tips of anterior ceca, 290–490 (4) long or 7–11% of body length or 39–54% of esophagus length, 140–160 (4) wide or 20–22% of body width, consisting of spherical or sub-spherical gland cells and refractive dorsoventral rod-like processes typical of those of other aporocotylids; posterior portion of esophageal gland eosinophilic in holotype but nearly indistinct in 4 paratypes, extensively lobed, primarily occupying space between anterior ceca and enveloping posterior portion of esophagus, 150–230 (4) wide at level of distal tips of anterior ceca, 180–250 (4) long, extending 35–60 (4) posterior to and ventral to cecal intersection, having acini (Fig. 2). Intestine "H-shaped," with paired anterior and posterior ceca intersecting medially; intersection of anterior and posterior ceca connecting with esophagus anteroventrally, 740–810 (5) or 15–21% of body length from anterior end; anterior ceca 150–225 (4) long, 4–7% of body length, 20–28% of esophagus length, 60–105 (4) wide, with each cecum extending anteriad between esophagus and nerve cords, having few diverticula (Figs. 1, 2); diverticula 8–33 (5) long and 20–45 (5) wide at base, containing material within lumen (Fig. 2); material granular, dense, brownish-yellow; posterior ceca extensively convoluted, extending posteriad dorsal to and slightly medial to respective ventrolateral nerve cord, 1,964–2,700 (5) long or 51–65% of body length, 9–18× length of respective anterior cecum, each approximately 40–75 (5) in maximum width, each having laterally expanded tip 80–125 (5) wide or 1.3–2.8× width of posterior cecum (Figs. 1–4).
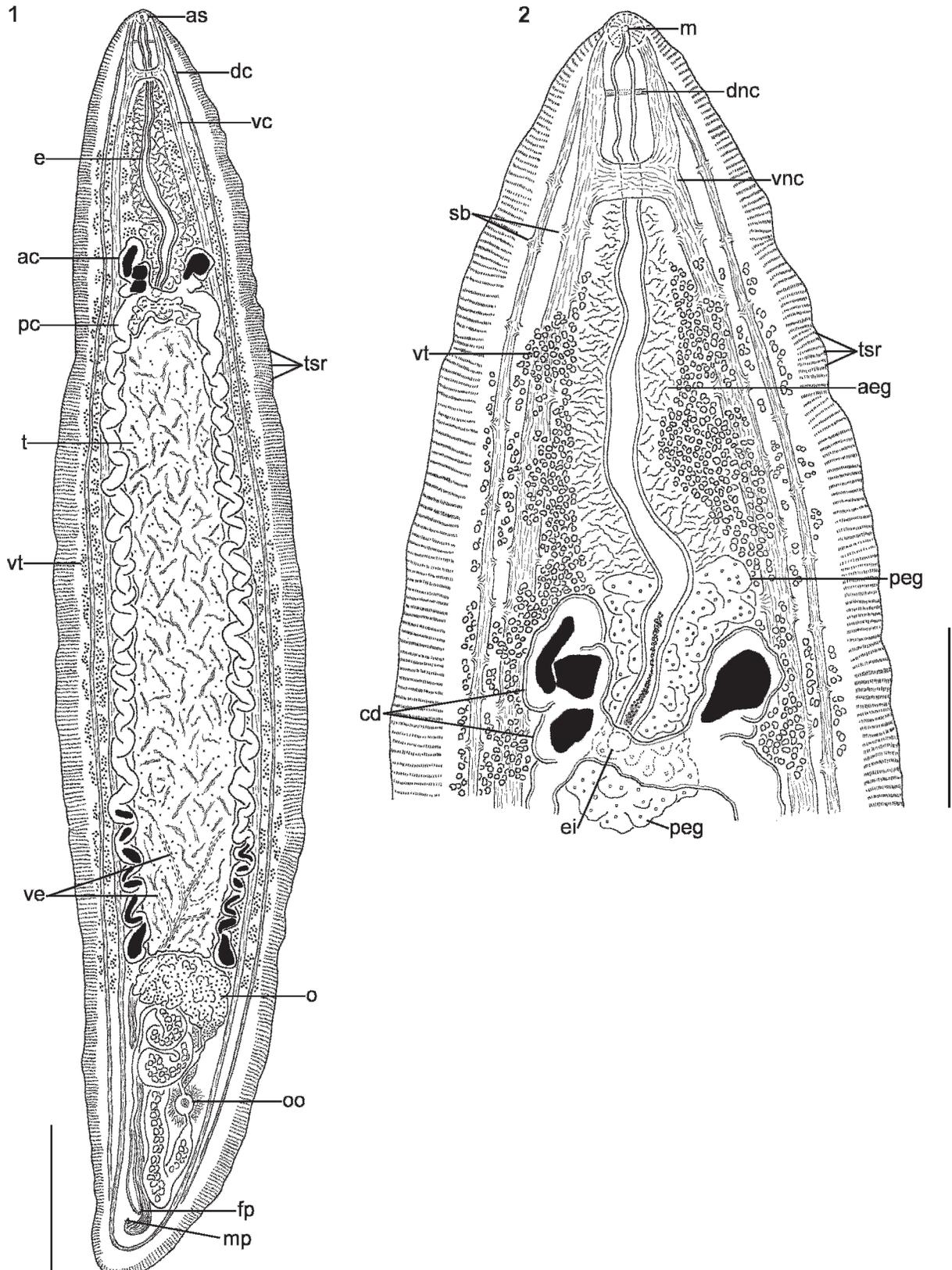
