Zootaxa 4803 (3): 463–482
https://www.mapress.com/j/zt/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

https://doi.org/10.11646/zootaxa.4803.3.3
http://zoobank.org/urn:lsid:zoobank.org:pub:45FB73BA-DF09-4603-AC61-0C1BDA825833

Two *Gamispatulus* Thatcher & Boger, 1984 (Cyclopoida: Ergasilidae) from *Schizodon intermedius* Garavello & Britski (Actinopterygii: Anostomidae), with description of a new species

RODRIGO B. NARCISO[1,2] & REINALDO JOSÉ DA SILVA[1]
[1]*São Paulo State University (Unesp), Institute of Biosciences, Botucatu, Brazil*
rodrigoparasitologia@gmail.com; https://orcid.org/0000-0002-8295-4742
reinaldo.silva@unesp.br; https://orcid.org/0000-0002-3426-6873
[2]*Corresponding author*

Abstract

A parasitological survey of fishes from two tributaries (Veados and Paranapananema Rivers) of the Jurumirim Reservoir, Upper Paranapanema River, São Paulo State, Brazil, was carried out a during a sampling survey in 2011 and 2012. Several ectoparasitic copepods were found inside the nostrils of the freshwater anostomid fish, *Schizodon intermedius* Garavello & Britski, 1990. The morphological analysis of the copepod specimens indicated that they represent two species of the ergasilid genus *Gamispatulus* Thatcher & Boeger, 1984: *Gamispatulus schizodontis* Thatcher & Boeger, 1984 (type species) and an undescribed species, *Gamispatulus ferrilongus* **n. sp.**, which are described herein. The present specimens of *G. schizodontis* agree in several respects with its original description; however, some differences were found regarding the morphology of mouthparts and the ornamentation of legs and antennules. These differences were not sufficient to propose a new species for this genus. However, it could indicate the need for reassessment of the type material to have a more complete representation of this species. *Gamispatulus ferrilongus* **n. sp.** shares several similarities with its congener *G. schizodontis* but the new species can be readily distinguished from its congener in having a unique combination of diagnostic features including: a long rostral spine with tip extending up to half of cephalothorax, simple retrostylets (lacking adjacent spatulate processes), and dorsal surface of genital double-somite with 2 rounded processes (anterior and posterior) on both lateral margins. A host-parasite list for all vaigamid genera and species is included.

Keywords: Crustacea, Copepoda, freshwater, Jurumirim Reservoir, Neotropical region, Paranapanema River, taxonomy

Introduction

Species of Crustacea present wide-ranging morphological variation, being considered even higher than other mega-diverse groups such as insects (Martin & Davis 2001). This morphological diversity provides crustaceans to occur in a wide variety of habitats, ranging from pools of glacial meltwaters to hypersaline lakes (Boxshall & Defaye 2008), and exhibit different lifestyles, from planktonic to parasitic (Tavares-Dias *et al*. 2015). The parasitism arose independently several times in the evolutionary history of crustaceans which provided this group with different parasitic life strategies, including groups with a single parasitic phase, e. g. post-mated adult females in Ergasilidae, to other groups where only eggs leave their hosts' body, as in several species of Pentastomida (Williams & Bunkley-Williams 2019).

In freshwater, three groups of parasitic crustaceans, Branchiura, Copepoda, and Isopoda, stand out due to their importance and diversity (Tavares-Dias *et al*. 2015). These three groups represent a great part of the parasitic crustacean fauna, especially in the Neotropical region, and have great relevance due to the impact that some species have on natural and cultivated fish populations (Eiras *et al*. 2010; Pavanelli *et al*. 2013). Among fish diseases those caused by copepods of the family Ergasilidae stand out. These small copepods, especially in massive infections, can cause significant mortality of their fish hosts (Piasecki *et al*. 2004; Pavanelli *et al*. 2008).

Ergasilidae is one of the largest families of parasitic copepods of the order Cyclopoida. Currently, this family

Accepted by E. Suárez-Morales: 29 May 2020; published: 29 Jun. 2020

comprises about 262 species in 30 valid genera (Narciso *et al*. 2019), which include representatives in all continents except the Antarctic (Boxshall & Defaye 2008). In Brazil, Ergasilidae represents the largest family of parasitic crustaceans with about 60 species from 17 genera (Luque *et al*. 2013; Marques *et al*. 2015).

Most ergasilids are found attached to the gills of their fish hosts, but some species are also found in nostrils. Currently, eight ergasilid genera have one or more species that parasitize the fish nostrils in Brazil: *Brasergasilus* Thatcher & Boeger, 1983; *Ergasilus* von Nordmann, 1832; *Gamidactylus* Thatcher & Boeger, 1984; *Gamispatulus* Thatcher & Boeger, 1984; *Gamispinus* Thatcher & Boeger, 1984; *Rhinergasilus* Boeger & Thatcher, 1984; *Therodamas* Krøyer, 1863; and *Vaigamus* Thatcher & Robertson, 1984 (Varella *et al*. 2019). *Gamidactylus*, *Gamispatulus*, *Gamispinus*, *Vaigamus*, together with *Pseudovaigamus* Amado, Ho & Rocha, 1995, compose the closely related subgroup within the Ergasilidae known as "vaigamids". Species from this subgroup are among the most commonly recorded species from fish nostrils in Brazil, and are characterized by the following diagnostic features: rostrum with rostral spine, antenna armed with 2 claws (middle and inner claw), and cephalothorax armed with a pair of dorsolateral stylets (retrostylets) (Amado *et al*. 1995). Except for *Gamidactylus*, all other vaigamid genera are still monotypic.

During a parasitological survey of fishes from two tributaries (Veados and Paranapanema Rivers) of the Jurumirim Reservoir, Upper Paranapanema River, São Paulo State, Brazil, we detected several ectoparasitic ergasilids parasitizing the nostrils of the anastomid teleost *Schizodon intermedius* Garavello & Britski, 1990. A morphological analysis of these specimens indicated that they represent two ergasilid species, *Gamidactylus schizodontis* Thatcher & Boeger, 1984, whose description is expanded, and an undescribed species, *Gamispatulus ferrilongus* **n. sp.**, which is herein described based on female specimens.

Material and Methods

Specimens of *S. intermedius* were collected during a sampling survey in 2011 and 2012 from two tributaries of the Jurumirim Reservoir, as follow: (1) Paranapenema River, Jurumirim Reservoir (23°29'16.54" S, 48°37'12.88" W), municipality of Angatuba, São Paulo State, Brazil; and (2) Veados River, Jurumirim Reservoir (23°16'2.49" S, 48°38'15.72" W), municipality of Itatinga, São Paulo State, Brazil. Fish collections were authorized by the Department of Fisheries Development and Inspection (license #SP/538/88), and all procedures followed the recommendations of the Ethical Commission for Animal Experimentation from the São Paulo State University (Unesp), Institute of Biosciences, Botucatu, Brazil (protocol #120-CEEA). Fish were collected using multi-panel gill nets (3-14 cm mesh) soaked for 14 h. Each specimen was individually stored in plastic bags and placed in a freezer before necropsy. The nostrils and branchial arches of each fish were sectioned and then flushed with distilled water. Wash contents were collected in Petri dishes and examined for copepods using a stereomicroscope. Copepod found were stored in 70% ethanol, cleared in lactic acid, and then mounted in Hoyer's medium. Whenever necessary, some specimens were dissected in glycerol medium and then each part was mounted on individual slides. Coverslips were sealed with transparent nail varnish.

TABLE 1. Abbreviations of body parts and segments used throughout the text to describe copepods.

Abbreviation	Meaning
Ae	asthetascs
AS-1 (2, 3)	To indicate the first (second, third) abdominal somite
PS-1 (2–5)	To indicate the first (second to fifth) pedigerous somite
P1 (2–5)	To indicate the first (second to fifth) leg
enp	Endopod
exp	Exopod
enp-1 (2, 3)	To indicate the first (second, third) endopodal segment
exp-1 (2, 3)	To indicate the first (second, third) exopodal segment

Morphological analyses and measurements of whole/dissected copepods were made using a microscope with differential interference contrast optics (Leica DMLB 5000, Leica Microsystems). Drawings were made with aid of

a microscope (LeicaDMLS, Leica Microsystems, Wetzlar, Germany) equipped with a drawing tube. All measurements are in micrometres (μm) and presented as the range followed by the mean in parenthesis. Morphological nomenclature followed Boxshall & Montú (1997) and Boxshall & Halsey (2004), also used to identify copepod specimens to family and genus level. Abbreviations used throughout the description text to refer the structures and segments described are shown in Table 1. The nomenclature used for the antennary segmentation assumed that: the ergasilid antenna is 4-segmented (comprising coxobasis and three endopodal segments) and the claw is an armature element derived from the third endopodal segment (El-Rashidy & Boxshall 1999). Ecological descriptors such as prevalence, mean abundance, and intensity were calculated following Bush *et al*. (1997).

Type specimens (holotype and paratypes) were deposited in the Invertebrate Collection of the Instituto Nacional de Pesquisas da Amazônia (INPA), municipality of Manaus, Amazonas State, Brazil.

Taxonomy

Order Cyclopoida Burmeister, 1834

Family Ergasilidae Burmeister, 1835

Genus *Gamispatulus* Thatcher & Boeger, 1984

Gamispatulus schizodontis Thatcher & Boeger, 1984

(Figs. 1–4)

Host. *Schizodon intermedius* Garavello & Britski, 1990 (Anostomidae)

Locality. Veados River, Jurumirim Reservoir, Upper Paranapanema River (23° 16′2.49″ S, 48° 38′15.72″ W), municipality of Itatinga, São Paulo State, Brazil.

Additional locality. Paranapenema River, Jurumirim Reservoir, Upper Paranapanema River (23° 29′16.54″ S, 48° 37′12.88″ W), municipality of Angatuba, São Paulo State, Brazil.

Site in host. Nostrils.

Specimens deposited. INPA 2526 to INPA 2529 (12 adult females) deposited in the Invertebrate Collection of the Instituto Nacional de Pesquisas da Amazônia (INPA), municipality of Manaus, Amazonas State, Brazil.

Prevalence and mean intensity in nostrils: 21 infect hosts in 28 analyzed fish (or 75%) and 17 ± 4,5 copepods per infected fish.

Prevalence and mean intensity on the gill filaments. None of the 28 analyzed fish.

Description of adult female. Based on 12 female specimens, no males observed. Body cyclopiform (Fig. 1A), comprising prosome, urosome, and caudal rami; prosome consisting of cephalosome and PS-1; PS-1 fused to cephalosome; and 3 free pedigerous somites (PS-2 to PS-4). Cephalothorax tapering anteriorly (Fig. 1A), maximum width at level of retrostylets tip (Table 2), dorsal eyespot, rostrum well-developed and protruded anteriorly, dorsal surface ornamented with bristles laterally, with paired dorsolateral stylets (= retrostylets) (Fig. 1B). Rostrum ornamented with paired bristles anteriorly, armed with rostral spine (Fig. 1D); rostral spine tapering posteriorly, extending up to one-third of cephalothorax length, with rounded tip (Fig. 1D). Retrostylets double (Fig. 1B) bearing medial spatulate processes, ornamented with bristles laterally; stylet curved, with acute tip; spatulate process rounded posteriorly. Free pedigerous somites decreasing gradually in width from anterior to posterior (Fig. 1A); PS-2 narrower than PS-1, with paired integumental windows laterally on tergite (Fig. 1C); PS-3 and PS-4, both lacking such integumental windows (Fig. 1A).

