Acta Parasitologica (2021) 66:436–445
https://doi.org/10.1007/s11686-020-00282-3

ORIGINAL PAPER

Three New Species of *Cosmetocleithrum* (Monogenea: Dactylogyridae) Gill Parasites of *Trachelyopterus galeatus* (Siluriformes: Auchenipteridae) in Southeastern Brazil

Priscilla de Oliveira Fadel Yamada[1] · **Fabio Hideki Yamada**[2] · **Reinaldo José da Silva**[1]

Received: 7 July 2020 / Accepted: 11 September 2020 / Published online: 19 October 2020

Abstract

Purpose To describe three new species of *Cosmetocleithrum* in the gills of *Trachelyopterus galeatus* (Siluriformes, Auchenipteridae) from Aguapeí River, Upper Paraná River basin, São Paulo State, Brazil.

Methods Fifty-three specimens of *T. galeatus* were captured in the mouth of the Aguapeí River from August 2013 to June 2014. Monogeneans were mounted unstained in Hoyer's and Gray and Wess's medium.

Results *Cosmetocleithrum spathulatum* sp. n., *Cosmetocleithrum baculum* sp. n., and *Cosmetocleithrum galeatum* sp. n. differ from all known congeneric species mainly in the morphology of the accessory piece (i.e. spatulate-shaped, claviform, and a straight rod with hook-shaped distal portion, respectively). Also, the three new species share hooks with different sizes with hooks pairs 5 and 7 bigger than others and with an erect delicate point, inconspicuous thumb, longer shaft, and slender shank.

Conclusions To date, 18 species of *Cosmetocleithrum* were recognised parasitizing siluriforms in the Neotropical region. The present study expands the number to 21 species, however, despite this increase, the number of known *taxa* of monogeneans in neotropics is far from representing the ideal situation.

Keywords Aguapeí River · Ancyrocephalinae · Catfishes · Neotropical region · Paraná River basin

Introduction

Freshwater fishes of the order Siluriformes present a rich fauna of gill monogeneans in the Neotropical region [1–3]. Among Siluriformes, fishes of the family Auchenipteridae harbour dactylogyrids from three genera in Brazil and Peru: *Cosmetocleithrum* Kritsky, Thatcher and Boeger, 1986, *Demidospermus* Suriano, 1983, and *Vancleaveus* Kritsky, Thatcher and Boeger, 1986 [4].

Cosmetocleithrum was erected by Kritsky *et al*. [5] to accommodate dactylogyrids parasitizing siluriforms in the Neotropical region. Species of this genus are characterized mainly by having a dorsal bar with two submedial projections. To date, 18 valid species of *Cosmetocleithrum* are known to parasitize freshwater fishes of the families Pimelodidae, Doradidae, and Auchenipteridae [3, 5–10] (Table 1). Among them, four species parasitize hosts of the family Auchenipteridae: *Cosmetocleithrum striatuli* Abdallah, Azevedo and Luque, 2012 from *Trachelyopterus striatulus* (Steindachner, 1877) and *Auchenipterus nuchalis* (Spix and Agassiz, 1829), *Cosmetocleithrum laciniatum* Yamada, Yamada, Silva and Anjos, 2017 from *Trachelyopterus galeatus* (Linnaeus, 1766), *Cosmetocleithrum berecae* Cohen, Justo, Gen and Boeger, 2020, and *Cosmetocleithrum nunani* Cohen, Justo, Gen and Boeger, 2020 from *Auchenipterus nuchalis*, all species described in Brazil.

During a parasitological survey of freshwater fishes from an environmental protection area, Aguapeí River, Upper Paraná River basin, São Paulo State, Brazil, were retrieved specimens of monogeneans on the gills of *T. galeatus*. Herein, we describe three new species of *Cosmetocleithrum* in this fish host.

✉ Priscilla de Oliveira Fadel Yamada
pf_yamada@hotmail.com

[1] Instituto de Biociências, Setor de Parasitologia, UNESP, Univ Estadual Paulista, Campus de Botucatu, Botucatu, SP, Brazil

[2] Departamento de Ciências Biológicas, Universidade Regional do Cariri (URCA), Crato, CE, Brazil

Table 1 List of species of *Cosmetocleithrum* Kritsky, Thatcher and Boeger, 1986, type hosts, and geographical distribution

Cosmetocleithrum species	Host	Family	Locality	References
C. gussevi Kritsky, Thatcher and Boeger, 1986 (type species)	*Oxydoras niger* (Valenciennes, 1821)	Doradidae	Janauacá Lake, Amazonas, Brazil	[5]
C. confusus Kritsky, Thatcher and Boeger, 1986	*Oxydoras niger* (Valenciennes, 1821)	Doradidae	Janauacá Lake, Amazonas, Brazil	[5]
C. bulbocirrus Kritsky, Thatcher and Boeger, 1986	*Pterodoras granulosus* (Valenciennes, 1821)	Doradidae	Janauacá Lake, Amazonas, Brazil	[5]
C. parvum Kritsky, Thatcher and Boeger, 1986	*Oxydoras niger* (Valenciennes, 1821)	Doradidae	Janauacá Lake, Amazonas, Brazil	[5]
C. rarum Kritsky, Thatcher and Boeger, 1986	*Oxydoras niger* (Valenciennes, 1821)	Doradidae	Janauacá Lake, Amazonas, Brazil	[5]
C. sobrinus Kritsky, Thatcher and Boeger, 1986	*Oxydoras niger* (Valenciennes, 1821)	Doradidae	Janauacá Lake, Amazonas, Brazil	[5]
C. longivaginatum Suriano and Incorvaia, 1995	*Pimelodus albicans* (Valenciennes, 1840)	Pimelodidae	De La Plata River, Argentina	[6]
C. striatuli Abdallah, Azevedo and Luque, 2012	*Trachelyopterus striatulus* (Steindachner, 1877)	Auchenipteridae	Guandu River, Rio de Janeiro, Brazil	[7]
C. tortum Mendoza-Franco, Mendoza-Palmero and Scholz, 2016	*Nemadoras hemipeltis* (Eigenmann, 1925)	Doradidae	Fish market in Belén, Iquitos, Peru	[24]
C. bifurcum Mendoza-Franco, Mendoza-Palmero and Scholz, 2016	*Hassar orestis* (Steindachner, 1875)	Doradidae	Aquarium Río Momón, Iquitos, Peru	[24]
C. laciniatum Yamada, Yamada, Silva and Anjos, 2017	*Trachelyopterus galeatus* (Linnaeus, 1766)	Auchenipteridae	Aguapeí River, Paraná River basin, São Paulo, Brazil	[8]
C. trachydorasi (=*Paracosmetocleithrum trachydorasi*) (Acosta, Scholz, Blasco-Costa, Alves and Silva, 2018)	*Trachydoras paraguayensis* (Eigenmann & Ward, 1907)	Doradidae	Aguapeí River Paraná River basin, São Paulo, Brazil	[2]
C. phryctophallus Soares, Neto and Domingues, 2018	*Hassar orestis* (Steindachner, 1875)	Doradidae	Xingu River, Pará	[3]
C. leandroi Soares, Neto and Domingues, 2018	*Hassar gabiru* Birindelli, Fayal and Wosiacki, 2011	Doradidae	Bacajá River, Pará	[3]
C. akuanduba Soares, Neto and Domingues, 2018	*Hassar gabiru* Birindelli, Fayal and Wosiacki, 2011	Doradidae	Xingu River, Pará	[3]
C. gigas Morey, Cachique and Babilonia, 2019	*Oxidoras niger* (Valenciennes, 1821)	Doradidae	Iquitos, Peru	[9]
C. berecae Cohen, Justo, Gen and Boeger, 2020	*Auchenipterus nuchalis* (Spix and Agassiz, 1829)	Auchenipteridae	Arraias River, Tocantins, Brazil	[10]
C. nunani Cohen, Justo, Gen and Boeger, 2020	*Auchenipterus nuchalis* (Spix and Agassiz, 1829)	Auchenipteridae	Mangues River, Tocantins, Brazil	[10]
Cosmetocleithrum spathulatum sp. n	*Trachelyopterus galeatus* (Linnaeus, 1766)	Auchenipteridae	Aguapeí River, Paraná River basin, São Paulo, Brazil	Present study
Cosmetocleithrum baculum sp. n	*Trachelyopterus galeatus* (Linnaeus, 1766)	Auchenipteridae	Aguapeí River, Paraná River basin, São Paulo, Brazil	Present study
Cosmetocleithrum galeatum sp. n	*Trachelyopterus galeatus* (Linnaeus, 1766)	Auchenipteridae	Aguapeí River, Paraná River basin, São Paulo, Brazil	Present study