FIGURES 1–2.   *Cardicola nonamo* n. sp. (Digenea: Aporocotylidae) (holotype, USNPC 103042) from the heart of white seaperch, *Phanerodon furcatus* Girard, 1854 (Perciformes: Embiotocidae) in Monterey Bay, California, dorsal view. Note that the lateral tegumental spines, which are ventral only, are illustrated in these dorsal views to demonstrate their position relative to structures of the sensory, alimentary, and reproductive systems. (**1**) Body showing location of anterior sucker (as), dorsolateral nerve cord (dc), ventrolateral nerve cord (vc), esophagus (e), anterior cecum (ac), posterior
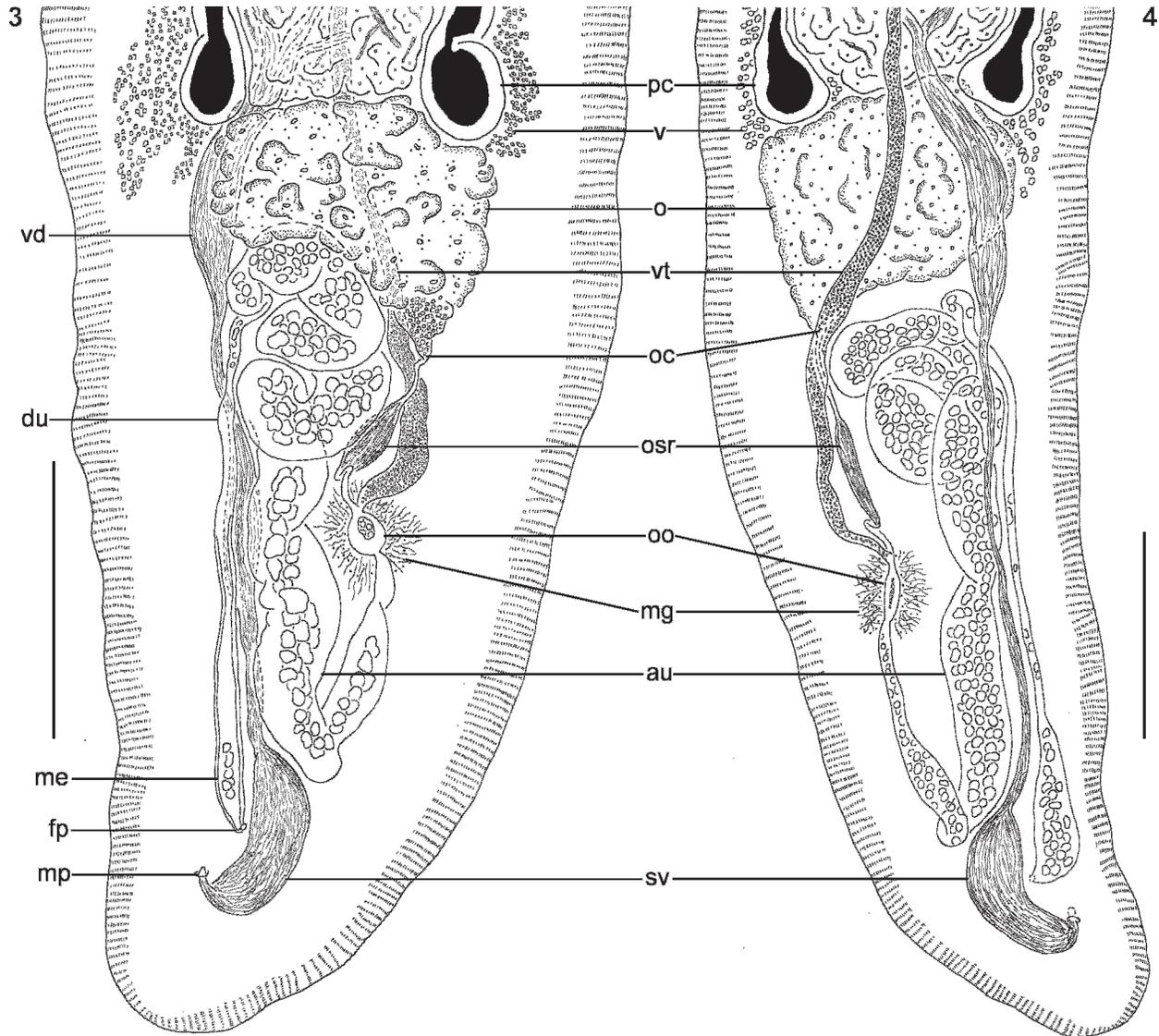
FIGURES 3–4. *Cardicola nonamo* n. sp. (Digenea: Aporocotylidae) from the heart of surfperches (Embiotocidae) in the eastern Pacific Ocean off California. (**3**) Posterior body end of holotype (USNPC 103042) from the heart of white seaperch, *Phanerodon furcatus* Girard, 1854 (Perciformes: Embiotocidae) in Monterey Bay, California, showing posterior ceca (pc), vitellarium (v), ovary (o), primary vitelline duct (vt), oviduct's connection (oc) with ovary, oviducal seminal receptacle (osr), ootype (oo), Mehlis' gland (mg), ascending uterus (au), seminal vesicle (sv), vas deferens (vd), descending uterus (du), metraterm (me), female genital pore (fp), and male genital pore (mp), dorsal view. Note that the lateral tegumental spines, which are ventral only, are illustrated in this dorsal view to demonstrate their position relative to reproductive structures, dorsal view. Bar = 250 μm. (**4**) Posterior body end of a paratype (USNPC 82424.03) from the branchial vessels of rubberlip seaperch, *Rhacochilus toxotes* Agassiz, 1854 (Embiotocidae) from Naples Reef, Santa Barbara Channel, off Santa Barbara, California, showing comparable morphological features as in Figure 3, ventral view. Bar = 300 μm.

