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Revision of *Aristocleidus* (Monogenoidea: Dactylogyridae), rediscovery of *Aristocleidus hastatus*, and description of *Aristocleidus lamothei* n. sp. from the Peruvian Mojarra *Diapterus peruvianus* (Teleostei: Gerreidae) in Mexico

Revisión de *Aristocleidus* (Monogenoidea: Dactylogyridae), redescripción de *Aristocleidus hastatus* y descripción de *Aristocleidus lamothei* n. sp. de la mojarra peruana *Diapterus peruvianus* (Teleostei: Gerreidae) en México

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Abstract. The generic diagnosis of *Aristocleidus* Mueller, 1936 is emended based on a collection of 2 species of the genus from the gills of the Peruvian mojarra, *Diapterus peruvianus* (Gerreidae), from a lagoon along the Pacific Coast of Mexico. The genus is characterized in part by species having a deeply incised base of the ventral anchor with the tip of the superficial root conspicuously directed toward that of the deep root. *Aristocleidus hastatus* Mueller, 1936 is redescribed and *Aristocleidus lamothei* n. sp. is described from *D. peruvianus* from the Tres Palos Lagoon, Guerrero State, Mexico. The finding of *A. hastatus* on *D. peruvianus* in Mexico represents new host and locality records for the species.

Key words: Monogenoidea, Dactylogyridae, *Aristocleidus*, *Aristocleidus hastatus*, *Aristocleidus lamothei* n. sp. , Peruvian mojarra, *Diapterus peruvianus*, Mexico.

Resumen. Se completa la descripción de *Aristocleidus* Mueller, 1936 con base en 2 ejemplares recolectados de las branquias de la mojarra peruana, *Diapterus peruvianus* (Gerreidae), de una laguna situada en la costa del Pacífico de México. El género se caracteriza por tener la base del macrogancho ventral profundamente hundida, con la punta de la raíz superfcial dirigida marcadamente hacia la de la raíz profunda. Se redescribe *Aristocleidus hastatus* Mueller, 1936 y se describe *Aristocleidus lamothei* n. sp. de *D. peruvianus* de la laguna de Tres Palos, Guerrero, México. El hallazgo de *A. hastatus* en *D. peruvianus* representa un nuevo registro de hospedero y localidad.

Palabras clave: Monogenoidea, Dactylogyridae, *Aristocleidus, Aristocleidus hastatus, Aristocleidus lamothei* n. sp., mojarra peruana, *Diapterus peruvianus*, México.

Introduction

Aristocleidus Mueller, 1936 (Dactylogyridae) was proposed for *Aristocleidus hastatus* Mueller, 1936, from the gills of the striped bass, *Roccus lineatus* (Bloch) [now *Morone saxatilis* (Walbaum)] collected from the Peace River near Fort Ogden, Florida. Mueller (1936) defined the genus primarily on the number and/or nature of the sclerites of the haptor and copulatory complex and on the position of the vaginal pore in the type species. Although the taxonomic status of *Aristocleidus* has fluctuated, *A. hastatus* has not been reported since its original description. In his emendation of the generic diagnosis, Price (1937) corrected some original observations of Mueller (1936) including the presence of 14 (7 pairs) haptoral hooks (originally reported as 12 hooks) and that the dorsoventral axis of the haptor of *A. hastatus* was reversed in the original description. Mizelle and Hughes (1938) rejected *Aristocleidus* and considered it a junior synonym of *Urocleidus* Mueller, 1934, arguing that the distinctive features of the anchors were not of generic significance. This view was held by Seamster (1938), Sproston (1946) and Mizelle et al. (1956). Yamaguti (1963) recognized *Aristocleidus*, for which a new diagnosis was presented in an appendix to the Ancyrocephalinae of the Dactylogyridae. Yamaguti's (1963) generic diagnosis, which states that members possessed 12 hooks and had a dorsoventral axis of the haptor as presented in the original diagnosis, apparently was based soley on Mueller's original report. Finally, Beverley-Burton et al. (1986) rejected

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the synonymy proposed by Mizelle and Hughes (1938), echoed the observations of Price (1937) on the errors in the original species description and generic diagnosis, and noted that the male copulatory organ was not of the type characterizing species of *Urocleidus* and that the genus was in need of revision.