Urosome consisting of PS-5, genital double-somite, and 3 free abdominal somites (AS-1 to AS-3) (Fig. 2B); PS-5 (Fig. 2B) reduced, smaller and thinner than prosome somites, unornamented; genital double-somite (Fig. 2B), about 1.5 times wider than long, bearing paired slit-like genital apertures dorsally, ventral surface with paired pores near anterior margin and ornamented with spinules laterally; abdominal somites decreasing in width from anterior to posterior, each somite ornamented with spinules laterally (Fig. 2B); AS-3 (= anal somite) deeply incised posteriorly (= anus).

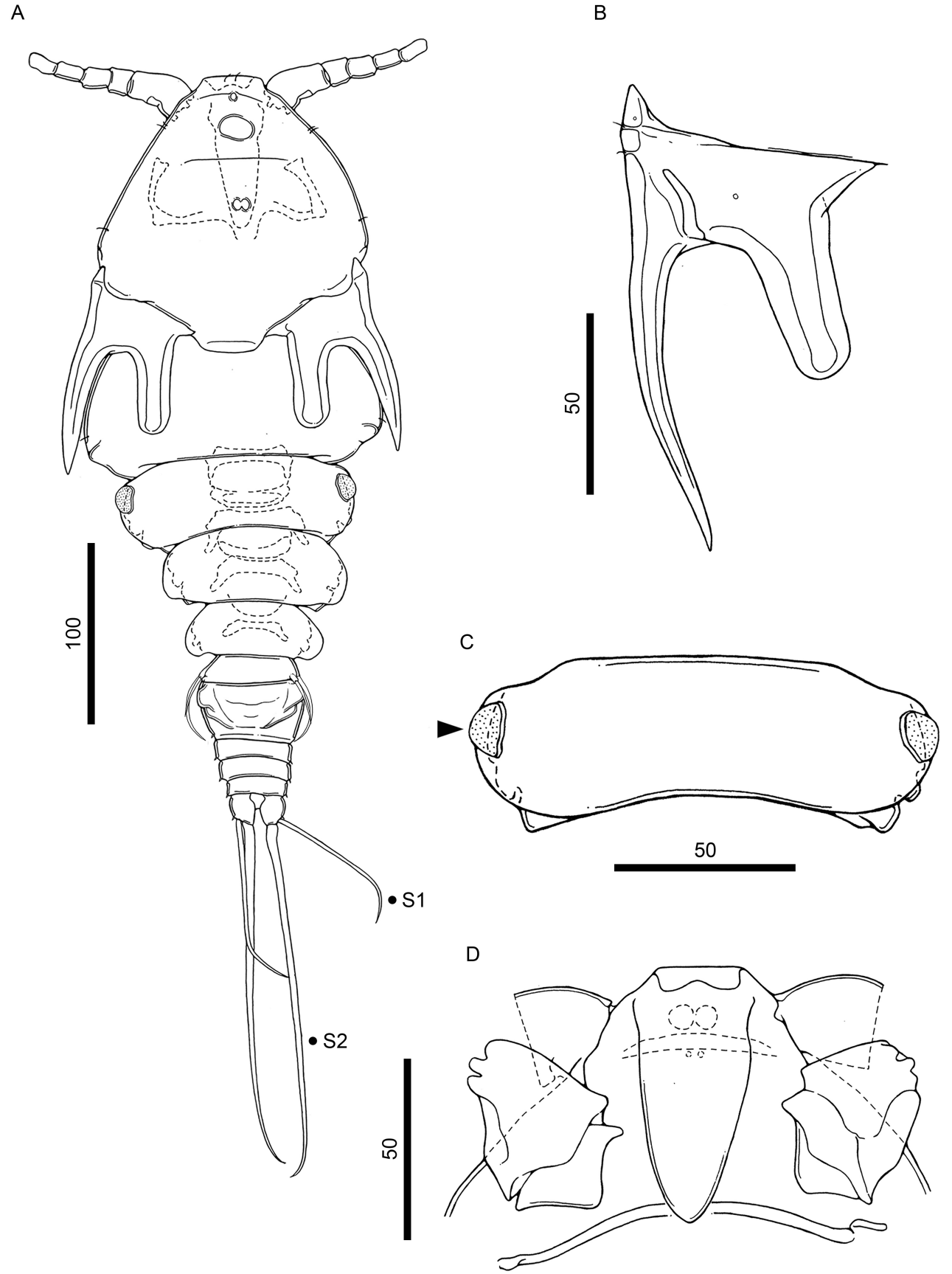

FIGURE 1. *Gamispatulus schizodontis* Thatcher & Boeger, 1984—adult female. **A** body, ventral view. **B** retrostylets, dorsal view. **C** second pedigerous somite, dorsal view, with paired integumental windows laterally on tergite (arrowhead). **D** rostral spine, ventral view. A, C—Specimen INPA 2527a. B—Specimen INPA 2527b. D—Specimen INPA 2528a. Scale bars in μm.

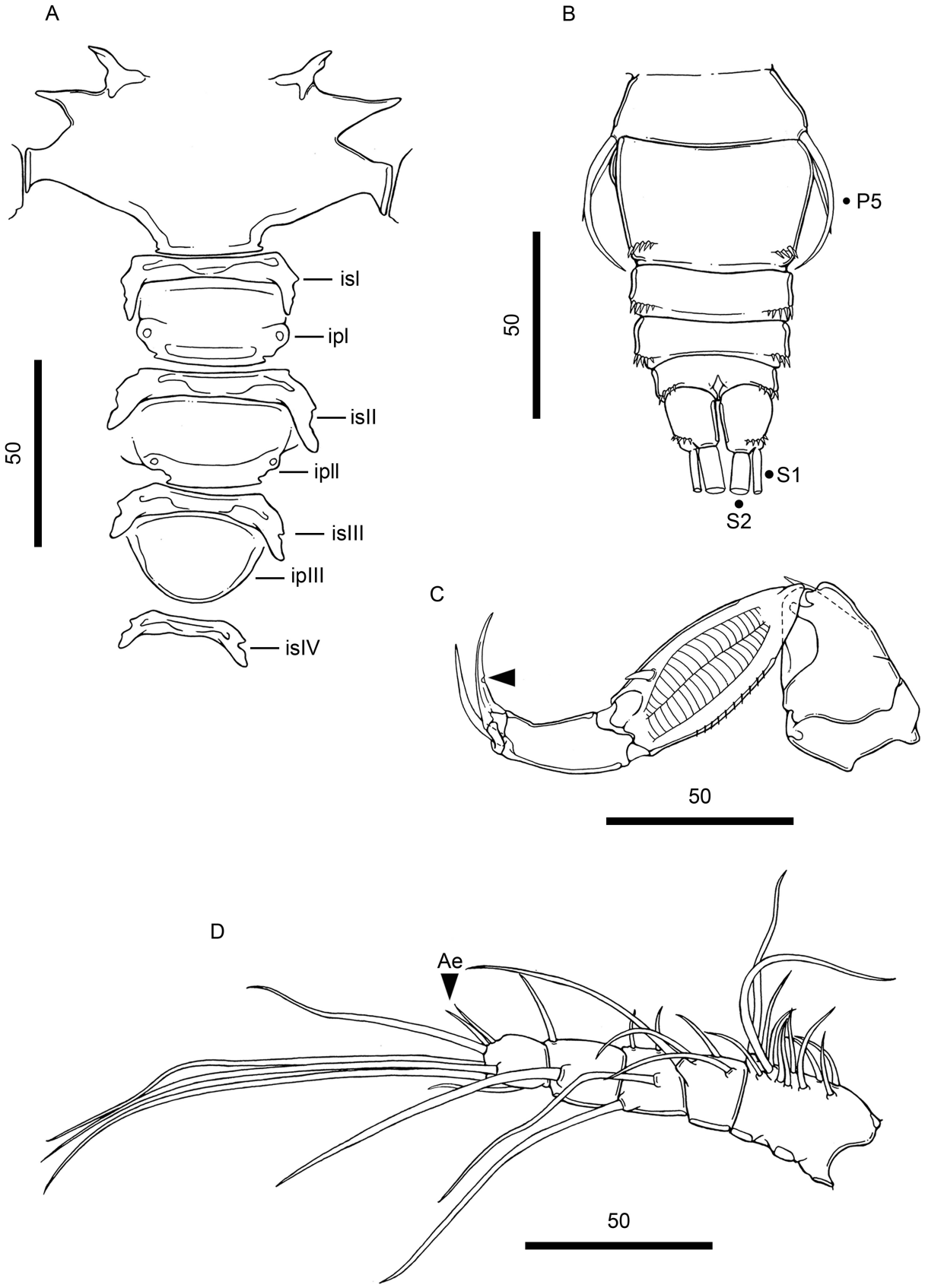

FIGURE 2. *Gamispatulus schizodontis* Thatcher & Boeger, 1984—adult female. **A** intercoxal sclerites and intercoxal plates, ventral view. **B** urosome, ventral view. **C** antenna, middle claw with fossa on concave margin (arrowhead). **D** antennule. Ae = aesthetascs. isI to isIV = first to fourth intercoxal sclerites. ipI to ipIII = first to third intercoxal plates. P5 = fifth leg. S1 = seta 1. S2 = seta 2. A, B, C—Specimen INPA 2527a. D—Specimen INPA 2529a. Scale bars in micrometers (μm).

Caudal rami (Fig. 2B), about 1.2 times longer than wide; each ramus ornamented with spinules on ventral surface and armed with 2 naked setae: seta 2 about 2 times longer than seta 1 (Table 2).

TABLE 2. Measurements in micrometers (μm) of adult females of *Gamispatulus schizodontis* Thatcher & Boeger, 1984 and *Gamispatulus ferrilongus* **n. sp.** SE = standard error.