Genitalia not extending lateral to ventrolateral nerve cords (Fig. 1). Testis approximately rectangular, 1,841–3,000 (5) long or 49–63% of body length, 300–400 (5) in maximum width or 42–54% of body width at level of midbody, intercecal, not extending laterad beyond posterior ceca, between cecal intersection and distal tips of posterior ceca, with border slightly irregular or occasionally slightly lobed, but never branching, enclosing refractive processes; processes 5–7 (5) in diameter; post-testicular space 980–1,400 (5) long or 22–27% of body length (Figs. 1, 3, 4). Vasa efferentia difficult to trace, an interconnecting meshwork of fine ducts entwining throughout testicular tissue, containing spermatozoa, approximately 10 in diameter, extending primarily along ventral surface of testis, uniting in posterior region of testis to form vas deferens; vas deferens 670–1,070 (5) long, 30–50 (5) wide, sinistral, extending posteriad from testis before curving slightly laterad and extending directly posteriad, containing sperm,

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cecum (pc), ventrolateral rows of tegumental spines (tsr), testis (t), vitellarium (vt), vasa efferentia (ve), ovary (o), ootype (oo), female genital pore (fp), and male genital pore (mp). Bar = 500 μm. (**2**) Anterior body end showing location of mouth (m), commissure of dorsolateral nerve cord (dnc), commissure of ventrolateral nerve cord (vnc), base of secondary branches of nerve cords (sb), vitellarium (vt), ventrolateral rows of tegumental spines (tsr), anterior portion of esophageal gland (aeg), posterior portion of esophageal gland (peg), cecal diverticula (cd), and esophageal intersection with ceca (ei). Bar = 200 μm.

narrowing distally before connecting with seminal vesicle. Seminal vesicle oblong, 154–230 (5) long, 50–80 (5) wide, medial, directing posteriad and slightly laterad, containing sperm, with wall approximately 3 thick (Figs. 3, 4). Gland surrounding seminal vesicle indistinct. Everted cirrus small, nipple-like, unarmed, 37 (1) long or 24% of seminal vesicle length, 7 (1) wide, 5.3× longer than wide, everting dorsally between sinistral ventro-lateral nerve cord and midline; cirrus sac indistinct (Figs. 3, 4).