Aristocleidus has remained monotypic and the type species has not been recorded since its original description. An unpublished abstract of a study presented at the VI Congreso Nacional de Ictiolgía, Tuxpan, Veracruz, Mexico, records *Aristocleidus* (sic) on the gills of 2 species of Gerreidae, *Diapterus rhombeus* (Cuvier) and *Diapterus auratus* Ranzani, from a coastal lagoon of the Gulf of Mexico (Tellez et al., 1998). However, the abstract does not indicate the number nor identity (or identities) of the *Aristocleidus* species found on these hosts. During a survey of the monogenoidean parasites of fishes from the Pacific Coast of Guerrero State of Mexico, specimens of the Peruvian mojarra, *Diapterus peruvianus* (Cuvier) were collected with infestations of 2 species of *Aristocleidus*. In this paper, descriptions of these species are provided and the diagnosis of *Aristocleidus* is emended based on these new specimens and the cotypes of *A. hastatus*.

Materials and methods

Specimens of the Peruvian mojarra were captured by hook and line and throw nets during August, 2003 from the Tres Palos Lagoon (16°47'N, 99°39'W) on the Pacific Coast of Guerrero State, Mexico. Scientific and common names of hosts were those provided in FishBase (Froese and Pauly, 2007). Gills were removed from freshly killed fish at the site of collection, placed in ambient (~ 30° C) 4% formalin, labeled, and shipped to Idaho State University for study. Helminths were subsequently removed from the gills or sediment by using a small probe and dissecting microscope. Some specimens were mounted unstained in Gray and Wess medium for study of sclerotized structures; other specimens were stained with Gomori's trichrome or Genacher borax carmine (Humason, 1979) and mounted in Canada balsam for observing internal anatomy. Illustrations were prepared with the aid of a camera lucida or microprojector. Measurements, all in micrometers, represent straight-line distances between extreme points and are expressed as the mean followed by the range and number (n) of structures measured in parentheses. Body length includes that of the haptor; measurements of the copulatory complex include the greatest distance from the base of the male copulatory organ (MCO) to the distal tip of the accessory piece or tube of the MCO. Type and voucher specimens of *Aristocleidus* species collected during the present study were deposited in the U. S. National Parasite Collection (USNPC), the National Helminthological Collection of Mexico (CNHE) and the British Museum of Natural History (BMNH) as indicated in the respective species accounts. Additional voucher specimens of *A. hastatus*, not used for the present study, are available in the CNHE (5819). Ten cotypes of *A. hastatus* (on 2 microscope slides) from the museum collection of SUNY College of Environmental Science and Forestry (no museum accession number), Syracuse, New York, were examined for comparative purposes.

Class Monogenoidea Bychowsky, 1937
Subclass Polyonchoinea Bychowsky, 1937
Order Dactylogyridea Bychowsky, 1937
Dactylogyridae Bychowsky, 1933
***Aristocleidus* Mueller, 1936**