	Gamispatulus schizodontis Thatcher & Boeger, 1984 (**present specimens**)	*Gamispatulus ferrilongus* **n. sp.**
Character	**Range (Mean)**	**Range (Mean)**
Total length [a]	417–535 (474)	451–677 (593)
Cephalothorax length	222–252 (238)	277–415 (317)
Cephalothorax width	165–205 (181)	215–284 (249)
Rostral spine length	62–82 (76)	170–186 (178)
Retrostylet length	108–141 (124)	142–171 (154)
Spatulate process length	34–51 (45)	-
Antennule length	95–117 (106)	114–126 (121)
Antenna segment 1 length	38–61 (49)	66–88 (80)
Antenna segment 2 length	66–78 (71)	84–96 (91)
Antenna segment 3 length	34–41 (38)	47–59 (53)
Antenna segment 4 length	7–10 (8)	9–13 (11)
Middle claw length	29–41 (36)	35–42 (39)
Inner claw length	25–35 (31)	26–39 (33)
Pedigerous somite 2 length	45–65 (55)	63–79 (73)
Pedigerous somite 2 width	131–163 (149)	166–186 (176)
Pedigerous somite 3 length	45–57 (48)	51-81 (64)
Pedigerous somite 3 width	102–119 (110)	121-140 (131)
Pedigerous somite 4 length	29–38 (33)	37–58 (46)
Pedigerous somite 4 width	71–83 (79)	87–101 (92)
Pedigerous somite 5 length	15–24 (19)	18–26 (22)
Pedigerous somite 5 width	56–72 (63)	59–88 (78)
Genital double-somite length	31–40 (34)	43–60 (52)
Genital double-somite width	53–71 (62)	79–94 (87)
Abdominal somite 1 length	12–16 (14)	15–21 (18)
Abdominal somite 1 width	39–52 (45)	51–65 (60)
Abdominal somite 2 length	12–18 (15)	15–22 (19)
Abdominal somite 2 width	37–50 (43)	47–60 (56)
Abdominal somite 3 length	10–15 (12)	14–18 (16)
Abdominal somite 3 width	35–46 (40)	42–56 (50)
Caudal ramus length	18–24 (22)	21–33 (28)
Caudal ramus width	14–22 (17)	17–25 (20)
Caudal ramus seta 1 length	84–136 (106)	15–25 (19)
Caudal ramus seta 2 length	177–277 (242)	102–119 (110)
Caudal ramus seta 3 length	-	17–22 (20)
Caudal ramus seta 4 length	-	203–246 (230)
Egg sac length	204–441 (333)	452–855 (538)
Egg sac width	75–86 (80)	74–118 (92)

[a] less caudal rami setae

Antennule 5-segmented (Fig. 2D), setal formula: 12, 4, 4, 2, 5 + 2 ae (total 29). Antenna (Fig. 2C) 4-segmented comprising coxobasis, and 3-segmented enp; coxobasis (= first segment) broad, with short naked seta; enp-1 (= second segment) ornamented with spinule row along outer margin and large spine near middle of inner margin; enp-2 (= third segment) slightly curved, unornamented; enp-3 (= fourth segment) reduced, unornamented; and 2 terminal claws (= inner and middle claw); middle claw curved, with fossa on concave margin (arrowed in Fig. 2C); inner claw needle-shaped, thinner than middle claw, without fossa.

Buccal apparatus (Fig. 3A) comprising labrum, mandible, and maxilla; labrum broad, rounded posteriorly, partially covering other buccal components (Fig. 3B); mandible armed with 2 blades (anterior and posterior blade); both blades ornamented with spinules along posterior margin; maxilla 2-segmented, comprising syncoxa (= first segment) and basis (= second segment); syncoxa broad, with distal pore (arrowed in Fig. 3D); basis with multiples spinules.

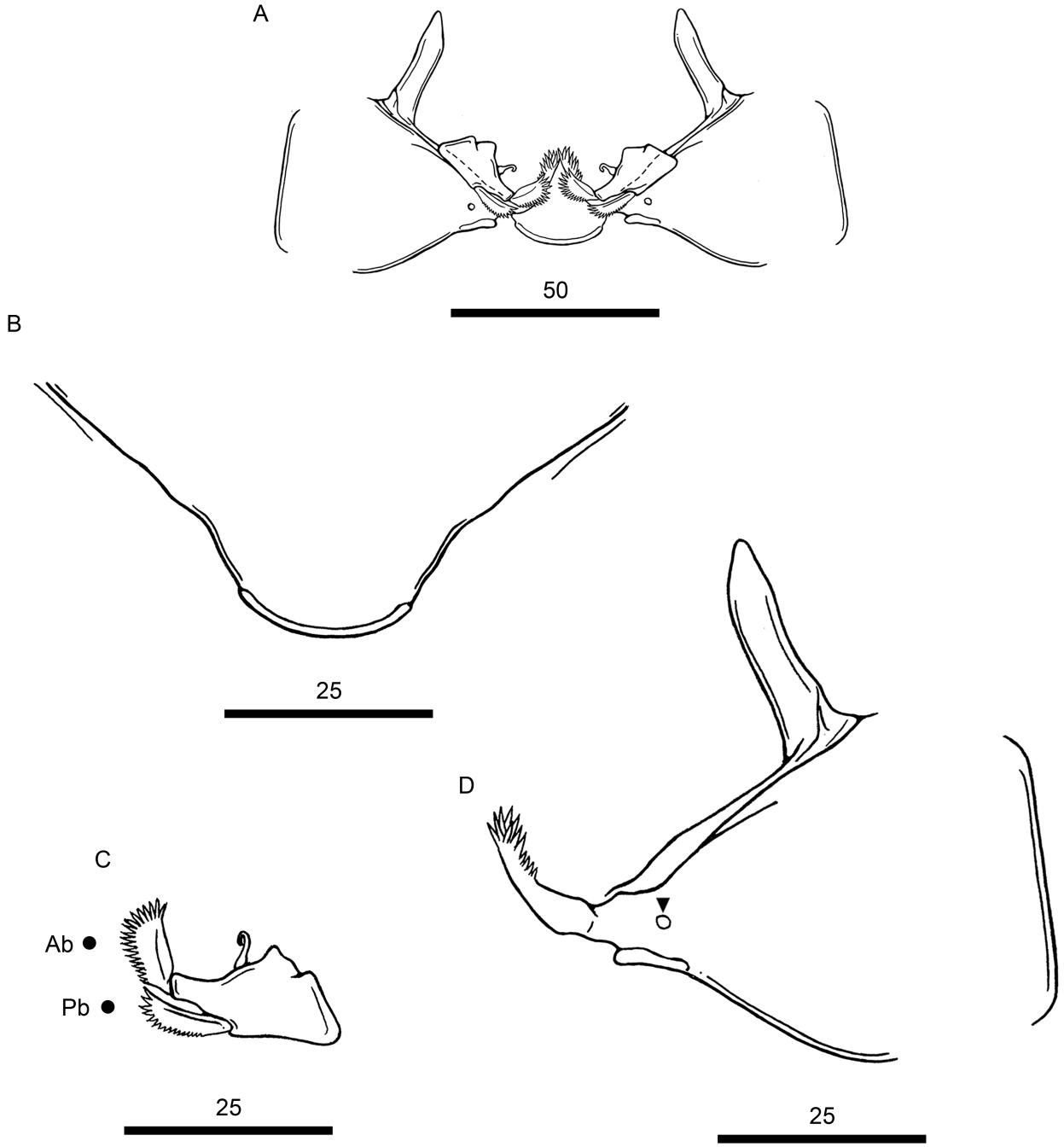

FIGURE 3. *Gamispatulus schizodontis* Thatcher & Boeger, 1984—adult female. **A** buccal apparatus. **B** labrum. **C** mandible. **D** maxilla, syncoxa with pore (arrowhead). Ab = anterior blade. Pb = posterior blade. A, C, D, E—Specimen INPA 2529b. Scale bars in micrometers (μm).

P1 to P4 biramous (Figs. 4A-C); each leg comprising coxa, basis, endopod (inner ramus) and exopod (outer ramus). P1 (Fig. 4A); coxa unornamented; basis with bare outer seta; enp 2-segmented, both segments ornamented with spinules and bristles on outer margin and lacking any ornament on inner margin; enp-1 (= proximal segment) armed with 1 plumose seta on inner margin; enp-2 (= distal segment) about 2 times longer than previous segment, armed with 2 serrated spines and 5 plumose setae; exp 3-segmented; exp-1 (= proximal segment) about 1.5 times longer than following segments, ornamented with spinules along outer margin and bristles on inner margin, armed with 2 unequal spines (= anterior and posterior spine) on outer margin; anterior spine short and triangular; posterior spine longer and thinner than previous spine, slightly curved; exp-2 (= middle segment) ornamented with two spinule rows on outer margin and lacking any ornament on inner margin; outermost spinules broad, scale-shaped; innermost spinules thinner and sharper than outermost spinules; armed with 1 plumose setae on inner margin; exp-3 (= distal segment) lacking any ornament on both margins, armed with 2 simple spines (not serrated) and 5 plumose setae.

P2 (Fig. 4B); coxa ornamented with 2 robust spinules; basis with bare outer seta; enp 3-segmented, all segments with spinules and bristles on outer margin and lacking any ornament on inner margin; enp-1 (= proximal segment) armed with 1 plumose setae on inner margin; enp-2 (= middle segment) armed with 2 plumose setae on inner margin; enp-3 (= distal segment) slightly smaller than previous segments, rounded, armed with 1 simple spine (not serrated) and 4 plumose setae; exp 3-segmented; exp-1 (= proximal segment) about 1.5 times longer than following segments, ornamented with 3 prominent spinules on outer margin and bristles on inner margin, armed with 1 simple spine (not serrated) on outer margin; exp-2 (= middle segment) ornamented with minute spinules on outer margin and lacking any ornamented on inner margin; spinules smaller than those present in exp-1; armed with 1 plumose seta on inner margin; exp-3 (= distal segment) ornamented with 2 set of minute spinules on outer margin, lacking any ornament on inner margin, armed with 6 plumose setae. P3 with same ornamentation and armament described for P2.