Ovary medial, arcuate or ovoid, not branching, slightly lobed along margins and along dorsal aspect, 250–350 (5) long or 6–7% of body length, 240–350 (5) wide or 35–47% of body width, 0.8–1.3× wider than long, medial, occupying space immediately posterior to testis, dorsal to vas deferens, not extending laterally beyond level of ventrolateral nerve cords, containing refractive rod-like dorsoventral processes similar to those of testis; processes occurring singly or clustered. Post-ovarian space 732–1,100 (5) long or 16–22% of body length (Figs. 1, 3, 4). Oviduct 211–590 (5) in total length, 10 (4) wide in proximal portion immediately posterior to ovary, with proximal portion comprising a thin tube emanating from posterodextral margin of ovary and extending posteriad before expanding laterally to form oviducal seminal receptacle; oviducal seminal receptacle comprising middle portion of oviduct, elongate oval in shape, having a conspicuous kink at distal (posterior) end, 75–155 (5) long, 12–28 (5) wide, slightly dextral, residing between level of ovary and seminal vesicle; distal portion of oviduct comprising a narrow tube recurving dorsolaterad before extending posteriad and connecting to ootype (Figs. 1, 3, 4). Vitellarium an extensive network of narrow interconnecting branching bands, primarily filling space both dorsal and ventral to alimentary tract and between level of alimentary tract and lateral body margin, extending laterad slightly beyond nerve cords, not extending far posteriad beyond level of distal tips of posterior ceca (Figs. 1–4); secondary collecting ducts indistinct; common collecting duct medioventral to testis, 427–550 (5) in length from level of testis to distal end, 15–35 (5) in maximum width at level of ovary. Ootype 40–50 (3) long, 15–40 (3) wide, elongate or nearly spherical in shape, dextral, located well anterior to junction of vas deferens and seminal vesicle (Figs. 1, 3, 4). Mehlis' gland approximately 124 in diameter, with individual cells approximately 3 in diameter (Figs. 3, 4). Uterus extending 240–390 (5) or 6–9% of body length posteriad from ootype and approximately in parallel with dextral ventrolateral nerve cord before curving dorsally and anteriad and forming ascending portion of uterus; ascending portion of uterus extending 390–650 (5) or 9–13% of body length anteriad before coiling 2 times medially and immediately posterior to level of ovary, occupying space between ootype and vas deferens, post-cecal, post-testicular, overlapping slightly ventral to posterior margin of ovary in holotype, but primarily post-ovarian, primarily anterior to level of uterus; descending portion of uterus an extremely thin-walled (approximately 1 thick) tube extending 292–450 (5) or 8–9% of body length posteriad, 20–30 (5) in maximum width, crossing dorsal to vas deferens lateral to first uterine coil, sinistral to ascending uterus, connecting with proximal portion of metraterm anterior to level of ootype (Figs. 3, 4); metraterm 110–280 (4) long, 25–50 (4) wide in proximal portion, having wall approximately 4 thick throughout, coursing primarily parallel to and between sinistral ventrolateral nerve cord and vas deferens. Uterine eggs 13–15 (4) long, 2–3 (4) wide, sub-spherical (Figs. 3, 4). Female genital pore dorsal, sinistral, post-ovarian, anteromedial to male genital pore (Figs. 3, 4). Excretory system indistinct.

Taxonomic summary

Type host: Phanerodon furcatus Girard, 1854 (Perciformes: Embiotocidae), white seaperch.

Other host: Rhacochilus toxotes Agassiz, 1854 (Embiotocidae), rubberlip seaperch.

Sites in host: Lumen of heart (holotype) and branchial vessels (paratypes).

Type locality: Eastern Pacific Ocean, Monterey Bay, California (geographic coordinates were not recorded for the exact collection site in the Bay).

Other localities: Eastern Pacific Ocean, Santa Barbara Channel, Naples Reef (approximately 1.4 km offshore), California (34°25.309′N, 119°57.137′W).