Description

Body fusiform, slightly flattened dorsoventrally, comprising body proper (cephalic region, trunk, peduncle), haptor. Tegument smooth. Two terminal, 2 bilateral cephalic lobes; 3 pairs of bilateral head organs; cephalic glands posterolateral to pharynx. Two pairs of eyespots; members of posterior pair with lenses, larger, closer together than those of anterior pair; anterior eyespots lacking lenses; accessory chromatic granules minute, ovate, few in number in cephalic region. Mouth subterminal, midventral, immediately anterior to pharynx; pharynx comprising muscular, glandular bulb; esophagus short; intestinal ceca 2, confluent posterior to gonads, lacking diverticula. Common genital pore midventral at level of intestinal bifurcation. Gonads intercecal, overlapping; germarium anteroventral to testis. Vas deferens not observed, apparently looping left intestinal cecum; seminal vesicle a simple dilation of vas deferens, dorsoposterior to single pyriform prostatic reservoir. Copulatory complex comprising nonarticulated male copulatory organ (MCO), accessory piece. MCO tubular, with simple basal funnel, rapidly tapered loosely coiled distal tube; coil clockwise (Kritsky et al., 1985). Accessory piece rod shaped, variable, distally serving as guide for MCO. Oviduct short; bilateral vitelline ducts not observed; Mehlis' gland present; uterus extending anteriorly along body midline to common genital pore; vitellarium coextensive with intestine. Haptor a simple extension of peduncle, subpentagonal, armed with dorsal, ventral anchor-bar complexes, 7 pairs of hooks with ancyrocephaline distribution (Mizelle, 1936; Mizelle and Price, 1963). Ventral anchor with deeply incised base forming deep and superficial roots, elongate shaft, point; superficial root bent toward deep root; dorsal anchor

unmodified, with short to nonexistent deep root, short shaft, elongate point. Ventral bar rod shaped, with anteromedial projection; dorsal bar rod shaped, with delicate concave ridge or flange near midlength. Hooks similar, each with upright acute thumb, slender shank comprising 1 subunit, filamentous hook (FH) loop. Parasites of gills of marine fishes.

Taxonomic summary

Type species: *Aristocleidus hastatus* Mueller, 1936 from the gills of striped bass, *Morone saxatilis* (Walbaum) [= *Roccus lineatus* (Bloch), type host], Moronidae; and Peruvian mojarra, *Diapterus peruvianus* (Cuvier), Gerreidae.
Other species: *Aristocleidus lamothei* n. sp. from the gills of *Diapterus peruvianus* (Cuvier), Gerreidae.

Remarks

The diagnostic characters used previously to distinguish *Aristocleidus* from other dactylogyrid genera involved the morphology of the haptoral armament and position of the vaginal pore as described by Mueller (1936) with corrections provided by Price (1937). The present diagnosis incorporates features of the internal organ systems as well as those of the haptoral armament and vagina. The organization of the internal organs of *Aristocleidus* species collected from the Peruvian mojarra is similar to that of species comprising some marine dactylogyrid genera, i.e., *Euryhaliotrematoides* Plaisance and Kritsky, 2004, *Euryhaliotrema* Kritsky and Boeger, 2002, *Aliatrema* Plaisance and Kritsky, 2004, among others, in that the vaginal pore is dextromarginal, the intestinal ceca are joined posterior to the gonads, and the gonads are slightly overlapping (testis dorsoposterior to germarium). *Aristocleidus* differs from *Euryhaliotrema* by its species having a funnel-shaped base of the MCO (bulbous in *Euryhaliotrema* spp.) and from the monotypic *Aliatrema* by forms possessing an accessory piece (accessory piece absent in *Aliatrema cribbi* Plaisance and Kritsky, 2004). *Aristocleidus* is differentiated from *Euryhaliotrematoides* by the MCO and accessory piece of *Aristocleidus* species being nonarticulated (articulated in *Euryhaliotrematoides* spp.). Although Mizelle and Hughes (1938) discounted the importance of the morphology of the haptoral sclerites in differentiating *Aristocleidus*, the present discovery of 2 species of *Aristocleidus* on the Peruvian mojarra suggests that the unique morphology of the ventral anchor base (base deeply incised with the superficial root directed toward the deep root) is an important generic character which separates the genus from all other dactylogyrid genera.

Aristocleidus hastatus Mueller, 1936 (Figs. 1-9)

Synonym: *Urocleidus hastatus* (Mueller, 1936) Mizelle and Hughes, 1938.