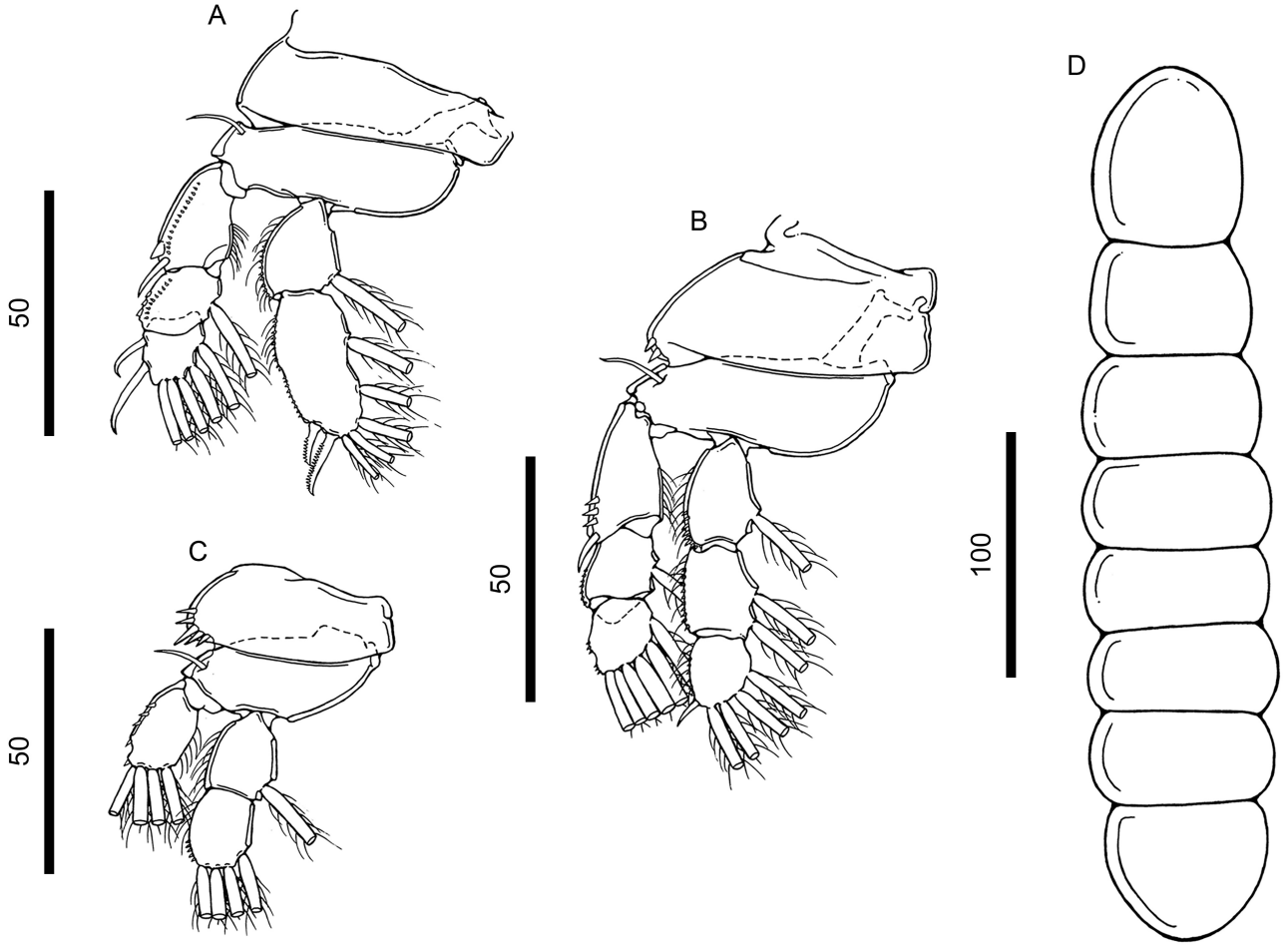

FIGURE 4. *Gamispatulus schizodontis* Thatcher & Boeger, 1984—adult female. **A** leg 1. **B** leg 2 (= leg 3). **C** leg 4. **D** egg sac. A, C, D—Specimen INPA 2527a. E—Specimen INPA 2526. Scale bars in micrometers (μm).

P4 (Fig. 4C); coxa ornamented with 5 robust spinules; basis with bare outer seta; enp 2-segmented; enp-1 (= proximal segment) with bristles along outer margin and lacking any ornament on inner margin, armed with 1 plumose seta on inner margin; enp-2 (= distal segment) ornamented with bristles (first half) and spines (second half) on outer margin, lacking any ornament on inner margin, armed with 4 plumose setae; exp 1-segmented; exopodal segment ornamented with prominent spinules on outer margin and bristles on inner margin; spinules slightly smaller than those present in P2 exp-1; armed with 2 minute spines and 4 plumose setae.

P5 reduced and represented by 2 naked setae (Fig. 2B). Spine and setal formula of biramous swimming legs is presented in Table 3.

TABLE 3. Armature of swimming legs of *Gamispatulus schizodontis* Thatcher & Boeger, 1984—adult female. (Roman numeral = spines; Arabic numerals = setae). P1-P4 = first to fifth swimming leg.

Swimming leg	Coxa	Basis	Endopod	Exopod
P1	0–0	1–0	0–1; II–5	II–0; 0–1; II–5
P2	II–0	1–0	0–1; 0–2; I–4	I–0; 0–1; 0–6
P3	II–0	1–0	0–1; 0–2; I–4	I–0; 0–1; 0–6
P4	V–0	1–0	0–1; 0–4	II–4

Intercoxal sclerites slender, unornamented, with both ends directed posteriorly (Fig. 2A). Intercoxal plates of P1 and P2 both with paired pores laterally; intercoxal plate of P4, absent (Fig. 2A). Egg sac paired (Fig. 4D), uniseriate.

Remarks. The examined specimens of *G. schizodontis* agree in several respects with its original description by Thatcher & Boeger (1988a). This species can be readily distinguished from all other ergasilids, including species of closely related genera like *Gamidactylus*, *Gamispinus*, *Pseudovaigamus*, and *Vaigamus* (also known as "vaigamids"), in having the following combination of diagnostic features: (1) rostrum armed with rostral spine; (2) antennule 5-segmented; (3) antenna armed with 2 terminal claws (middle and inner claw); (4) cephalothorax armed with dorsolateral retrostylets bearing medial spatulate processes; and (5) P4 with enp 2-segmented and exp 1-segmented. The presence of retrostylets is a diagnostic feature present in all vaigamids, but the possession of spatulate processes has been found to be exclusive to *G. schizodontis* (Thatcher & Boeger, 1984b).

The specimens examined show minor differences in relation to the original description, as follows: (1) third antennary segment (= enp-2) unornamented (vs. with spine on inner margin); (2) antennule setal formula: 12, 4, 4, 2, 5 + 2 ae (vs. 10, 3, 4, 2, 8); and (3) general morphology of buccal apparatus — e.g., mandible with anterior blade lacking distal tooth (present in the original description). During the study of the attachment strategies in Ergasilidae, El-Rashidy (1999) did not report the antennary ornamentation described by Thatcher & Boeger (1988), in paratypes of *G. schizodontis.* These differences are not deemed sufficient to propose a new species based on these variations; they indicate the need for reassessment of the type material to have a more complete and accurate representation of these structures in *G. schizodontis* The present specimens represent the first report of *G. schizodontis* from *S. intermedius* as well as its second report of *G. schizodontis* in Southeast Brazil.

Gamispatulus ferrilongus n. sp.

(ZooBank registration: urn:lsid:zoobank.org:act:CCB1F932-89B1-4494-B429-CC7D8CAD94AC)
(Figs 5–8)

Type host. *Schizodon intermedius* Garavello & Britski, 1990 (Anostomidae)

Type Locality. Veados River, Jurumirim Reservoir, Upper Paranapanema River (23° 16′2.49″ S, 48° 38′15.72″ W), municipality of Itatinga, São Paulo State, Brazil.

Additional locality. Paranapenema River, Jurumirim Reservoir, Upper Paranapanema River (23° 29′16.54″ S, 48° 37′12.88″ W), municipality of Angatuba, São Paulo State, Brazil.

Site in host. Nostrils.

Specimens deposited. Holotype INPA 2521 (adult female) and Paratypes INPA 2522 to INPA 2525 (7 adult females) deposited in the Invertebrate Collection of the Instituto Nacional de Pesquisas da Amazônia (INPA), municipality of Manaus, Amazonas State, Brazil.

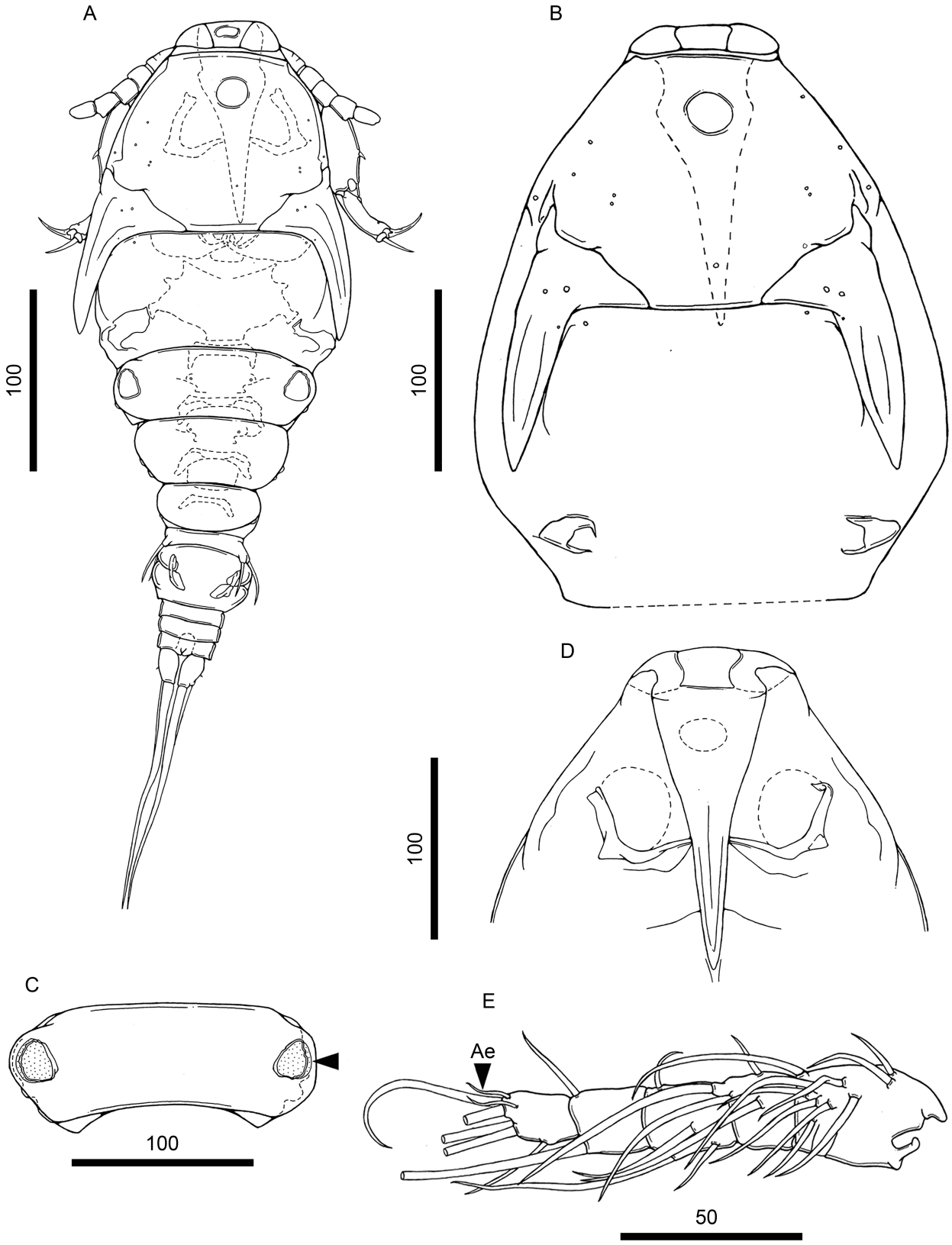

FIGURE 5. *Gamispatulus ferrilongus* **n. sp.**—adult female. **A** body, dorsal view. **B** cephalothorax, dorsal view. **C** second pedigerous somite, dorsal view, with paired integumental windows laterally on tergite (arrowhead). **D** rostral spine. **E** antennule. Ae = aesthetascs. A, C—holotype INPA 2521. B, D—paratype INPA 2522a. E—paratype INPA 2524a. Scale bars in micrometers (μm).