Specimens deposited: Holotype USNPC 103042; Paratypes USNPC 82424.03.

Specimens compared: Paratypes of *Cardicola laruei* Short, 1953 from the heart of sand weakfish, *Cynoscion arenarius* Ginsburg, 1930 (Perciformes:

Sciaenidae), in the Gulf of Mexico off Franklin and Wakulla Counties, Florida, USA (USNCP 37378 and 37379); paratype of *Cardicola coridodacis* Manter, 1954 from the branchial blood vessels or the coelom of greenbone, *Odax pullus* (Forster, 1801) (Perciformes: Odacidae), (as *Coridodax pullus*) in the southwest Pacific Ocean off Wellington, New Zealand (HWML 656); paratype of *Cardicola whitteni* Manter, 1954 from the branchial blood vessels of tarakihi, *Nemadactylus macropterus* (Forster, 1801) (Perciformes: Cheilodactylidae), from off Wellington (HWML 657); holotype of *C. mugilis* from the heart or blood vessels of flathead mullet, *Mugil cephalus* (Mugiliformes: Mugilidae), in the central Pacific Ocean off the Hawaiian Islands (USNPC 63553); holotype of *Cardicola chaetodontis* Yamaguti, 1970 from the gill or heart of millet butterflyfish, *Chaetodon miliaris* Quoy and Gaimard, 1825 (Perciformes: Chaetodontidae), or bluestriped butterflyfish, *Chaetodon fremblii* Bennett, 1828, from off the Hawaiian Islands (USNPC 63552); holotype of *C. ahi* from gill washings of yellowfin tuna, *Thunnus albacares* (Bonnaterre, 1788) (Perciformes: Scombridae), (as *Neothunnus macropterus*) from off the Hawaiian Islands (USNPC 63551); paratypes of *C. brasiliensis* from the heart or blood vessels of the kidney, liver, or gill of a mullet, *Mugil platanus*, from the southwestern Atlantic Ocean (Baía de Sepetiba, Estado do Rio de Janeiro) off Brazil (HWML 31717 and 31718); paratypes of *Cardicola forsteri* Cribb, Daintith, and Munday, 2000 from the heart of captive southern bluefin tuna, *Thunnus maccoyii* (Castelnau, 1872), in the Tasman Sea (southwestern Pacific Ocean) off Rabbit Island, South Australia (SAM 28336 and 28337); and voucher specimens maintained in the collection of SAB from the heart of Gulf of Mexico fishes: *Elaphrobates euzeti* Bullard and Overstreet, 2003 from red snapper, *Lutjanus campechanus* Poey, 1860 (Perciformes: Lutjanidae), *C. laruei* from the heart of *C. arenarius* and spotted weakfish, *Cynoscion nebulosus* (Cuvier, 1830), *Cardicola palmeri* Bullard and Overstreet, 2004 from black drum, *Pogonias cromis* Linnaeus, 1766 (Perciformes: Sciaenidae), and *Cardicola currani* Bullard and Overstreet, 2004 from red drum, *Sciaenops ocellatus* (Linnaeus, 1766) (Sciaenidae).

Etymology: The specific epithet *nonamo* incorporates, in chronological order, the first 2 letters of the last name of each worker who handled the holotype and paratypes, i.e., Nobel, Nahhas, and Moser, and it is a phonetic derivative of "no name;" which intends to underscore that the holotype and paratypes lacked a specific epithet for many years after they were collected in 1936 and 1980, respectively.