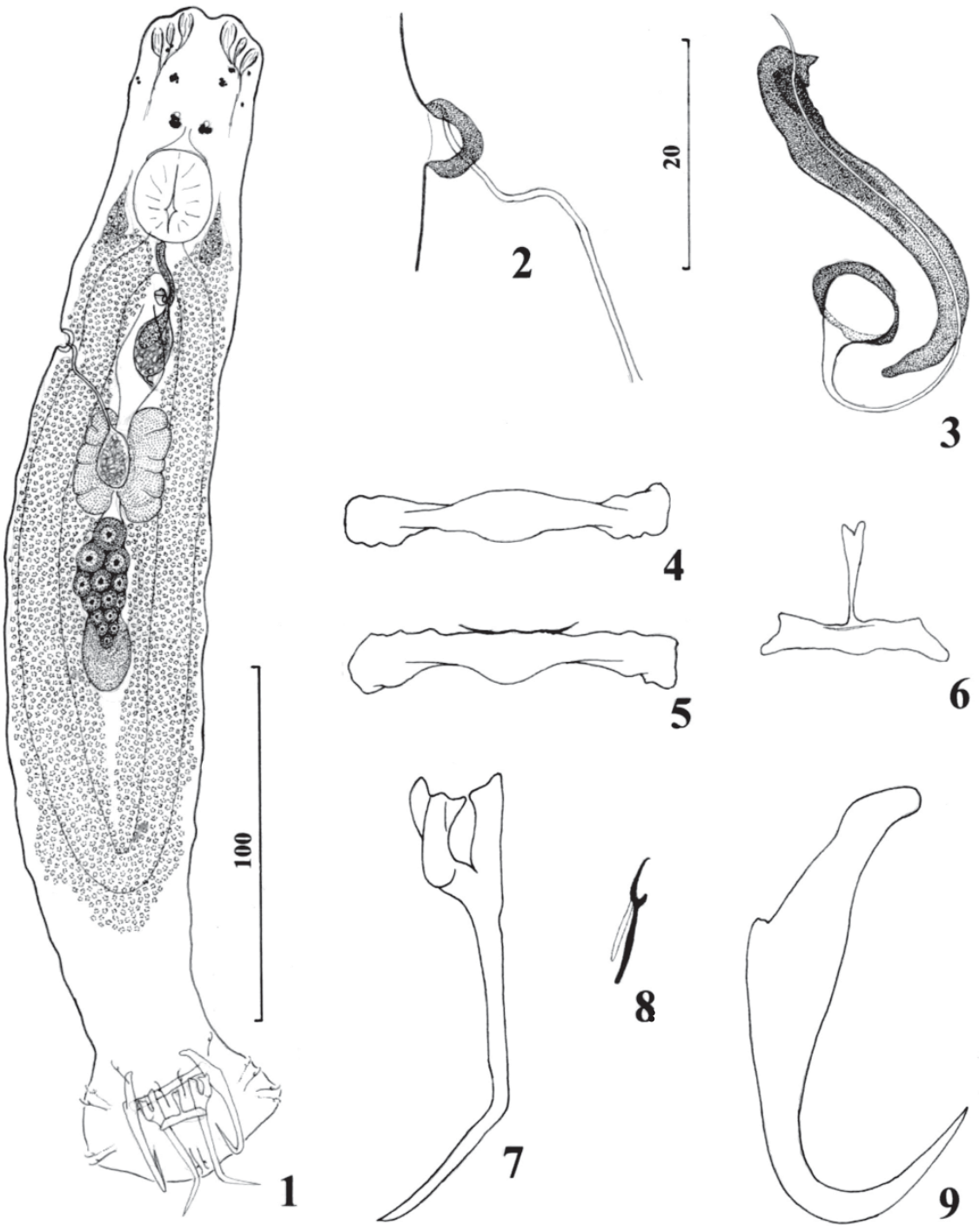
Measurements of cotypes follow in brackets those from Mexico, respectively). Body 379 (304-439; n= 34) long; greatest width 76 (57-100; n= 34) usually at level of gonads. Cephalic lobes well developed; each head organ comprising groupings of terminations of cephalic-gland ducts. Pharynx 28 (21-34; n= 33) wide, subspherical to ovate. Testis 29 (21-36; n= 3) long, 17 (13-20; n= 3) wide, ovate; seminal vesicle comparatively large; prostatic reservoir pyriform. Copulatory complex 32 (27-36; n= 8) [36-37 (n= 1)] long; MCO comprising proximal funnel-shaped base, coiled tube with about 1 complete ring; accessory piece proximally rod shaped, becoming flattened distally to serve as guide for MCO. Germarium 41 (30-57; n= 10) long, 22 (16-35; n= 9) wide, fusiform; vaginal pore with thickened, apparently lightly sclerotized saucer-shaped internal wall; vaginal tube delicate, extending to seminal receptacle; vitellarium dense. Haptor 65 (50-83; n= 33) long, 70 (60-84; n= 33) wide. Ventral anchor 40 (38-43; n= 14) [47 (41-50; n= 10)] long, with trifid tip of superficial root, conspicuous angular union of straight shaft and point. Dorsal anchor 37 (33-41; n= 14) [45 (40-49; n= 9)] long, elongate superficial root, short to nonexistent deep root, tapered shaft, elongate recurved point. Ventral bar 19 (16-21; n= 20) [23 (21-24; n= 6)] long, with elongate distally bifurcate anteromedial process; dorsal bar 30 (26-35; n= 25) [37 (35-38; n= 7)] long, with slightly expanded ends, delicate anteromedial flange. Hook 12 (11-13; n= 21) [12 (11-13; n= 8)] long; FH loop about 80% shank length.