Materials and Methods

Fifty-three specimens of *T. galeatus* (standard length in cm: 13.66 ± 1.61 [mean ± sd] and 11–17 [range] were captured in the mouth of the Aguapeí River (21° 03′03.16″ S; 51° 45′58.16″ W) (the map of the study area is available in [11]) from August 2013 to June 2014. The hosts were collected under the license number 577/2015 IBAMA (Brazilian Institute of Environment and Renewable Natural Resources) and SP/538/88 DEFOP (Department of the Development of Fishery and Inspection). All animal procedures were performed in full compliance with the Animal Experimentation Ethics Commission (Authorisation No.120-CEEA of the São Paulo State University—UNESP). In the laboratory, fishes were identified according to Graça and Pavanelli [12].

After capture, some hosts were frozen and later examined in the laboratory, whereas some freshly killed hosts were examined in situ, having the monogeneans recovered and fixed with a glycerin–ammonium picrate (GAP) mixture to study their sclerotized structures [13]. In the laboratory, gills were removed and placed in Petri dishes with tap water, and then examined under a stereomicroscope. Monogenean specimens were mounted unstained in Hoyer's and Gray and Wess's medium [5].

The parasites were analysed using a V3 Leica Application Suite (LAS) computerised system for image analysis adapted in a microscope with differential interference contrast. Drawings were obtained with the aid of a camera lucida mounted on a Leica DMLS microscope equipped with phase-contrast optics. Measurements are in micrometers and expressed as the mean is followed by the range and the number of specimens measured in parentheses. Landmark definition and morphometric measurements of haptor sclerotized parts and copulatory complex were taken according to Gussev [14] and Řehulková *et al*. [15] (Fig. 1). The numbering and distribution of hook pairs follow Mizelle [16]. Specific terminology of the genus *Cosmetocleitrum* follows Kritsky *et al*. [5]. The prevalence and mean intensity of infection were calculated following Bush *et al*. [17].

Type and voucher specimens were deposited in the Helminthological Collection of the Instituto Oswaldo Cruz (CHIOC), Rio de Janeiro, Brazil. Other paratypes were deposited in the Helminthological Collection of the Institute of Biosciences (CHIBB), Botucatu, São Paulo State, Brazil.

Results

Dactylogyridae Bychowsky, 1933.

Ancyrocephalinae Bychowsky, 1937.

Cosmetocleithrum Kritsky, Thatcher and Boeger, 1986.

Cosmetocleithrum spathulatum sp. n.

(Fig. 2a–h).

Taxonomic Summary

Type-host: *Trachelyopterus galeatus* (Linnaeus, 1766) (Siluriformes: Auchenipteridae).

Type-locality: Mouth of the Aguapeí River, Upper Paraná River, São Paulo State, Brazil (21° 03′03.16″ S and 51° 45′58.16″ W).

Site of infestation: Gill lamellae.

Type-material: Holotype, CHIOC 39420a; Paratypes, CHIOC 39420b, 39421a, 39421b and CHIBB 607L, 608L, 609L, 610L, 611L, 612L, 613L, 614L.

Prevalence and mean intensity of infestation: 94% (50 of 53 fishes examined) and 21.54 parasites per parasitized host.

Etymology: The specific name derives from Latin (*spathula* = "spatula") and refers to the shape of the base of the accessory piece.

Description

[Based on 25 specimens: seven fixed in GAP, five stained with Gray and Wess´s medium, and 13 stained with Hoyer's medium]. Body fusiform 385 (286–527, $n = 10$) long,