Remarks

Cardicola nonamo n. sp. differs from other species assigned to *Cardicola* by the combination of having (1) rows of minute tegumental spines distributing along the entire ventrolateral body margin; (2) an aspinous anterior sucker comprising a nearly indistinct spheroid structure centering on the mouth; (3) an esophagus 17–21% of the total body length; (4) convoluted posterior ceca 51–65% of the total body length and 9–18× length of the anterior ceca; (5) a rectangular, intercecal testis not extending posteriad beyond the posterior ceca; (6) a post-testicular and post-cecal ovary; (7) an oviduct emanating from the posterodextral margin of the ovary; (8) a post-ovarian uterus coiling twice just posterior to the ovary; and (9) male and female genital pores opening dorsomedially and posterior to the uterus and ootype (Figs. 1–4). The new species most closely resembles *Cardicola ambrosioi* Braicovich, Echegoin, Timi, and Sardella, 2006, which infects the blood vessels of the gill and liver of the Brazilian flathead, *Percophis brasiliensis* Quoy and Gaimard, 1825 (Perciformes: Percophidae) in the southwestern Atlantic Ocean off Argentina. Both aporocotylids have (1) relatively short anterior ceca; (2) ventrolateral nerve cords coursing ventral to the posterior ceca; (3) a sinistral vas deferens coursing ventral to the ovary and in parallel with the metraterm and descending uterus; (4) a male genital pore immediately posterior to the female genital pore; (5) an oviduct emanating from the posterodextral margin of the ovary; (6) a uterus coiling immediately posterior to the ovary; and (7) a seminal vesicle and metraterm adjacent to each other in the posterior body extremity. However, the new species can be most easily distinguished from *C. ambrosioi* by having rows of tegumental spines distributing along the entire ventrolateral body margin and by having posterior ceca that are 9–18× length of the anterior ceca. *Cardicola ambrosioi* reportedly lacks post-ovarian spine rows and has posterior ceca that are only 4× length of the anterior ceca. Although infrequently used as a source of taxonomic characters for species of *Cardicola*, the course of the uterus, specifically described in terms of its

ascending portion (that which extends anteriad) and descending portion (that which extends posteriad to connect with the metraterm), as well as the relative position of the ootype together hold promise as reliable taxonomic characteristics. For example, *C. nonamo* and *C. ambrosioi* each have a descending uterus that extends directly posteriad in parallel with and between the vas deferens and body margin as well as an ootype that occupies the space at level of the middle region of the ascending uterus.

Cardicola nonamo and *C. ambrosioi* presently are known only from the Pacific and Atlantic Ocean basins, respectively. Moreover, these species presently are known only from the heart and gill vessels of 2 surfperches (Perciformes: Embiotocidae) and the gill and liver vessels of a duckbill (Perciformes: Percophidae), respectively.

Cardicola nonamo can be most easily distinguished from the remaining species that previously have been assigned to *Cardicola* by considering features associated with the anterior sucker, relative lengths of the esophagus and ceca, position of the gonads relative to the ceca, the medial or lateral origin of the oviduct relative to the posterior margin of the ovary, relative location of the uterus and genital pores, and the course of the uterus (Figs. 1–4).

The absence of a spheroid anterior sucker bearing concentric spine rows distinguishes the new species from the species assigned to *Cardicola* that infect the Australian siganids and lutjanid (Nolan and Cribb, 2006) and *Cardicola aurata* Holzer, Montero, Repullés, Nolan, Sitja-Bodabilla, Alvarez-Pellitero, Zarza, and Raga, 2008 (see Holzer et al., 2008) as well as *Elaphrobates euzeti* Bullard and Overstreet, 2003 (see Bullard and Overstreet, 2003) (Figs. 1, 2). It is unclear whether *C. cardiocolum*, the type species, has a spheroid anterior sucker with concentric spine rows or not, and indeed some of the species presently assigned to *Cardicola* apparently lack the feature. Nolan and Cribb (2006) studied a digital photograph of the holotype and judged that the specimen possessed an anterior sucker; however, they could not discern whether spines were present or absent on the surface of the anterior sucker. Indeed, the holotype of *C. cardiocolum* is in poor condition, and it is likely that if spines were present that they probably became detached before fixation of the specimen. I have observed that the anterior sucker spines of *E. euzeti* detach within minutes of the specimen dying in physiologic saline and before it is placed in formalin. Moreover, if morphologically similar aporocotylids infect phylogenetically related definitive fish hosts, e.g., fishes in the same family, the fact that *C. aurata* and *C. cardiocolum* both mature in porgies (Sparidae) hints that their adults may have the same type of spinous anterior sucker. Moreover, a new species that matures in another sparid in the Gulf of Mexico has such an anterior sucker (A. Bullard, pers. obs.). Although Nolan and Cribb (2006) regarded *Elaphrobates* as a junior subjective synonym of *Cardicola* based on the fact that *C. cardiocolum* has an anterior sucker, the presence of an anterior sucker having spines was just one of several characters used by Bullard and Overstreet (2003) to justify their proposal of *Elaphrobates* Bullard and Overstreet, 2003 and differentiate it from *Cardicola*. The species documented by Nolan and Cribb (2006) and Holzer et al. (2008) possibly should be allocated to *Elaphrobates*, i.e., congeneric with its type species *E. euzeti*, because they each possess a spinous anterior sucker as well as those additional features included in the diagnosis of *Elaphrobates* (see Bullard and Overstreet, 2003). Alternatively, and pending a redescription of Manter's (1947) *C. cardiocolum*, perhaps *E. euzeti* should be regarded as congeneric with *C. cardiocolum*, thereby making *Elaphrobates* a junior subjective synonym of *Cardicola*, as proposed by Nolan and Cribb (2006). And, simultaneously, it may be that several species presently allocated to *Cardicola* should be reassigned to newly proposed genera that are morphologically similar to *Elaphrobates* and *Cardicola*. Regardless, I think the presence or absence of the spinous anterior sucker in the adult fluke is a generic feature among aporocotylids, and the fact that *Cardicola* collectively includes species having and lacking this feature is more indicative of the systematic disarray of the genus rather than this feature not being of generic importance. Doubtless, clarification of this matter hinges on the future collection of better quality specimens of *C. cardiocolum*, and such collections are in progress.