Taxonomic summary

Host: Peruvian mojarra, *Diapterus peruvianus* (Cuvier), Gerreidae.
Locality: Tres Palos Lagoon (16°47'N, 99°39'W), Pacific Coast of Guerrero State, Mexico (August, 2003).
Previous record: *Morone saxatilis* (Walbaum) [as *Roccus lineatus* (Bloch)], Moronidae; Peace River near Fort Ogden, Florida (Mueller, 1936).
Site of infestation: gills.
Specimens studied: 10 Cotypes, SUNY College of Environmental Science; 50 vouchers from *Diapterus peruvianus*, USNPC 99637, BMNH 2007.4.3.6-17, CNHE 5818.

Remarks

Aristocleidus hastatus is the type species of the genus. The present finding of this species on the Peruvian mojarra in Mexico represents new host and locality records for the



Figures 1-9. *Aristocleidus hastatus* Mueller, 1936. 1, whole mount (ventral view, composite). 2, vagina. 3, copulatory complex (dorsal view). 4, 5, dorsal bars. 6, Ventral bar. 7, ventral anchor. 8, hook. 9, dorsal anchor. All figures are drawn to the 20µ scale except Fig. 1 (100µ).

helminth. Our examination of the highly cleared cotypes of *A. hastatus* confirms the observations of Price (1937) that Mueller (1936) had reversed the dorsoventral axis of the haptor and that the typical dactylogyrid complement of 7 pairs of haptoral hooks are present in this species. Comparative morphology of the haptoral sclerites and copulatory complex of the cotypes and specimens from Mexico is not significantly different. While dimensions of the haptoral armament of specimens of *A. hastatus* from the Peruvian mojarra were somewhat smaller than those of the cotypes, these differences are not deemed sufficient to separate the 2 populations into separate species and likely resulted from different environmental (host) influences.

Striped bass, *Morone saxatilis*, have been introduced into freshwaters of the western states from the eastern United States for a sport fishery. Examination of the gills of 4 striped bass from a land-locked population in Lake Havasu, California, a reservoir on the Colorado River, did not result in recovery of *A. hastatus*.