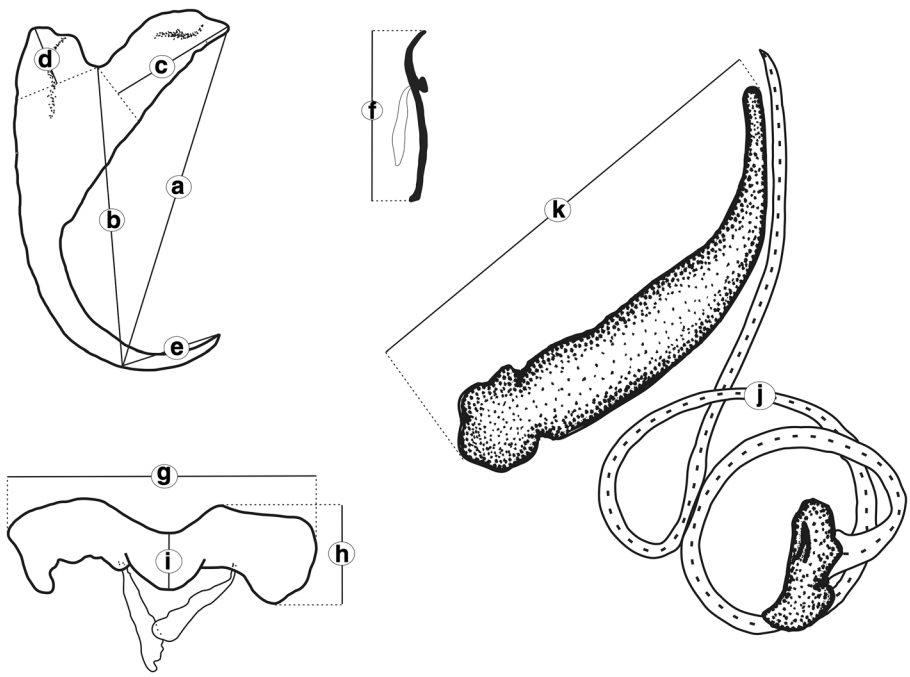

Fig. 1 Scheme of measurements for the sclerotized structures of the haptor and copulatory complex of *Cosmetocleitrum* spp.: **a** total length of anchor, **b** length of base, **c** length of superficial root, **d** length of deep root, **e** length of point, **f** total length of hook, **g** total length of bar, **h** bar height, **i** bar width, **j** total curve length of MCO (dash line), **k** accessory piece length

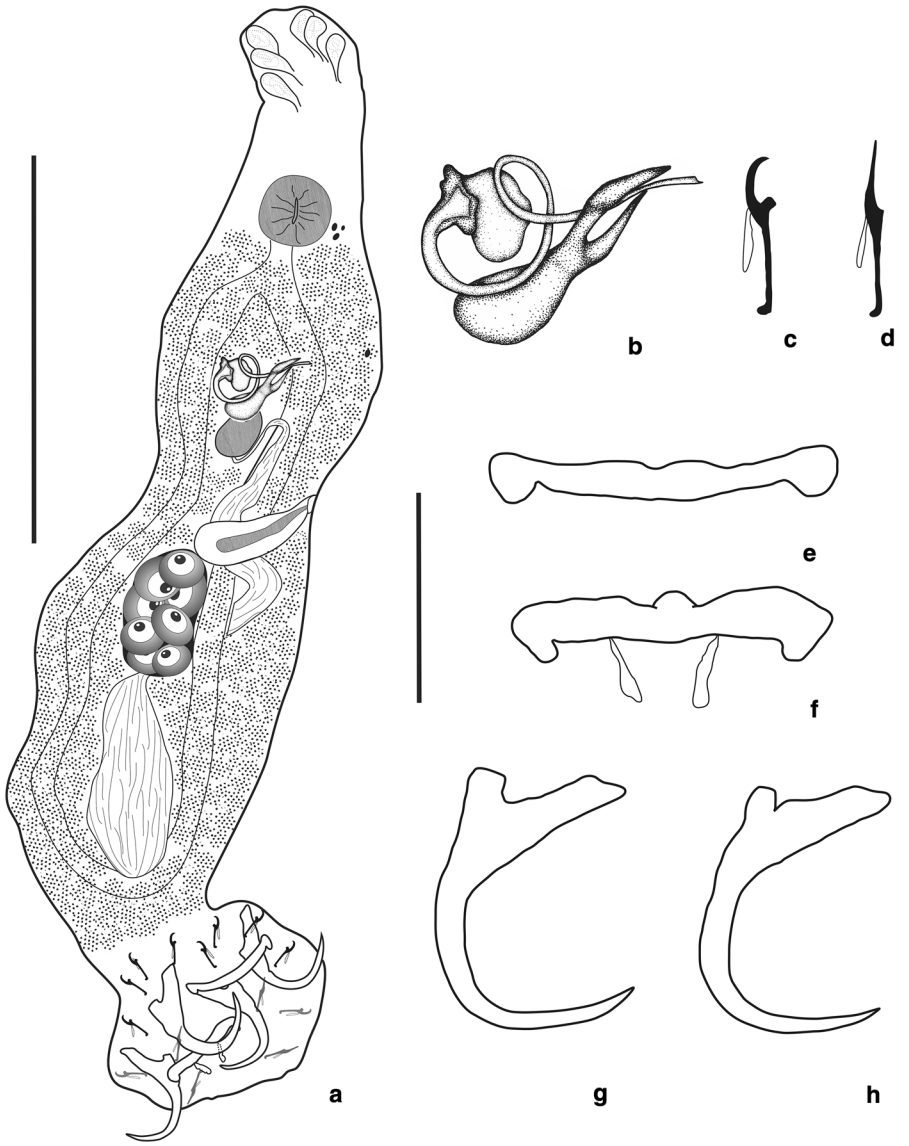

Fig. 2 *Cosmetocleithrum spathulatum* sp. n. from the gills of *Trachelyopterus galeatus* (Linnaeus, 1766). **a** Whole mount in ventral view (composite); **b** Copulatory complex (ventral view); **c** Hook pairs 1–4 and 6; **d** Hook pairs 5 and 7; **e** Ventral bar; **f** Dorsal bar; **g** Ventral anchor; **h** Dorsal anchor. Scale bars: **a** = 100 µm; **b**–**h** = 20 µm

126 (71–192, $n = 9$) wide near mid-length (Fig. 2a). Three bilateral pairs of head organs poorly developed. Eye-spot granules subspherical, scattered throughout cephalic region. Pharynx spherical 26 (20–33, $n = 8$) in diameter, muscular, glandular; esophagus short. Two intestinal caeca confluent posteriorly to testis, lacking diverticula. Gonads in tandem, germarium pre-testicular 36 (31–45, $n = 3$) long, 26 (24–27, $n = 3$) wide. Testis posterior to germarium 53 (48–62, $n = 3$) long, 25 (18–32, $n = 3$) wide; vas deferens looping left intestinal caecum. Seminal vesicle a dilation of vas deferens; prostatic reservoir spherical, anterior to seminal vesicle. Copulatory complex (Fig. 2b) comprising male copulatory organ (MCO) 56 (50–64, $n = 17$) long, sclerotized, coiled, with about 1½ counterclockwise ring, a sclerotized base bulb-shaped; and an accessory piece 22 (18–27, $n = 18$) long, not articulated with MCO, spatula-shaped, distally bifurcate, robust, distal portion serving as guide from middle portion of MCO. Vagina single, muscular, with thickened wall opening on left margin of body. Peduncle narrow; haptor subhexagonal 89 (78–104, $n = 7$) long, 80 (65–98, $n = 9$) wide, with seven pairs of hooks, with ancyrocephaline distribution. Ventral bar with enlarged ends (Fig. 2e): (g) 28 (22–34, $n = 20$); (h) 5 (3–8, $n = 19$); (i) 3 (2–5, $n = 21$). Dorsal bar yoked-shaped, with two submedial projections (Fig. 2f): (g) 27 (21–33, $n = 19$); (h) 5 (4–7, $n = 19$); (i) 4 (3–7, $n = 20$). Anchors similar, with well-developed roots, tapered superficial root, conspicuous deep root, evenly curved shaft and elongated point. Ventral anchor (Fig. 2g): (a) 27 (25–29, $n = 19$); (b) 23 (20–25, $n = 19$); (c) 10 (8–11, $n = 19$); (d) 2 (1–3, $n = 19$); (e) 12 (8–14, $n = 19$). Dorsal anchor (Fig. 2h): (a) 25 (24–27, $n = 20$); (b) 22 (19–24, $n = 20$); (c) 10 (7–11, $n = 20$); (d) 2 (2–3, $n = 20$); (e) 11 (8–14, $n = 20$). Hooks pairs 1–4 and 6 (Fig. 2c) 15 (14–16, $n = 22$) long, with FH loop about 60% shank length, slender uniform shank,