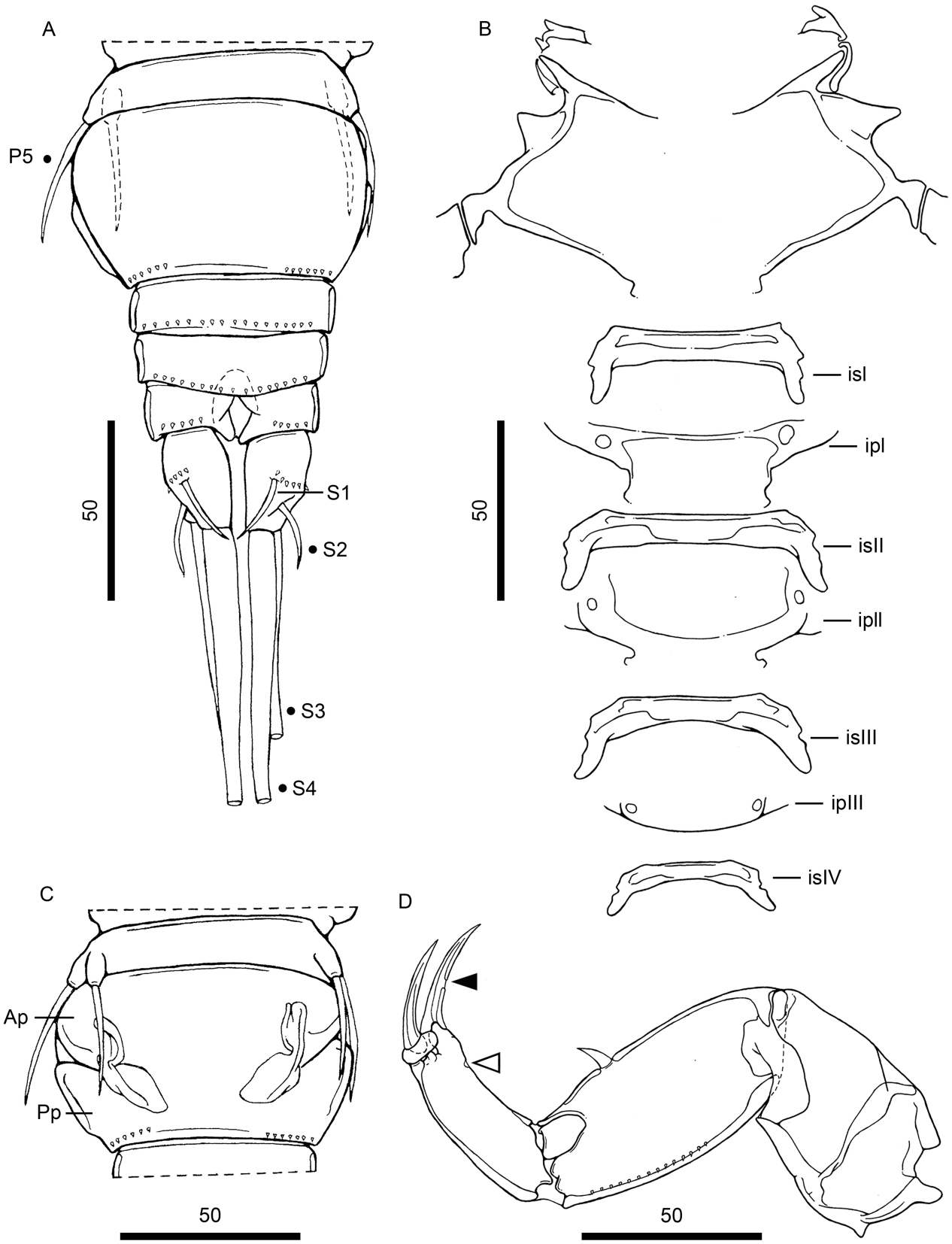

FIGURE 6. *Gamispatulus ferrilongus* **n. sp.**—adult female. **A** urosome, ventral view. **B** intercoxal sclerites and intercoxal plates. **C** fifth pedigerous somite and genital double-somite, dorsal view. **D** antenna, second endopodal segment with a distal pore (white arrowhead) and middle claw with fossa on concave margin (black arrowhead). Ap = anterior processes. isI to isIV = first to fourth intercoxal sclerites. ipI to ipIII = first to third intercoxal plates. P5 = fifth leg. Pp = posterior processes. S1 to S4 = seta 1 to seta 4. A, B, C, D—holotype INPA 2521. Scale bars in micrometers (μm).

Prevalence and mean intensity in nostrils. Seven infected hosts in 28 analyzed fish (or 25%) and 2 ± 0,4 copepods per infected fish.

Prevalence and mean intensity on the gill filaments. None of the 28 analyzed fish.

Etymology. The specific name results from the combination of two Latin words: *ferri* (= any iron tool or weapon, including a sword) and *longus* (= long), in reference to the shape and size of the rostral spine, resembling an ancient Roman sword.

Differential diagnosis. Rostrum well-developed, armed with long rostral spine; rostral spine with acute tip; tip extending up to half of cephalothorax. Retrostylets simple, without adjacent spatulate processes. Dorsal surface of the genital double-somite with 2 rounded processes (= anterior and posterior process) on both lateral margins.

Description of adult female. Based on 11 female specimens, no males observed. Body cyclopiform (Fig. 5A), comprising prosome, urosome, and caudal rami; prosome consisting of cephalosome and PS-1; PS-1 fused to cephalosome; and 3 free pedigerous somites (PS-2 to PS-4). Cephalothorax triangular (Fig. 5B), decreasing in width anteriorly, maximum width at level of retrostylets tip (Table 2), dorsal eyespot, rostrum well-developed and protruded anteriorly, dorsal surface with several pores; pores distributed in anterior half of cephalothorax; and armed with paired dorsolateral stylets (= retrostylets). Rostrum armed with ventral rostral spine; rostral spine long, extending up to half of cephalothorax, with sharp tip (Fig. 5D). Retrostylets simple (Fig. 5B), without adjacent spatulate processes; stylet process broad, with acute tip. Free pedigerous somites tapering posteriorly (Fig. 5A); PS-2 narrower than PS-1, with paired integumental windows laterally on tergite (Fig. 5C); PS-3 and PS-4, both lacking such integumental windows (Fig. 5A).

Urosome consisting of PS-5, genital double-somite, and 3 free abdominal somites (AS-1 to AS-3) (Fig. 6A); PS-5 (Figs. 6A, C) reduced, smaller and thinner than other prosome somites, unornamented; genital double-somite (Figs. 6A, C), 1.5 times wider than long, bearing paired slit-like genital apertures dorsally, ornamented with transverse row of spinules on ventral surface, dorsal surface with 2 rounded processes (= anterior and posterior process) on both lateral margins (Fig. 6C); abdominal somites decreasing in width from anterior to posterior, each somite ornamented with posterior spinule row along ventral margin (Fig. 6A); AS-3 (= anal somite) deeply incised posteriorly (= anus).

Caudal rami (Fig. 6A), about 1.5 times longer than wide; each ramus ornamented with paired spinule rows on ventral surface and armed with 4 setae, all naked: seta 1 and 3 shortest, both setae inserted on ventral surface; seta 2 and 4, both setae inserted on posterior margin; seta 4 longest.

Antennule 5-segmented (Fig. 5E), setal formula: 10, 4, 4, 2, 5 + 2 ae (total 27). Antenna (Fig. 6D) 4-segmented comprising coxobasis, and 3-segmented enp; coxobasis (= first segment) broad, unornamented; enp-1 (= second segment) ornamented with spinule row along outer margin and large spine near middle of inner margin; enp-2 (= third segment) slightly curved, with single pore on concave margin (arrowed in Fig. 26D); enp-3 (= fourth segment) reduced, unornamented; and 2 terminal claws (= inner and middle claw); middle claw curved, with fossa on concave margin (arrowed in Fig. 6D); inner claw without fossa.

Buccal apparatus (Fig. 7A) comprising labrum, mandible, and maxilla; labrum broad, truncated posteriorly, partially covering other buccal components (Fig. 7B); mandible armed with 2 blades (= anterior and posterior blade); anterior blade ornamented with spinules along posterior margin and armed with apical tooth; posterior blade longer and thinner than previous blade, ornamented with spinules along posterior margin; maxilla 2-segmented, comprising syncoxa (= first segment) and basis (= second segment); syncoxa broad, with large subdistal pore (arrowed in Fig. 7D); basis with multiples spinules.

P1 to P4 biramous (Figs. 8A-D), each leg comprising coxa, basis, endopod (inner ramus) and exopod (outer ramus). P1 (Fig. 8A); coxa unornamented; basis with bare outer seta; enp 2-segmented, both segments with spinules along outer margin and lacking any ornament on inner margin; enp-1 (= proximal segment) armed with 1 plumose seta on inner margin; enp-2 (= distal segment) about 2 times longer than previous segment, armed with 2 serrated spines and 5 plumose setae; exp 3-segmented; exp-1 and -2, both with spinules along outer margin; all segments lacking any ornament on inner margin; exp-1 (= proximal segment) about 1.5 times longer than following segments, armed with single distal spine on outer margin; exp-2 (= middle segment) protrude laterally, armed with 1 plumose seta on inner margin; exp-3 (= distal segment) ornamented with few spinules (3-4 spinules) located immediately next to first seta (arrowed in Fig. 8A), armed with 2 simple spines (not serrated) and 5 plumose setae.

P2 (Fig. 8B); coxa ornamented with spinules (4 spinules); basis with bare outer seta; enp 3-segmented, all segments with spinules along outer margin and lacking any ornament on inner margin; enp-1 (= proximal segment)

armed with 1 plumose seta on inner margin; enp-2 (= middle segment) armed with 2 plumose setae on inner margin; enp-3 (= distal segment) armed with simple spine (not serrated) and 4 plumose setae; exp 3-segmented; exp-1 and -2, both with spinules on outer margin; all segments lacking any ornament on inner margin; exp-1 (= proximal segment) about 1.5 longer than following segments, armed with single distal spine on outer margin; exp-2 (= middle segment) armed with 1 plumose seta on inner margin; exp-3 (= distal segment) armed with 2 minute spines; spines smaller than those present in P1 exp-3; and 6 plumose setae. P3 (Fig. 8c) with same ornamentation and armament described for P2.