Aristocleidus lamothei n. sp. (Figs. 10-17)

Body 224 (192-298; n= 10) long; greatest width 42 (29-61; n= 9) usually near body midlength. Cephalic lobes well developed; each head organ comprising groupings of terminations of cephalic-gland ducts. Pharynx 16 (13-19; n= 7) wide, subspherical to elongate ovate. Testis 20 (17-26; n= 4) long, 15 (12-16; n= 4) wide, ovate; seminal vesicle comparatively large, fusiform; prostatic reservoir pyriform. Copulatory complex 24 (22-26; n= 2) long; MCO comprising proximal funnel, coiled tube of less than 1 ring; accessory piece with 3 distal branches. Germarium 21 (19-23; n= 4) long, 13 (10-15; n= 4) wide, comprised of few oocytes; vaginal vestibule thick walled, internal, communicating with vaginal pore by short duct; variable rod-like structure originating from the vaginal vestibule, extending toward sinistral side of body; vaginal tube short, delicate, extending to ovate seminal receptacle; vitellarium dense, vitelline ducts not observed. Haptor 46 (37-58; n= 10) long, 49 (40-72; n= 10) wide. Ventral anchor 29 (26-33; n= 6) long, with elongate evenly curved shaft and point, small base with distal end of superficial root tapered. Dorsal anchor 31 (30-33; n= 8) long, with elongate superficial root, short to nonexistent deep root, slightly arced shaft, elongate recurved point. Ventral bar 20 (18-23; n= 5) long, with short indistinct anteromedial process; dorsal bar 21 (18-24; n= 5) long, with slightly expanded ends, indistinct saucer-shaped flange closely appressed to bar proper. Hook 10 (9-11; n= 7) long; FH loop about 60% shank length.

Taxonomic summary

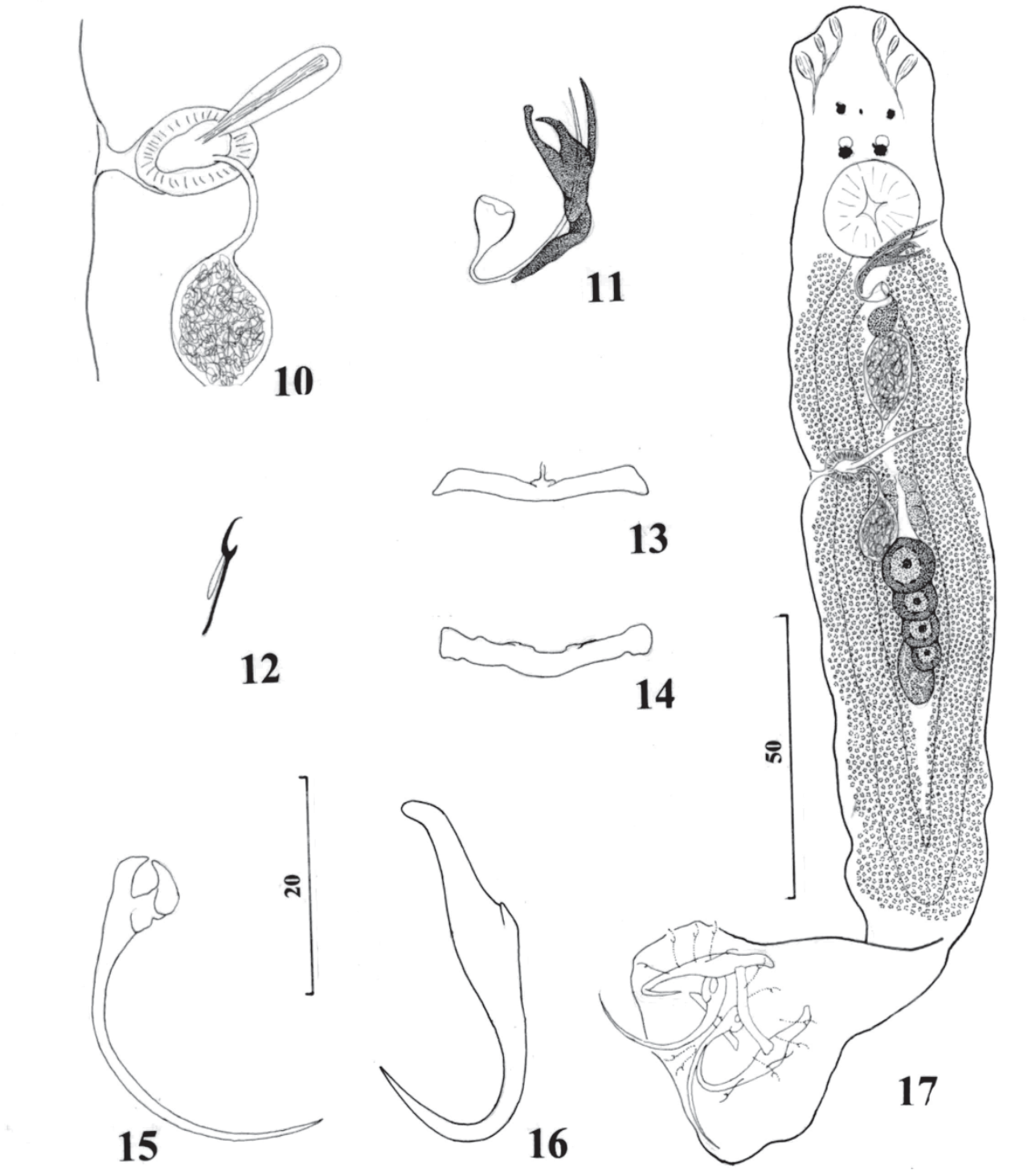
Type host: Peruvian mojarra, *Diapterus peruvianus* (Cuvier), Gerreidae.
Type locality: Tres Palos Lagoon (16°47'N, 99°39'W), Pacific Coast of Guerrero State, Mexico (August, 2003).
Site of infestation: Gills.
Specimens studied: Holotype, CNHE 5816; 10 paratypes, CNHE 5817, USNPC 99638, BMNH 2007.4.3.3-5.
Etymology: This species is named in honor of Professor Rafael Lamothe-Argumedo in recognition of his research on the parasite fauna of Mexico.