expanded tip, posteriorly directed thumb, straight shaft, and evenly curved point. Hooks pairs 5 and 7 (Fig. 2d)16 (16–17, $n=8$) long, with FH loop about 50% shank length, erect shaft, straight shank, erect delicate point, and inconspicuous thumb. Oviduct, ootype, seminal receptacle, uterus, and egg not observed. Vitelline follicles dense, dispersed throughout trunk but absent in region of reproductive organs and MCO.

Remarks

Cosmetocleithrum spathulatum sp. n. differs from all previously known congeneric species in the morphology of its accessory piece, i.e. spatulate-shaped proximal region. The new species closely resembles *Cosmetocleithrum parvum* Kritsky, Thatcher and Boeger, 1986, *Cosmetocleithrum phryctophallus* Soares, Neto and Domingues, 2018, *Cosmetocleithrum tortum* Mendoza-Franco, Mendoza-Palmero and Scholz, 2016, and *Cosmetocleithrum trachydorasi* (Acosta, Scholz, Blasco-Costa, Alves and da Silva, 2018) Cohen, Justo, Gen and Boeger, 2020 by possessing a vaginal vestibule cup-shaped. Despite this similarity, only *C. tortum* presents a dextral vagina. *Cosmetocleithrum spathulatum* sp. n. resembles *Cosmetocleithrum longivaginatum* Suriano and Incorvaia, 1995, *Cosmetocleithrum bifurcum* Mendoza-Franco, Mendoza-Palmero and Scholz, 2016, *C. tortum*, and *C. nunani* which present hooks dissimilar in size. However, the new species can be distinguished from these species, by presenting members of hooks pairs 5 and 7 bigger than others and with an erect delicate point, inconspicuous thumb, longer shaft, and slender shank.

Cosmetocleithrum baculum sp. n.
(Fig. 3a–h).

Taxonomic Summary

Type-host: *Trachelyopterus galeatus* (Linnaeus, 1766) (Siluriformes: Auchenipteridae).

Type-locality: Mouth of the Aguapeí River, Upper Paraná River, São Paulo State, Brazil (21° 03′03.16″ S and 51° 45′58.16″ W).

Site of infestation: Gill lamellae.

Type-material: Holotype, CHIOC 39417; Paratypes, CHIOC 39418, 39419 and CHIBB 618L, 619L.

Prevalence and mean intensity of infestation: 17% (9 of 53 fishes examined) and 1.22 parasites per parasitized host.

Etymology: The specific name derives from Latin (*baculum* = "a little stick") and refers to the clavate shape of the accessory piece.

Description

[Based on 18 specimens: 15 stained with Hoyer's medium, one stained with Gray and Wess's medium and two fixed in GAP]. Body fusiform and robust 667 (509–814, $n=11$) long, 155 (117–198, $n=10$) wide near midlength (Fig. 3a). Three pairs of head organs poorly developed. Eye-spot granules subspherical, scattered throughout cephalic area. Pharynx spherical 35 (26–44, $n=6$) in diameter, esophagus short. Gonads in tandem, germarium pre-testicular 58 (44–67, $n=3$) long, 50 (38–65, $n=3$) wide. Testis posterior to germarium 93 (68–121, $n=3$) long, 48 (37–58, $n=3$) wide; vas deferens looping left intestinal caecum. Seminal vesicle a dilation of vas deferens; prostatic reservoir spherical, anterior to seminal vesicle. Copulatory complex (Fig. 3b) comprising MCO 126 (111–143, $n=17$) long, with about 2½ counterclockwise rings with a sclerotized base; and an accessory piece 35 (24–46, $n=16$) long not articulated to cirrus base, claviform. Vagina sinistral, marginal, and slightly sclerotized. Peduncle short, broad; haptor globose 153 (106–210, $n=12$) long, 119 (94–152, $n=10$) wide, with 7 pairs of hooks, with ancyrocephaline distribution. Ventral bar yoked-shaped, with an anterior protuberance at middle portion and with enlarged ends (Fig. 3e): (g) 45 (39–50, $n=12$); (h) 11 (8–12, $n=10$); (i) 9 (6–11, $n=12$). Dorsal bar yoked-shaped, with two submedial projections (Fig. 3f): (g) 48 (41–53, $n=12$); (h) 11 (9–13, $n=12$); (i) 7 (5–10, $n=12$). Ventral anchor, with well-developed roots, tapered superficial root, evenly curved shaft and short point (Fig. 3g): (a) 50 (47–53, $n=14$); (b) 43 (38–47, $n=14$); (c) 18 (14–21, $n=14$); (d) 5 (3–6, $n=14$); (e) 16 (13–21, $n=12$). Dorsal anchor, triangular superficial root, deep root inconspicuous, evenly curved shaft and short point (Fig. 3h): (a) 44 (40–52, $n=14$); (b) 38 (34–44, $n=14$); (c) 15 (13–21, $n=14$); (d) 4 (3–5, $n=13$); (e) 13 (12–15, $n=13$). Hooks dissimilar in size; each with slender uniform shank, expanded tip, posteriorly directed thumb, straight shaft, and evenly curved point. Hooks pairs 1–4 and 6 (Fig. 3c) 20 (18–25, $n=66$) long, with FH loop about 70% shank length, slender uniform shank, expanded tip, posteriorly directed thumb, straight shaft, and evenly curved point. Hooks pairs 5 and 7 (Fig. 3d) 26 (24–26, $n=28$) long, with FH loop about 60% shank length, erect shaft, straight shank, erect delicate point, and inconspicuous thumb. Oviduct, ootype, seminal receptacle, uterus, and egg not observed. Vitelline follicles dense, dispersed throughout trunk but absent in the region of reproductive organs and MCO.