The new species can be further distinguished from many of the species assigned to *Cardicola* in possessing a short esophagus (17–21% of the total body length) and relatively long posterior ceca (9–18× longer than the anterior ceca) (Fig. 1). *Cardicola cardiocolum*, *C. coridodacis*, *C. laruei*, *C. palmeri*, *C. currani*, Nolan and Cribb's (2006) species, and *C. aurata* each have a long esophagus (35–50% of the total body length), and *C. cardiocolum*, *C. coridodacis*, *C. laruei*, *C. kurochkini*, *C. forsteri*, *C.*

palmeri, *C. currani*, *C. ambrosioi*, *C. congruenta*, Nolan and Cribb's (2006) species, and *C. aurata* each have relatively short posterior ceca (1–5× longer than the anterior ceca).

Cardicola nonamo has a testis that is rectangular and limited both laterally and posteriorly by the intestinal ceca, i.e., the testis does not extend laterally beyond the level of the posterior ceca nor posteriad beyond the distal tips of the posterior ceca (Figs. 1, 3, 4), and a post-cecal ovary abutting the testis. This combination of characteristics differentiates the new species from *C. laruei* and *C. palmeri*, which both have posterior ceca extending posterior to the ovary; from *C. whitteni*, which has a testis extending posteriad beyond the tips of the posterior ceca thereby forming a triangular-shaped posterior region; and from *C. forsteri*, which has a testis extending beyond the limits of the posterior ceca.

The new species has an oviduct that emanates from the posterodextral margin of the ovary (Figs. 3, 4). Although this character is indeterminate for some *Cardicola* spp., it does differentiate several species. *Cardicola cardiocolum*, *C. laruei*, *C. whitteni*, *C. congruenta*, *C. mugilis*, *C. ahi*, *C. forsteri*, *C. palmeri*, *C. currani*, and Nolan and Cribb's (2006) species all have an oviduct that emanates from the posteromedial margin of the ovary. In contrast and similar to the new species, *C. coridodacis*, *C. grandis*, *C. chaetodontis*, and *C. ambrosioi* apparently have an oviduct that emanates from the posterodextral margin of the ovary. *Cardicola aurata* reportedly has an oviduct that can be dextral or medial (Holzer et al., 2008), but the oviduct origin in all specimens of the *Cardicola* spp. studied herein (see Specimens compared) did not vary intraspecifically.

The new species has a post-ovarian uterus (Figs. 3, 4), whereas *C. whitteni*, *C. currani*, *C. congruenta*, *C. chaetodontis*, and *C. ahi* have a uterus that to some degree courses slightly lateral to the ovary. In addition, *C. nonamo* has male and female genital pores that open dorsomedially and posterior to the uterus and ootype (Figs. 1, 3, 4), thereby differentiating it from other *Cardicola* spp. having 1 or both genital pores that open marginally, i.e., *C. whitteni*, *C. brasiliensis*, and *C. mugilis*, or from species having a female genital pore that opens anterior to a portion of the uterus, i.e., *C. laruei*, *C. whitteni*, *C. forsteri*, *C. currani*, and *C. chaetodontis*. The presence of 2 uterine coils immediately posterior to the ovary comprise a seemingly reliable species-level character further differentiating the new species from *C. laruei*, *C. coridodacis*, *C. congruenta*, *C. grandis*, *C. currani*, and *C. aurata*.

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