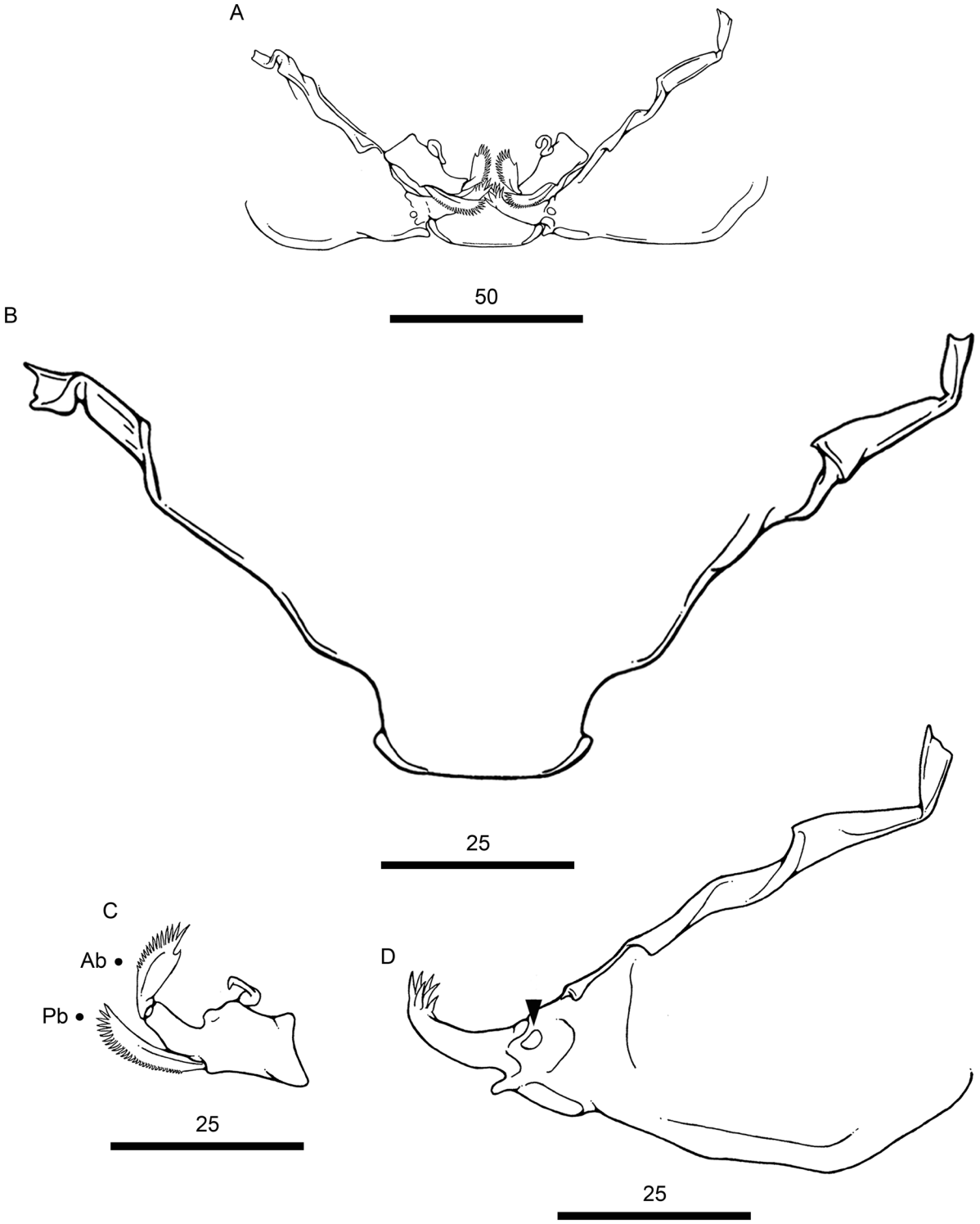

FIGURE 7. *Gamispatulus ferrilongus* **n. sp.**—adult female. **A** buccal apparatus. **B** labrum. **C** mandible. **D** maxilla, syncoxa with pore (arrowhead). Ab = anterior blade. Pb = posterior blade. A—holotype INPA 2521. B, C, D—paratype INPA 2523a. Scale bars in micrometers (μm).

P4 (Fig. 8D); coxa ornamented with spinules (3 spinules); basis with bare outer seta; enp 2-segmented, both segments lacking any ornament on outer and inner margin; enp-1 (= proximal segment) armed with 1 plumose seta on inner margin; enp-2 (= distal segment) armed with 4 plumose setae distally, lacking any spines; exp 1-segmented; exopodal segment lacking any ornament on outer and inner margin, armed with 2 minute spines; spines smaller than those present in P1 exp-3; and 4 plumose setae.

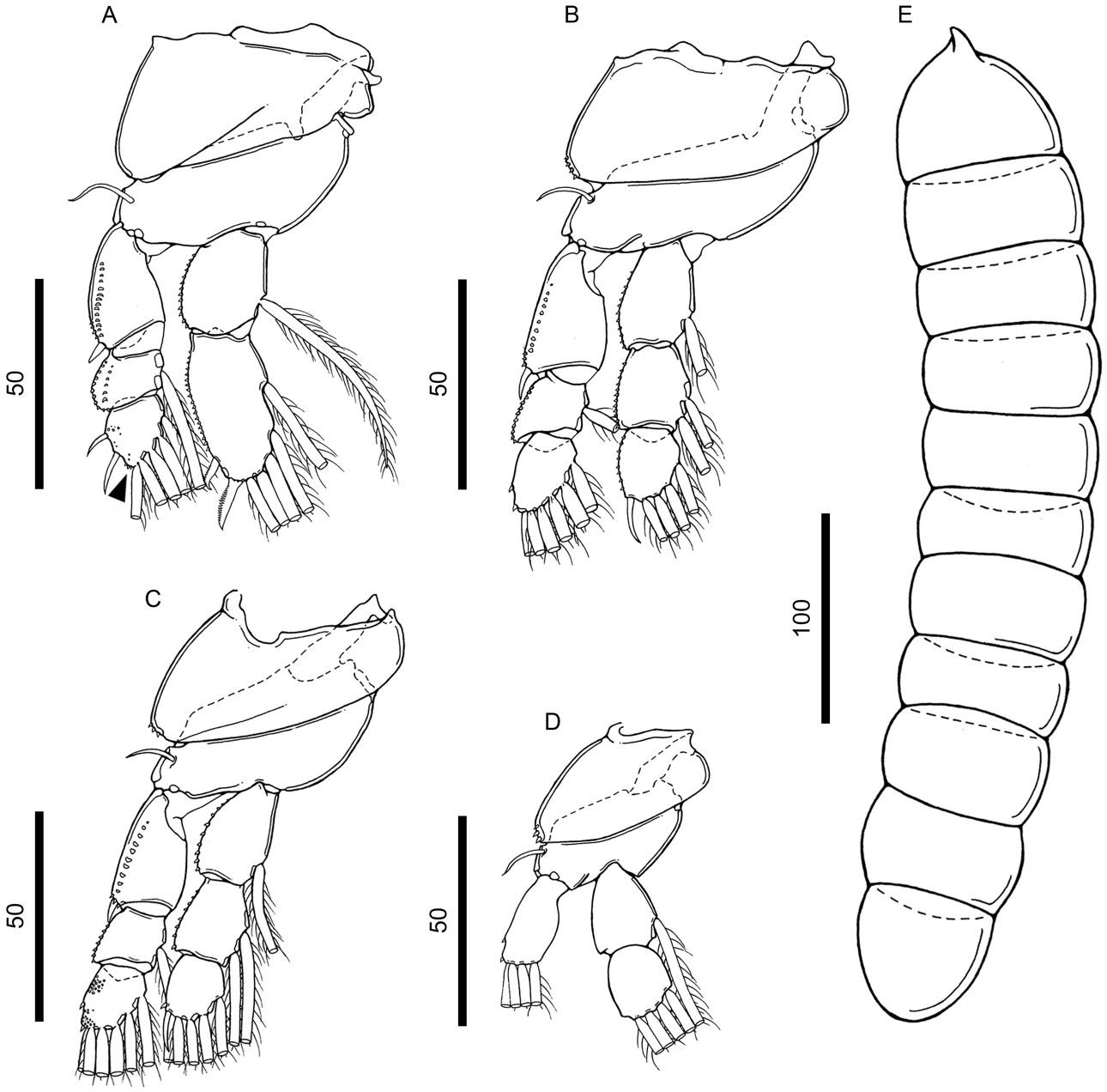

FIGURE 8. *Gamispatulus ferrilongus* **n. sp.**—adult female. **A** leg 1. **B** leg 2. **C** leg 3. **D** leg 4. **E** egg sac. A, B, C, D—holotype INPA 2521. E—paratype 2522a. Scale bars in micrometers (μm).

P5 reduced and represented by 2 naked setae (Figs. 6A, C). Spine and setal formula of biramous swimming legs is presented in Table 4.

Intercoxal sclerites slender, unornamented, with both ends directed posteriorly (Fig. 6B). Intercoxal plates from P1 to P3 with paired lateral pores; intercoxal plate of P4, absent (Fig. 6B). Egg sac paired (Fig. 8E), uniseriate.

Remarks. The new copepod was identified as member of the Ergasilidae based on the absence of maxillipeds and the presence of uniramous antennae comprising coxobasis (= first segment) and 3-segmented enp with fourth segment (= enp-3) armed with 1 or more terminal claws, mandible bearing 2 spinulate blades, 2-segmented maxilla with the distal segment (= basis) ornamented with multiple spinules, and P4 exp 2-segmented in adult females

(Boxshall & Halsey 2004). Among ergasilids, the new copepod resembles species from the vaigamid subgroup (*Gamidactylus*, *Gamispatulus*, *Gamispinus*, *Pseudovaigamus*, and *Vaigamus*) in having the combination of a 2-segmented enp for P1 and cephalothorax armed with a pair of dorsolateral stylets (or retrostylets).

The new copepod was identified as member of *Gamispatulus* for possessing the following combination of diagnostic features: (1) rostrum armed with rostral spine (lacking in *Gamidactylus* and *Gamispinus*); (2) 5-segmented antennule (6-segmented in species of *Gamidactylus, Pseudovaigamus*, and *Vaigamus*); (3) antenna with 2 terminal claws (a single claw is present in *Pseudovaigamus* and *Vaigamus*); (4) third antennary segment unornamented (ornamented with long spinules in *Gamispinus*), and (5) P4 with 2-segmented enp and 1-segmented exp. In addition to these generic features, the new copepod also resembles its congener, *G. schizodontis* (type species), in possessing smooth intercoxal plates in P1-P3, second antennary segment (or enp-2) ornamented with spinule row along outer margin and large spine near middle of inner margin, and egg sacs uniseriate.

TABLE 4. Armature of swimming legs of *Gamispatulus ferrilongus* **n. sp.**—adult female. (Roman numeral = spines; Arabic numerals = setae). P1-P4 = first to fifth swimming leg.