Remarks

Cosmetocleithrum baculum sp. n. closely resembles *C. longivaginatum*, *C. striatuli*, *C. laciniatum*, and *Cosmetocleithrum leandroi* Soares, Neto and Domingues, 2018 by the shape of the dorsal (yoked-shaped) and ventral bar (straight with enlarged ends). The new species can be distinguished from all congeners in having MCO base with a single lateral flap, accessory piece clavate shaped, and ventral

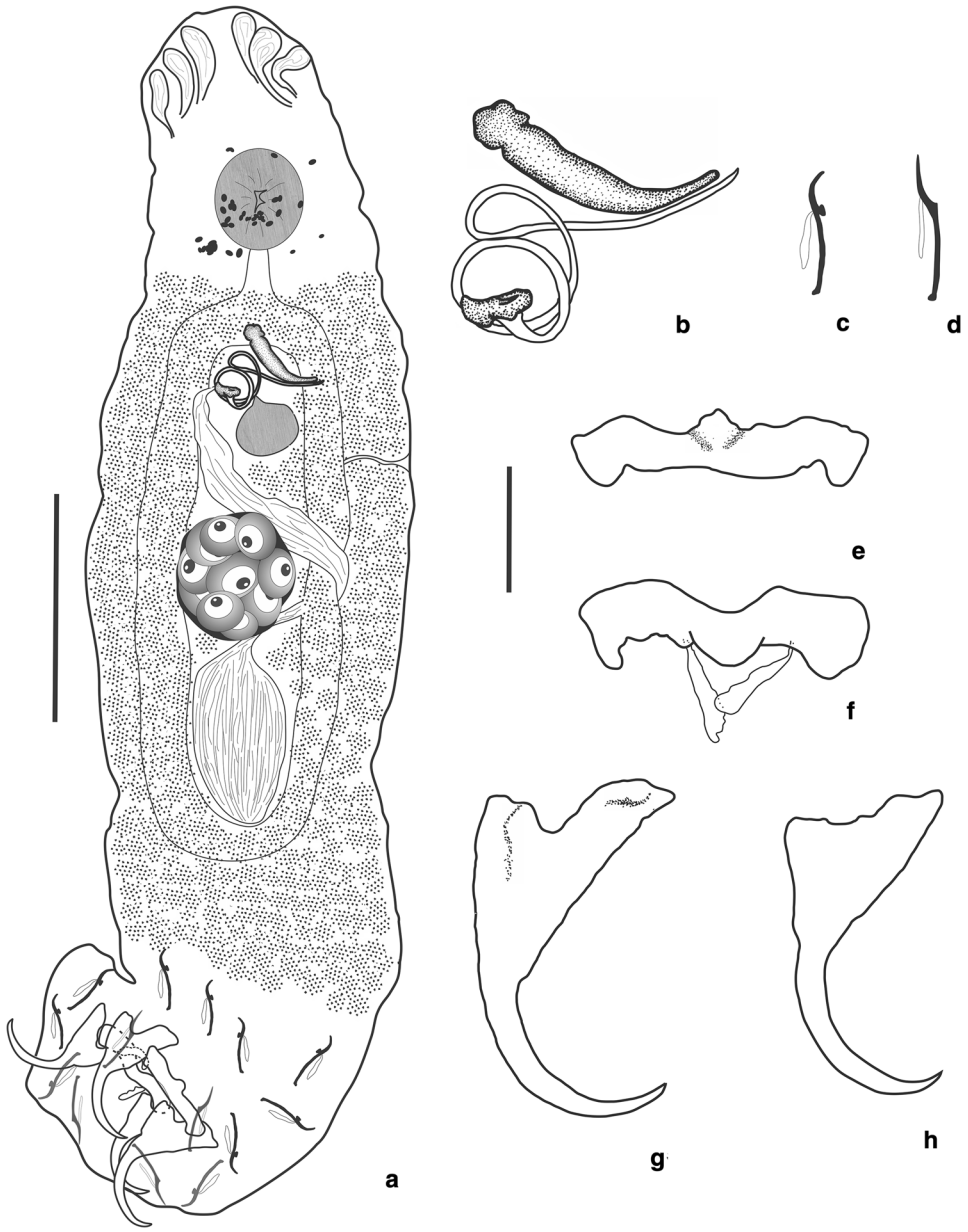

Fig. 3 *Cosmetocleithrum baculum* sp. n. from the gills of *Trachelyopterus galeatus* (Linnaeus, 1766). **a** Whole mount in ventral view (composite); **b** Copulatory complex (ventral view); **c** Hook pairs 1–4 and 6; **d** Hook pairs 5 and 7; **e** Ventral bar; **f** Dorsal bar; **g** Ventral anchor; **h** Dorsal anchor. Scale bars: **a** = 100 µm; **b**–**h** = 20 µm

bar with anteromedial rotund projection. It is noteworthy that *Cosmetocleithrum baculum* sp. n. also possesses hooks with different sizes and similar morphology to *Cosmetocleithrum spathulatum* sp. n.

Cosmetocleithrum galeatum sp. n.

(Fig. 4a–h).

Taxonomic Summary

Type-host: *Trachelyopterus galeatus* (Linnaeus, 1766) (Siluriformes, Auchenipteridae).

Type locality: Mouth of the Aguapeí River, Upper Paraná River, São Paulo State, Brazil (21° 03′03.16″ S and 51° 45′58.16″ W).

Site of infestation: Gill lamellae.

Type-material: Holotype, CHIOC 39414; Paratypes, CHIOC 39415, 39416 and CHIBB 622L, 623L, 624L, 625L, 626L.

Prevalence and mean intensity of infestation: 91% (48 of 53 fishes examined) and 5.04 parasites per parasitized host.

Etymology: The specific name *galeatum* refers to the specific name of the type-host.

Description

[Based on 25 specimens: 2 fixed in GAP, 3 stained with Gray and Wess's medium, and 20 stained with Hoyer´s medium]. Body fusiform, robust, 652 (431–917, $n = 17$)