Remarks

Based on the comparative morphology of the base of the ventral anchor, *A. lamothei* n. sp. is clearly congeneric with *A. hastatus*. It differs from *A. hastatus* by have a smoothly arcing ventral anchor shaft and point (point and shaft united at an angular bend in *A. hastatus*), an elongate rod-like structure originating from the vaginal vestibule and extending toward the left side of the body (absent in *A. hastatus*), a short anteromedial projection on the ventral bar (anteromedial projection elongate in *A. hastatus*), and a distally trifid accessory piece (distal branches lacking in *A. hastatus*).

Discussion

The proposal of synonymy of *Aristocleidus* with *Urocleidus* by Mizelle and Hughes (1938) suggests that these authors considered *A. hastatus* to be a freshwater species, because all known species of *Urocleidus* at the time were parasitic on primary freshwater fishes of North America. However, Mueller (1936) did not provide a precise location along the Peace River from which his specimens of *A. hastatus* were collected, and Fort Ogden occurs near the mouth of the Peace River into Charlotte Harbor, an apparently marine or brackish water outlet to the Gulf of Mexico. Along the southeastern coast of the United States, *M. saxatilus*, the type host of *A. hastatus*, is anadromous, entering fresh or tidally-influenced fresh to slightly brackish waters for spawning (Hill et al., 1989; Secor, 2002). Thus, the possibility exists that *A. hastatus* was carried into the Peace River by its host from the marine environment and that the parasite species has marine rather than freshwater affinities. The occurrence of species of *Aristocleidus* on gerreid fishes (*Diapterus* spp.) from marine or brackish water lagoons of Mexico (Tellez et al., 1998; *nobis*) provides support for this hypothesis. Further, 4 striped bass examined from an introduced population present in the freshwater reservoir, Lake Havasu on the



Figures. 10-17. *Aristocleidus lamothei* sp. n. 10, vagina. 11, copulatory complex (dorsal view). 12, hook. 13, ventral bar. 14, dorsal bar. 15, ventral anchor. 16, dorsal anchor. 17, whole mount (ventral view, haptor in dorsal view; composite). All figures are drawn to the 20µ scale except Fig. 17 (50µ).