Swimming leg	Coxa	Basis	Endopod	Exopod
P1	0–0	1–0	0–1; II–5	I–0; 0–1; II-5
P2	IV–0	1–0	0–1; 0–2; I–4	I–0; 0–1; II-6
P3	IV–0	1–0	0–1; 0–2; I–4	I–0; 0–1; II-6
P4	III–0	1–0	0–1; 0–4	II-4

The new copepod, *Gamispatulus ferrilongus* **n. sp.**, can be readily separated from its congener in having simple retrostylets, thus diverging from restrostylets with medial spatulate process of *G. schizodontis*. Furthermore, the size of rostral spine is also different in these two species: in *Gamispatulus ferrilongus* **n. sp.** it is about three times longer than that in *G. schizodontis*: 180 in *Gamispatulus ferrilongus* **n. sp.** vs. ≅60 in *G. schizodontis* [see figure 5 in Thatcher & Boeger (1984b)]. The morphology of the genital double-somite in *G. ferrilongus* **n. sp.** also differs from that of *G. schizodontis*: in *G. ferrilongus* **n. sp.** the dorsal surface of this somite carries 2 rounded processes (= anterior and posterior process) with similar size on both lateral margins (Fig. 6C), whereas in *G. schizodontis* this somite, even though it carries similar processes (see Fig. 1A), they are relatively smaller and different in size from each other. Another distinct difference between both species is the armature of the caudal rami: in *G. ferrilongus* **n. sp.** each ramus bears 4 setae being 2 smaller (= seta 1 and 3) and 2 longer (= seta 2 and 4), whereas in *G. schizodontis* each ramus bears only 2 long setae (due to their position these setae are putative equivalent to seta 2 and 4 from *G. ferrilongus* **n. sp.**), lacking any short setae. Finally, the ornamentation of the legs of *G. ferrilongus* **n. sp.** differs in several aspects from those present in *G. schizodontis*, as follow: (1) coxa from P2 to P4 carries minute spinules (3-4 spinules) laterally in *G. ferrilongus* **n. sp.** vs. coxa with long spinules (2-5 spinules) in *G. schizodontis*; (2) P1 exp-1 armed with single distal spine on outer margin in *G. ferrilongus* **n. sp.** vs. P1 exp-1 armed with 2 unequal spines (i.e. anterior spine short and triangular, and posterior spine long and thinner) in *G. schizodontis*; and (3) exp-1 of P2 and P3 ornamented with a row of minute spinules along outer margin in *G. ferrilongus* **n. sp.** vs. exp-1 of P2 and P3 ornamented with three prominent spines located in the distal half of the segment as in *G. schizodontis*.

Based on the morphological differences listed above, the present specimens were considered as a new species, *Gamispatulus ferrilongus* **n. sp.**, of the ergasilid genus *Gamispatulus*.

Discussion

Currently, all known species of the six vaigamid genera, including the new species proposed herein, are found only in Brazil. Vaigamid species have been reported from 3 and 11 different host orders and families, respectively (Table 5). *Gamispatulus schizodontis* is the species that occur in the largest variety of fish hosts, in 12 different fish species from 4 families: Anostomidae (7 spp.), Erythrinidae (2 spp.), Pimelodidae (1 sp.), and Serrasalmidae (2 spp.). On the other hand, *Gamidactylus hoplius* Varella & Malta, 1996, *G. piraya* Thatcher, Santo & Brasil-Sato, 2008 and *G. ferrilongus* **n. sp.** have so far only been reported from a single host each (Table 5). The occurrence of vaigamids in hosts from 3 different orders, Characiformes (majority), Siluriformes, and Perciformes, suggest a low level of specificity at fish order level.

TABLE 5. List of fish parasitized by vaigamid species. SH = Site in host. SB = Brazilian states.

	SH	BS	Host List	Reference
Gamidactylus bryconis Varella, 1995	Nostrils	Rondônia	*Brycon amazonicus* (Spix & Agassiz, 1829) *Brycon melanopterus* (Cope, 1872)	Varella (1994) Thatcher (1998) Luque & Tavares (2007) Eiras *et al*. (2010) Luque *et al*. (2013) Pavanelli *et al*. (2013)
Gamidactylus hoplius Varella & Malta, 1996	Nostrils	Rondônia	*Hoplias malabaricus* (Bloch, 1794)	Varella & Malta (1995) Luque & Tavares (2007) Eiras *et al*. (2010) Luque *et al*. (2013) Pavanelli *et al*. (2013)
Gamidactylus jaraquensis Thatcher & Boeger, 1984	Nostrils	Amazonas Paraná	*Colossoma macropomum* (Cuvier, 1816) *Prochilodus lineatus* (Valenciennes, 1837) *Semaprochilodus insignis* (Jardine, 1841) *Serrasalmus altispinis* Merckx, Jégu & Santos, 2000	Thatcher & Boeger (1984b) Thatcher (1998) Fischer *et al*. (2003) Lizama *et al*. (2005) Lizama *et al*. (2006a) Lizama *et al*. (2006b) Thatcher (2006) Lacerda *et al*. (2007) Luque & Tavares (2007) Takemoto *et al*. (2009) Eiras *et al*. (2010) Luque *et al*. (2013) Pavanelli *et al*. (2013) Tavares-Dias *et al*. (2013) Morey & Malta (2016a) Morey & Malta (2016b) Morey *et al*. (2016) Oliveira *et al*. (2017)
Gamidactylus piraya Thatcher, Santos & Brasil-Sato, 2008	Nostrils	Minas Gerais	*Pygocentrus piraya* (Cuvier, 1819)	Thatcher *et al*. (2008)
Gamidactylus sp.	Gills	Amapá Paraná	*Curimata incompta* Vari, 1984 *Pimelodus maculatus* Lacepède, 1803	Takemoto *et al*. (2009) Luque *et al*. (2013) Neves & Tavares-Dias (2019)
Gamispatulus ferrilongus **n. sp.**	Nostrils	São Paulo	*Schizodon intermedius* Garavello & Britski, 1990	Present contribution
Gamispatulus schizodontis Thatcher & Boeger. 1984	Nostrils	Amazonas Paraná Minas Gerais	*Hoplias lacerdae* Miranda Ribeiro, 1908 *Hoplias malabaricus* (Bloch, 1794) *Leporinus friderici* (Bloch, 1794) *Leporinus lacustris* Amaral Campos, 1945 *Megaleporinus elongatus (*Valenciennes, 1850) *Megaleporinus obtusidens* (Valenciennes, 1837) *Pimelodus maculatus* Lacepède, , 1803 *Serrasalmus maculatus* Kner, 1858 *Serrasalmus marginatus* Valenciennes, 1837 *Schizodon borellii* (Boulenger, 1900) *Schizodon fasciatus* Spix & Agassiz, 1829 *Schizodon intermedius* Garavello & Britski, 1990	Present contribution Thatcher & Boeger (1984a) Thatcher (1998) Guidelli *et al*. (2006) Thatcher (2006) Lacerda *et al*. (2007) Guidelli *et al*. (2009) Takemoto *et al*. (2009) Eiras *et al*. (2010) Rosim *et al*. (2010) Guidelli *et al*. (2011) Luque *et al*. (2013) Pavanelli *et al*. (2013) Oliveira *et al*. (2017)

...Continued on the next page

TABLE 5. (continued)

	SH	BS	Host List	Reference
Gamispatulus sp.	Unspecified	Paraná Minas Gerais São Paulo	*Pachyurus squamipennis* Agassiz, 1831 *Piaractus mesopotamicus* (Holmberg, 1887) *Prochilodus lineatus* (Valenciennes, 1837)	Lizama *et al*. (2005) Lizama *et al*. (2006a) Lizama *et al*. (2006b) Lizama *et al*. (2007) Luque & Tavares (2007) Takemoto *et al*. (2009) Pavanelli *et al*. (2013) Luque *et al*. (2013)
Gamispinus diabolicus Thatcher & Boeger, 1984	Nostrils	Amazonas Minas Gerais Paraná	*Ageneiosus inermis* (Linnaeus, 1766) *Pimelodus maculatus* Lacepède, 1803	Thatcher & Boeger (1984c) Thatcher (1998) Thatcher (2006) Brasil-Sato *et al*. (2000) Brasil-Sato (2003) Luque *et al*. (2013) Pavanelli *et al*. (2013) Ferreira & Tavares-Dias (2017)
Pseudovaigamus spinicephalus (Thatcher & Robertson, 1984)	Plankton	Amazonas	Free-living	Thatcher & Robertson (1984) Thatcher (1998) Luque & Tavares (2007) Luque *et al*. (2013)
Vaigamus retrobarbatus Thatcher & Robertson, 1984	Plankton	Amazonas	Free-living	Thatcher & Robertson (1984) Thatcher (1998) Luque *et al*. (2007) Luque *et al*. (2013)
Vaigamus sp.	Gills Liver Nostrils	Paraná Minas Gerais	*Astyanax lacustris* (Lütken, 1875) *Cichla temensis* Humboldt, 1821 *Pimelodus maculatus* Lacépede, 1803 *Pseudoplatystoma punctifer* (Castelnau, 1855) *Pseudoplatystoma tigrinum* (Valenciennes, 1840)	Brasil-Sato (2003) Luque & Tavares (2007) Lizama *et al*. (2008) Lopes *et al*. (2009) Takemoto *et al*. (2009) Eiras *et al*. (2010) Luque *et al*. (2013) Pavanelli *et al*. (2013) Camargo *et al*. (2016)
Vaigamidae gen. sp.	Nostrils	Paraná	*Auchenipterus osteomystax* (Miranda Ribeiro, 1918) *Leporinus friderici* (Bloch, 1794) *Leporinus lacustris* Amaral Campos, 1945 *Megaleporinus elongatus (*Valenciennes, 1850) *Megaleporinus obtusidens* (Valenciennes, 1837) *Pimelodus maculatus* Lacépede, 1803 *Pinirampus pirinampu* (Spix & Agassiz, 1829) *Pseudoplatystoma corruscans* (Spix & Agassiz, 1829)	Guidelli *et al*. (2006) Takemoto *et al*. (2009) Tavernari *et al*. (2009) Guidelli *et al*. (2011) Oliveira *et al*. (2017)

In Brazil, vaigamids were recorded in 6 different states from the North, South, and Southeastern regions (Table 5). The absence of these copepods in other states and regions — e.g. Central-West and Northeast Brazil, can be attributed to a reduced number of limnological studies in these regions when compared to the other (Silva & Perbiche-Neves 2017). Although São Paulo State is considered the region with the largest number of studies about microcrustaceans (Silva & Perbiche-Neves 2017), the present report of *G. schizodontis* and *G. ferrilongus* **n. sp.** in *S. intermedius* indicates that this region still has great potential for discovering new taxa and new records of known species.

Acknowledgments

This study was supported by Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) (Proc. #2011/24159-3). R. B. N. thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the financial support provided (132844/2018-4). R.J.S. is supported by FAPESP #2016/50377-1; CNPq #309125/2017-0; CNPq-PROTAX #440496/2015-2.

References

Amado, M.A.P.M., Ho, J. & Rocha, C.E.F. (1995) Phylogeny and biogeography of the Ergasilidae (Copepoda, Poecilostomatoida), with reconsideration of the taxonomic status of the Vaigamidae. *Contributions to Zoology*, 65 (4), 233–243. https://doi.org/10.1163/26660644-06504002

Brasil-Sato, M.C. (2003) Parasitos de peixes da bacia do São Francisco. *In*: Godinho, H.P. & Godinho, A.L. (Eds.), *Águas, peixes e pescadores do São Francisco das Minas Gerais*. Puc Minas, Belo Horizonte, pp. 149–166.