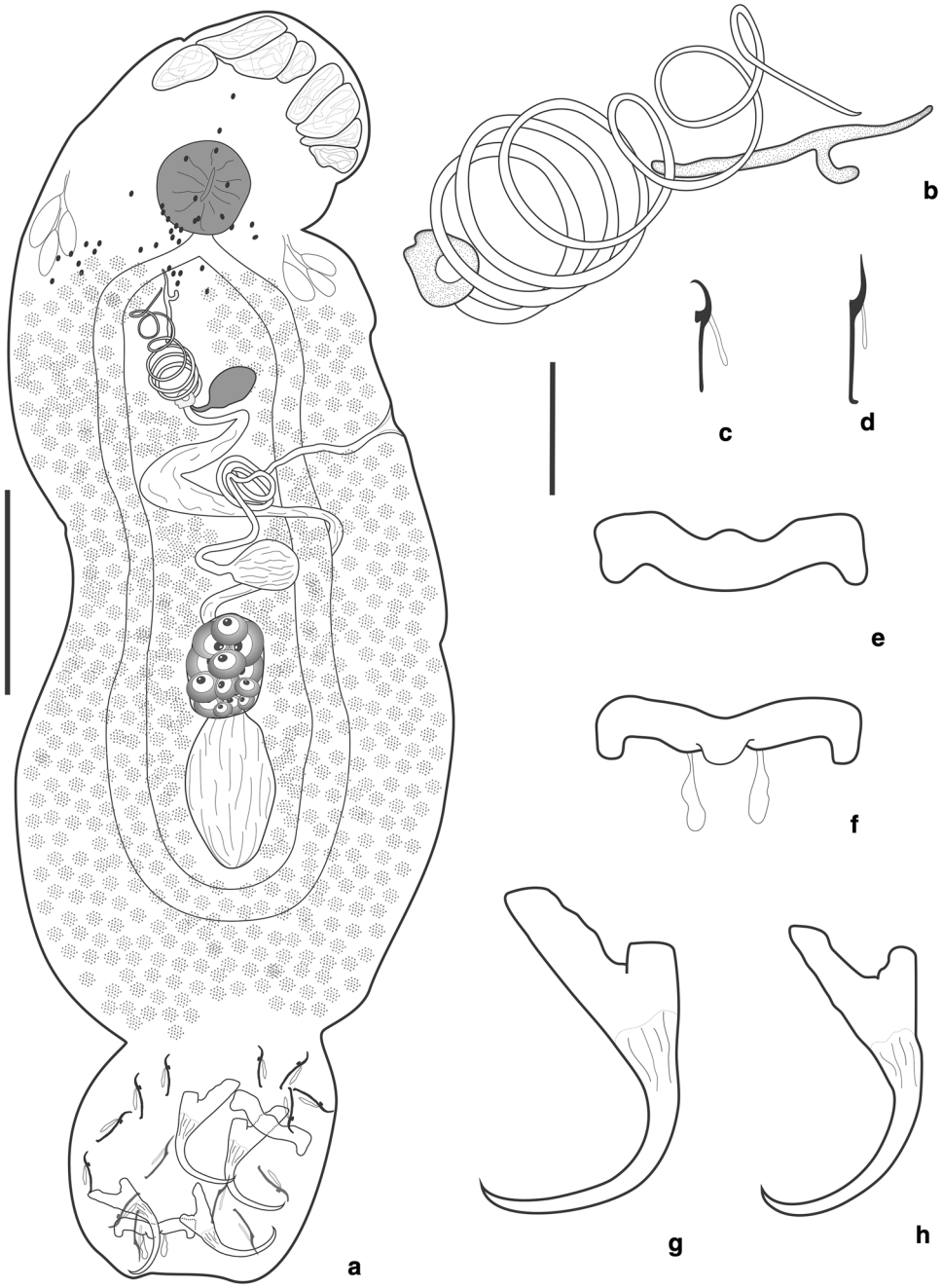

Fig. 4 *Cosmetocleithrum galeatum* sp. n. from the gills of *Trachelyopterus galeatus* (Linnaeus, 1766). **a** Whole mount in ventral view (composite); **b** Copulatory complex (ventral view); **c** Hooks pairs 1–4 and 6; **d** Hooks pairs 5 and 7; **e** Ventral bar; **f** Dorsal bar; **g** Ventral anchor; **h** Dorsal anchor. Scale bars: **a** = 100 µm; **b**–**h** = 20 µm

long, 157 (115–230, $n = 20$) wide near mid-length (Fig. 4a). Cephalic lobes poorly developed. Four pairs of head organs. Eye-spot absent, granules scattered in the cephalic region. Pharynx spherical 39 (24–57, $n = 11$) in diameter, esophagus inconspicuous. Two intestinal caeca confluent posterior to gonads, lacking diverticula. Gonads in tandem, germarium pre-testicular 21 ($n = 1$) long, 11 ($n = 1$) wide. Testis posterior to germarium 46 ($n = 1$) long, 25 ($n = 1$) wide; vas deferens looping left intestinal caecum. Seminal vesicle a dilation of vas deferens; seminal receptacle anterior to germarium, prostatic reservoir present. Copulatory complex (Fig. 4b) comprising MCO 396 (317–471, $n = 23$) long, with 6 counterclockwise rings, with irregularly sclerotized base; and a straight rod accessory piece 36 (25–46, $n = 19$) with hook-shaped distal portion, guarding termination of MCO, and non-articulated. Vagina a poorly sclerotised elongate tube opening on left margin of body. Peduncle short, broad; haptor sub-square 128 (87–173, $n = 13$) long, 110 (84–183, $n = 11$) wide, with 7 pairs of hooks with ancyrocephaline distribution. Ventral bar yoked-shaped (Fig. 4e): (g) 43 (33–49, $n = 20$); (h) 10 (8–13, $n = 20$); (i) 7 (5–11, $n = 20$). Dorsal bar yoked-shaped, with two submedial projections, and a

posteromedial protuberance (Fig. 4f): (g) 39 (30–46, $n=17$); (h) 10 (7–12, $n=16$); (i) 7 (4–9, $n=17$). Anchors similar, each with tapering superficial root, short deep root, short shaft with the presence of grooves, elongate point. Ventral anchor, with well-developed roots, superficial root elongate, short and straight shaft, elongated point with slightly curved tip (Fig. 4g): (a) 48 (42–55, $n=22$); (b) 40 (36–44, $n=22$); (c) 19 (14–22, $n=22$); (d) 5 (2–9, $n=22$); (e) 17 (13–20, $n=22$). Dorsal anchor, with well-developed roots, superficial root elongate, evenly curved shaft and short point with slightly curved tip (Fig. 4h): (a) 42 (38–46, $n=19$); (b) 35 (29–39, $n=19$); (c) 15 (12–19, $n=19$); (d) 5 (3–6, $n=19$); (e) 12 (9–16, $n=19$). Hooks different in size. Hooks pairs 1–4 and 6 (Fig. 4c) 17 (16–19, $n=50$) long, (smallest in length) with FH loop about 50% shank length, slender uniform shank, expanded tip, posteriorly directed thumb, straight shaft, and evenly curved point. Hooks pairs 5 and 7 (Fig. 4d) 21 (18–23, $n=25$) long, (largest in length) morphologically distinct from remaining hooks with FH loop about 30% shank length, erect shaft, erect delicate point, straight shank, and inconspicuous thumb. Oviduct, ootype, uterus, prostatic reservoir, and egg not observed. Vitelline follicles dense, dispersed throughout trunk but absent in the region of reproductive organs and MCO.