Colorado River in California, were negative for species of *Aristocleidus*. If the introduced stock of striped bass in Lake Havasu was originally parasitized by species of this genus, the parasites may have been lost from their host after extended exposure to freshwater. Finally, species of *Aristocleidus* do not infest any of the remaining 3 species of North American temperate sea basses [white perch, *Morone americana* (Gmelin); yellow bass, *Morone mississippiensis* Jordan and Evermann; and white bass, *Morone chrysops* (Rafinesque)] that have been examined from freshwater. However, these moronids are infested by monogenoids currently placed in *Onchocleidus* Mueller, 1936 and *Pterocleidus* Mueller, 1937, species of which are restricted to freshwater hosts in North America (Beverley-Burton et al., 1986).

Geminate species pairs (Jordan, 1908) occurring on either side of the Panamanian Isthmus are well documented for a variety of animal taxa and are generally based on morphological and/or molecular similarities (e.g., Lessios et al., 1995; Lessios, 1998; Tringali et al., 1999). An apparent example of a geminate pair associated with the isthmus is found among the Monogenoidea: *Euryhaliotrema atlantica* Kritsky and Boeger, 2002 and *Euryhaliotrema paralonchuri* (Lugue and Iannacone, 1989) Kritsky and Boeger, 2002 (Dactylogyridae) from the gills of the sciaenids, *Paralonchurus brasiliensis* (Steindachner) from the Atlantic Ocean and *Paralonchurus peruanus* (Steindachner) from the Pacific Ocean, respectively (Kritsky and Boeger, 2002). In addition, possible geminate pairs associated with the isthmus apparently exist among species of *Rhabdosynochus* Mizelle and Blatz, 1941 (Diplectanidae) (Mendoza-Franco, unpubl.) and *Tagia* Sproston, 1946 (Discocotylidae) (Vidal-Martínez and Kritsky, unpubl.). Further study, especially determination of the presence of *Aristocleidus* species on other marine fishes (particularly *Diapterus* spp.) in the Gulf of Mexico and the eastern Pacific would be necessary to determine affinities of *Aristocleidus* species to these hosts and their environment and whether or not geminate pairs associated with the Panamanian Isthmus exist within the genus.

While species of *Aristocleidus* that occur on gerreid fishes along the Atlantic and Pacific sides of Mexico may also include geminate pairs, the presence of *A. hastatus* on a moronid in Florida and on a gerreid on the Pacific side of Mexico is an enigma. Specimens of *A. hastatus* from *Diapterus peruvianus* in the Tres Palos Lagoon (Pacific Coast) do not differ by any significant morphometric way from the type specimens collected from striped bass in Florida. At least 3 possibilities might explain this biogeographic distribution of the parasite: 1), although unlikely based on putative speciation rates (Boeger et al., 2003; but see Mendoza-Franco et al., 2004) and host specificity (Bychowsky, 1957; Rohde, 1979; Plaisance and Kritsky, 2004; Kritsky et al., 2007) of other monogenoids, *A. hastatus*, with low host specificity, may be an exceptionally old species that developed prior to the formation of the Panamanian Isthmus; 2), the parasites occurring in the 2 regions may represent 2 distinct species that cannot be differentiated morphologically, or 3), *A. hastatus* may have been introduced to the Pacific environments by human transfer of its host, the striped bass, to the Pacific side of the continent. Striped bass provide an important sport fishery, and as a result the species has been transplanted to river drainages in western North America. While many of these transplants have remained land locked, striped bass have been recorded from the Pacific Ocean subsequent to its introduction to western North America (see Frose and Pauly, 2007). Because species of *Diapterus* are suitable hosts for *Aristocleidus* species, the possibility exists that *A. hastatus* invaded populations of *D. peruvianus* and perhaps other species of *Diapterus* when these fishes came into contact with striped bass in the Pacific environment.

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