Remarks

Cosmetocleithrum galeatum sp. n. closely resembles *C. longivaginatum* by sharing similar morphology of the MCO with six counterclockwise rings, and the shape of the vaginal canal, but differs from this species in having a straight rod accessory piece with a hook-shaped distal portion (a straight rod accessory piece with bifid proximal portion). The morphology of accessory piece of the new species is most similar to *C. trachydorasi*, however, *Cosmetocleithrum galeatum* sp. n. can be distinguished from this species by presenting MCO with six counterclockwise rings (a single counterclockwise ring in *C. trachydorasi*). This species resembles *Cosmetocleithrum baculum* sp. n. in the general morphology of the bars. Also, *Cosmetocleithrum galeatum* sp. n. possesses hooks with different sizes and similar morphology to *Cosmetocleithrum spathulatum* sp. n., and *Cosmetocleithrum baculum* sp. n.

Discussion

Currently, studies on monogenean diversity from freshwater fishes in the neotropics have progressively increased [4]. This finding is promoting due to an increasing number of studies mainly focused on fishes from Amazon and Paraná basins in South America [18–20]. In particular, freshwater fishes of the order Siluriformes present 14 genera of dactylogirids in the Neotropical region [1–3]. According to Cohen *et al*. [10], *Demidospermus* Suriano, 1983 and *Cosmetocleithrum* are the most representatives genera. Mendoza-Palmero *et al*. [21] consider catfish as a suitable group of host for an extraordinarily rich and diverse fauna of gill monogeneans, that represents an interesting model for phylogenetic studies in Neotropical region.

Cosmetocleithrum spp. were originally described parasitizing gills of doradid hosts from the Amazon basin [5]. To date, the majority species of *Cosmetocleithrum* is restricted to hosts of this family [3, 5]. Other congeners were described from the gills of pimelodids and auchenipterids. *Cosmetocleithrum striatuli*, *C. laciniatum*, *C. berecae*, *C. nunani,* and the three new species here described also have been found parasitizing host of Auchenipteridae. *Cosmetocleithrum bulbocirrus* Kritsky, Thatcher and Boeger, 1986 is the only species that have been reported in fishes of three families (Doradidae, Auchenipteridae, and Erythrinidae) [3]. Nevertheless, Graça *et al*. [22] considered the infestation with *C. bulbocirrus* in *Hoplias* aff. *malabaricus* (Bloch, 1794) (Characiformes, Erythrinidae) as accidental due to low prevalence (1.8%) and intensity of infestation (one single monogenean per infected fish). Recently, *C. rarum* and *C. longivaginatum* were reported by Yamada *et al*. [23] in *T. galeatus*. However, these species were reviewed in this study and correctly described as *Cosmetocleithrum baculum* sp. n. and *Cosmetocleithrum galeatum* sp. n., respectively.

Previously, Suriano and Incorvaia [6] reported the presence of hooks with similar morphology and a different size in *C. longivaginatum* from *Pimelodus albicans* Valenciennes, 1840 in Argentina. Afterward, Mendoza-Franco *et al.* [24] and Cohen *et al*. [10] pointed out differences in size and morphology of hooks in *C. bifurcum*, *C. tortum*, and *C. nunani*, respectively. In the present study, the three new species recovered from *T. galeatus* also showed these differences on hooks (Table 2). So, based on the fact that the original description of the genus by Kritisky *et al*. [5] did not mention hooks with different size and morphology, we propose these differences as an emended morphological diagnosis.

Cohen *et al*. [10] comparing *Cosmetocleithrum gussevi* Kritsky, Thatcher and Boeger, 1986 (type species of *Cosmetocleithrum*) and *Paracosmetocleithrum trachydorasi*, highlighted their similarity and, in this way, proposing a new combination to *P. trachydorasi* as *C. trachydorasi*. Also, these authors distinguished two groups among *Cosmetocleithrum* species according to bars and accessory piece morphologies: the first group comprises species with non-articulated bars and accessory piece distally bifid, and the second species with articulated bars with accessory piece variably. *Cosmetocleithrum spathulatum* sp. n., and *Cosmetocleithrum galeatum* sp. n. closely resembles

Table 2 Comparative measurements (μm) of the three new species of *Cosmetocleithrum* Kritsky, Thatcher and Boeger, 1986 from the gills of *Trachelyopterus galeatus* (Linnaeus, 1766) from the mouth of Aguapeí River, Upper Paraná River basin, São Paulo State, Brazil

Sclerotized structure	*Cosmetocleithrum spathulatum* sp. n	*Cosmetocleithrum baculum* sp. n	*Cosmetocleithrum galeatum* sp. n
MCO (length)	56 (50–64, $n=17$)	126 (111–143, $n=17$)	396 (317–471, $n=23$)
Accessory piece (length)	22 (18–27, $n=18$)	35 (24–46, $n=16$)	36 (25–46, $n=19$)
Ventral bar (g)	28 (22–34, $n=20$)	45 (39–50, $n=12$)	43 (33–49, $n=20$)
Dorsal bar (g)	27 (21–33, $n=19$)	48 (41–53, $n=12$)	39 (30–46, $n=17$)
Ventral anchor (a)	27 (25–29, $n=19$)	50 (47–53, $n=14$)	48 (42–55, $n=22$)
Dorsal anchor (a)	25 (24–27, $n=20$)	44 (40–52, $n=14$)	42 (38–46, $n=19$)
Hooks pairs 1–4 and 6 (length)	15 (14–16, $n=22$)	20 (18–25, $n=66$)	17 (16–19, $n=50$)
Hooks pairs 5 and 7 (length)	16 (16–17, $n=8$)	26 (24–26, $n=28$)	21 (18–23, $n=25$)

Measurements (a) and (g) according to Gussev [14]

members of the first group, however, *Cosmetocleithrum baculum* sp. n. possess non-articulated bars and a non-bifid accessory piece.

Conclusions

Considering the 3 new species here described, to date 21 species of *Cosmetocleithrum* are recognised parasitizing siluriforms in the Neotropical region. Notwithstanding, the number of known *taxa* of monogeneans in neotropics is far from representing the ideal situation. Future studies describing new *taxa* should be encouraged to understanding the evolutionary relationship in the parasite-host system.

Acknowledgements We are so grateful to the São Paulo Energy Company (CESP) for the facilities offered for the development of this work.

Author Contributions POFY concept of the manuscript, data collection, collection, and preservation of the material, identified the parasites species, performing morphometrical analysis and wrote the manuscript; FHY identified the species, performing morphometrical analysis and editing the manuscript; and RJS concept of the manuscript, data collection, identified the parasites species and editing the manuscript.

Funding The authors thank the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for the scholarship granted to P.O.F.Y. #2013/25786-7 and F.H.Y. #2011/22603-3; 2014/14298-4. R.J.S. is supported by CNPq-PROTAX #440496/2015-2; FAPESP #2016/50377-1; and CNPq #309125/2017-0.

Data Availability The datasets of the present study are available from the corresponding author.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

References

1. Braga MP, Araújo SBL, Boeger W (2014) Patterns of interaction between Neotropical freshwater fishes and their gill Monogenoidea (Platyhelminthes). Parasitol Res 113:481–490. https://doi.org/10.1007/s00436-013-3677-8
2. Acosta AA, Scholz T, Blasco-Costa I, Alves PV, Silva RJ (2018) A new genus and two new species of dactylogyrid monogeneans from gills of Neotropical catfishes (Siluriformes: Doradidae and Loricariidae). Parasitol Int 67:4–12. https://doi.org/10.1016/j.parint.2017.09.012
3. Soares GB, Neto JFS, Domingues MV (2018) Dactylogyrids (Platyhelminthes: Monogenoidea) from the gills of *Hassar gabiru* and *Hassar orestis* (Siluriformes: Doradidae) from the Xingu Basin, Brazil. Zool 35:1–16. https://doi.org/10.3897/zoologia.35.e23917
4. Cohen SC, Kohn A, Justo MCN (2013) South American Monogenoidea parasites of fishes, amphibian and reptiles. Oficina de Livros, Rio de Janeiro, p 663
5. Kritsky DC, Thatcher VE, Boeger WA (1986) Neotropical Monogenea. 8. Revision of *Urocleidoides* (Dactylogyridae, Ancyrocephalinae). ProcHelmintholSoc Wash 53:1–37
6. Suriano DM, Incorvaia IS (1995) Ancyrocephalid (Monogenea) parasites from siluriform fishes from the Paranean-Plateanichthyogeographical province in Argentina. Acta Parasitol 40:113–124
7. Abdallah VD, Azevedo RK, Luque LF (2012) Three new species of Monogenea (Platyhelminthes) parasites of fish in the Guandu river, southeastern Brazil. Acta Sci Biol Sci 34:483–490. https://doi.org/10.4025/actascibiolsci.v34i4.10466
8. Yamada POF, Yamada FH, Silva RJ, Anjos LAS (2017) A New Species of *Cosmetocleithrum* (Monogenea, Dactylogyridae), a gill parasite of *Trachelyopterus galeatus* (Siluriformes, Auchenipteridae) from Brazil, with notes on the morphology of *Cosmetocleithrum striatuli*. Comp Parasitol 84:119–123. https://doi.org/10.1654/1525-2647-84.2.119
9. Morey GAM, Cachique JCZ, Babilonia JJS (2019) *Cosmetocleithrum gigas* sp. n. (Monogenoidea: Dactylogyridae) from the gills of *Oxidoras niger* (Siluriformes: Doradidae) from the Peruvian Amazon. Biologia 74:1–4. https://doi.org/10.2478/s11756-019-00331-x
10. Cohen SC, Justo MCN, Gen DVS, Boeger WA (2020) Dactylogyridae (Monogenoidea, Polyonchoinea) from the gills of *Auchenipterus nuchalis* (Siluriformes, Auchenipteridae) from the Tocantins River, Brazil. Parasite 27:1–12. https://doi.org/10.1051/parasite/2020002

11. Acosta AA, Smita NJ, Silva RJ (2020) Diversity of helminth parasites of eight siluriform fishes from the Aguapeí River, upper Paraná basin, São Paulo state, Brazil. IJP Parasites Wildl 11:120–128. https://doi.org/10.1016/j.ijppaw.2020.01.003
12. Graça WJ, Pavanelli CS (2007) Peixes da planície de inundação do Alto rio Paraná e áreas adjacentes. Eduem, Maringá
13. Ergens R (1969) The suitability of ammonium picrate-glycerin in preparing slides of lower Monogenoidea. Folia Parasit 16:320
14. Gussev AV (1985) Monogenea. In: Bauer ON (ed) Key to parasites of the freshwater fish fauna of the USSR, 2nd edn. Nauka Publications, USSR, pp 87–99
15. Řehulková E, Mendlová M, Šimková A (2013) Two new species of *Cichlidogyrus* (Monogenea: Dactylogyridae) parasitizing the gills of African cichlid fishes (Perciformes) from Senegal: morphometric and molecular characterization. Parasitol Res 112:1399–1410. https://doi.org/10.1007/s00436-013-3291-9
16. Mizelle JD (1936) New species of trematodes from the gills of Illinois fishes. Am Midl Nat 17:785–806
17. Bush AO, Lafferty KD, Lotz JM, Shostak AW (1997) Parasitology meets ecology on its own terms: Margolis revisited. J Parasitol 83:575–583
18. Thatcher VE (2006) Amazon fish parasites, 2nd edn. Pensoft Publishers, Sofia-Moscow, p 508
19. Takemoto RM, Pavanelli GC, Lizama MAP, Lacerda ACF, Yamada FH, Moreira LHA, Ceschini TL, Bellay S (2009) Diversity of parasites of fish from the Upper Paraná River floodplain, Brazil. Braz J Biol 69:691–705. https://doi.org/10.1590/S1519-69842009000300023
20. Eiras JC, Takemoto RM, Pavanelli GC, Adriano EA (2011) About the biodiversity of parasites of freshwater fish from Brazil. Bull EurAssoc Fish Pathol 31:161–168
21. Mendoza-Palmero CA, Scholz T, Mendoza-Franco EF, Kuchta R (2012) New species and geographical records of dactylogyrids (Monogenea) of catfish (Siluriformes) from the Peruvian Amazonia. J Parasitol 98:484–497. https://doi.org/10.1645/GE-2941.1
22 Graça RJ, Ueda BH, Oda FH, Takemoto RM (2013) Monogenea (Platyhelminthes) parasites from the gills of *Hoplias* aff. *malabaricus*(Bloch, 1794) (Pisces: Erythrinidae) in the Upper Paraná River Floodplain, States of Paraná and Mato Grosso do Sul, Brazil. Check List 9:1484–1487. https://doi.org/10.15560/9.6.1484
23. Yamada POF, Yamada FH, Silva RJ, Anjos LA (2017) Ecological implications of floods on the parasite communities of two freshwater catfishes in a Neotropical floodplain. Acta Parasitol 62:312–318. https://doi.org/10.1515/ap-2017-0039
24. Mendoza-Franco EF, Mendoza-Palmero CA, Scholz T (2016) New species of *Ameloblastella* Kritsky, Mendoza-Franco and Scholz, 2000 and *Cosmetocleithrum* Kritsky, Thatcher and Boeger, 1986 (Monogenea: Dactylogyridae) infecting the gills of catfishes (Siluriformes) from the Peruvian Amazonia. SystParasitol 93:847–862. https://doi.org/10.1007/s11230-016-9671-7