Brasil-Sato, M.C., Pavanelli, G.C. & Luque, J.L. (2000) Ocorrência e aspectos quantitativos de *Gamispinus diabolicus* (Copepoda: Ergasilidae) parasitando o mandi-amarelo, *Pimelodus maculatus* (Siluroidei: Pimelodidae), no Rio Paraná, Brasil. *Revista da Universidade Rural, Ciência Vida*, 22, 67–69.

Boxshall, G.A. & Defaye, D. (2008) Global diversity of copepods (Crustacea: Copepoda) in freshwater. *Hydrobiologia*, 595, 195–207. https://doi.org/10.1007/978-1-4020-8259-7_21

Boxshall, G. A. & Halsey, S.H. (2004) *An introduction to copepod diversity*. Ray Society, London, 966 pp. https://doi.org/10.1645/0022-3395-91.6.1512

Boxshall, G.A. & Montú, M.A. (1997) Copepods parasitic on Brazilian coastal fishes: a handbook. *Nauplius*, 5 (1), 1–225.

Bush, A.O., Lafferty, K.D., Lotz, J.M. & Shostak, A. W. (1997) Parasitology meets ecology on its own terms: Margolis et al. Revisited. *The Journal of Parasitology*, 83, 575–583. https://doi.org/10.2307/3284227

Camargo, A.A., Negrelli, D.C., Pedro, N.H.O., Azevedo, R.K., Silva, R.J. & Abdallah, V.D. (2016) Metazoan parasite of lambari *Astyanax altiparanae*, collected from the Peixe river, São Paulo, southeast of Brazil. *Ciência Rural*, 46 (5), 876–880. https://doi.org/10.1590/0103-8478cr20151100

Eiras, J.C., Takemoto, R.M. & Pavanelli, G.C. (2010) *Diversidade dos parasitas de peixes de água doce do Brasil*. Cliche Tec, Maringá, 333 pp.

El-Rashidy, H.H. (1999) *Ergasilid copepods and grey mullet*. Queen Mary University of London, London, 468 pp.

El-Rashidy, H.H. & Boxshall, G.A. (1999) Ergasilid copepods (Poecilostomatoida) from the gills of primitive Mugilidae (grey mullets). *Systematic Parasitology*, 42 (3), 161–186. https://doi.org/10.1023/A:1006075223683

Ferreira, D.O. & Tavares-Dias, M. (2017) Ectoparasites and endoparasitas community of *Ageneiosus ucayalensis* (Siluriformes: Auchenipteridae), catfish from Amazon River system in northern Brazil. *Journal of Parasitic Diseases*, 41 (3), 639–646. https://doi.org/10.1007/s12639-016-0857-3

Fischer, C., Malta, J.C.O. & Varella, A.M.B. (2003) A fauna de parasitas do tambaqui, *Colossoma macropomum* (Cuvier, 1818) (Characiformes: Characidae) do Médio Rio Solimões, Estado do Amazonas (AM) e do Baixo Rio Amazonas, Estado do Pará (PA), e seu potencial como indicadores biológicos. *Acta amazônica*, 33 (4), 651–662. https://doi.org/10.1590/S0044-59672003000400012

Guidelli, G., Takemoto, R.M. & Pavanelli, G.C. (2009) Ecologia das infrapopulações ectoparasitas das cavidades nasais de *Leporinus lacustris* (Anostomidae) da planície de inundação do alto rio Paraná, Brasil. *Acta Scientiarum. Biological Sciences*, 31 (2), 209–214. https://doi.org/10.4025/actascibiolsci.v31i2.3309

Guidelli, G., Tavechio, W.L.G., Takemoto, R.M. & Pavanelli, G.C. (2006) Fauna parasitária de *Leporinus lacustris* e *Leporinus friderici* (Characiformes, Anostomidae) da planície de inundação do alto rio Paraná, Brasil. *Acta Scientiarum. Biological Sciences*, 28 (3), 281–290. https://doi.org/10.4025/actascibiolsci.v28i3.228

Guidelli, G., Tavechio, W.L.G., Takemoto, R.M. & Pavanelli, G.C. (2011) Relative condition factor and parasitism in anostomid fishes from the floodplain of the Upper Paraná River, Brazil. *Veterinary Parasitology*, 177 (1–2), 145–151. https://doi.org/10.1016/j.vetpar.2010.11.035

Lacerda, F.A.C., Takemoto, M.R., Lizama, M.A.P. & Pavanelli, G.C. (2007) Parasitic copepods in the nasal fossae of five fish species (Characiformes) from the upper Paraná river floodplain, Paraná, Brazil. *Acta Scientiarum, Biological Sciences*, 29 (4), 429–435.

Lizama, M.A.P., Takemoto, R.M. & Pavanelli, G.C. (2005) Influence of host sex and age on infracommunities of metazoan parasites of *Prochilodus lineatus* (Valenciennes, 1836) (Prochilodontidae) of the Upper Paraná River floodplain, Brazil. *Parasite*, 12 (4), 299–304.

https://doi.org/10.1051/parasite/2005124299
Lizama, M.A.P., Takemoto, R.M. & Pavanelli, G.C. (2006a) Parasitism influence on the hepato, splenosomatic and width /length relation and relative condition factor of *Prochilodus lineatus* (Valenciennes, 1836) (Prochilodontidae) of the Upper Paraná River floodplain, Brazil. *Brazilian Journal of Veterinary Parasitology*, 15 (3), 116–122.
Lizama, M.A.P., Takemoto, R.M. & Pavanelli, G.C. (2006b) Influence of the seasonal and environmental patterns and host reproduction on the metazoan parasites of *Prochilodus lineatus*. *Brazilian Archives of Biology and Technology*, 49 (4), 611–622.
https://doi.org/10.1590/S1516-89132006000500011
Lizama, M.A.P., Takemoto, R.M. & Pavanelli, G.C. (2008) Ecological aspects of metazoan parasites of *Astyanax altiparanae* Garutti & Britski, 2000 (Characidae) of the Upper Paraná River Floodplain, Brazil. *Boletim do Instituto de Pesca*, 34 (4), 527–533.
Lizama, M.A.P., Takemoto, R.M., Ranzani-Paiva, M.J.T., Ayroza, M.S. & Pavanelli, G.C. (2007) Relação parasito-hospedeiro em peixes de pisciculturas da região de Assis, Estado de São Paulo, Brasil. 2. *Piaractus mesopotamicus* (Holmberg, 1887). *Acta Scientiarum. Biological Sciences*, 29, 4, 437–445.
https://doi.org/10.4025/actascibiolsci.v29i4.888
Lopes, L.P.C., Varella, A.M.B. & Malta, J.C.O. (2009) Metazoan parasites of *Pseudoplatystoma punctifer* (Linnaeus, 1766) and *Pseudoplatystoma tigrinum* (Spix & Agassiz, 1829) (Siluriformes: Pimelodidae) of the Central Amazon Basin, Brazil. *Biologia Geral e Experimental*, 9 (2), 3–15.
Luque, J.L. & Tavares, L.E.R. (2007) Checklist of Copepoda associated with fishes from Brazil. *Zootaxa*, 1579 (1), 1–39.
https://doi.org/10.11646/zootaxa.1579.1.1
Luque, J.L., Vieira, F.M., Takemoto, R.M., Pavanelli, G.C. & Eiras, J.C. (2013) Checklist of Crustacea parasitizing fishes from Brazil. *Check List*, 9 (6), 1449–1470.
https://doi.org/10.15560/9.6.1449
Marques, T.M., Boeger, W.A. & Brasil-Sato, M.C. (2015) Two new species of *Ergasilus* Nordmann, 1832 (Copepoda: Ergasilidae) and a redescription of *Ergasilus salmini* Thatcher & Brazil-Sato, 2008 from *Salminus brasiliensis* Cuvier and *S. franciscanus* Lima & Britsky (Teleostei: Characidae) in Brazil. *Systematic Parasitology*, 90 (1), 81–89.
https://doi.org/10.1007/s11230-014-9529-9
Martin, J.W. & Davis, G.E. (2001) *An updated classification of the recent Crustacea*. Natural History Museum of Los Angeles County, Los Angeles, 129 pp.
https://doi.org/10.1651/0278-0372(2003)023[0495:br]2.0.co;2
Morey, G.A.M. & Malta, J.C.O. (2016a) As espécies de copepoda (Crustacea: Ergasilidae) parasitas dos filamentos branquiais e narinas de *Serrasalmus altispinis* (Merckx, Jégu e Santos, 2000) (Characiformes—Serrasalmidae) em Lagos de Várzea do Brasil. *Folia Amazónica*, 25 (1), 55–60.
https://doi.org/10.24841/fa.v25i1.384
Morey, G.A.M. & Malta, J.C.O. (2016b) Metazoários parasitas das narinas do Tambaqui *Colossoma macropomum* (Cuvier, 1818) (Characiformes: Characidae) coletadas em Lagos de Várzea da Amazônia Central, Brasil. *Folia Amazónica*, 25 (1), 71–76.
https://doi.org/10.24841/fa.v25i1.386
Morey, G.A.M., Moreira, A.C., Morais, A.M., Atroch, F.M.P.B., Santana, H.P., Brandão, N.R., Dumbo 1, J.C., Vital, F.J. & Malta, J.C.O. (2016) Copepods (Crustacea: Ergasilidae) fish parasites of floodplain Lakes of Central Amazon, Brazil. *Neotropical Helminthology*, 10 (2), 281–294.
Narciso, R.B., Brandão, H., Perbiche-Neves, G. & Silva, R.J. (2019) A New Genus of Ergasilidae (Copepoda: Cyclopoida) from the gills of *Astyanax fasciatus* (Cuvier, 1819) (Actinopterygii: Characidae). *Acta Parasitologica*, 64 (4), 850–865.
https://doi.org/10.2478/s11686-019-00108-x
Neves, L.R. & Tavares-Dias, M. (2019) Low levels of crustacean parasite infestation in fish species from the Matapi River in the state of Amapá, Brazil. *Brazilian Journal of Veterinary Parasitology*, 28 (3), 493–498.
https://doi.org/10.1590/s1984-29612019006
Oliveira, M.S.B., Corrêa, L.L., Ferreira, D.O., Neves, L.R. & Tavares-Dias, M. (2017) Records of new localities and hosts for crustacean parasites in fish from the eastern Amazon in northern Brazil. *Journal of Parasitic Diseases*, 41 (2), 565–570.
https://doi.org/10.1007/s12639-016-0852-8
Pavanelli, G.C., Eiras, J.C. & Takemoto, R.M. (2008) *Doenças de Peixes: profilaxia, diagnóstico e tratamento*. Eduem, Maringá, 305 pp.
Pavanelli, G.C., Takemoto, R.M. & Eiras, J.C. (2013) *Parasitologia de peixes de água doce do Brasil*. Eduem, Maringá, 452 pp.
Piasecki, W., Goodwin, A.E., Eiras, J.C. & Nowak, B.F. (2004) Importance of Copepoda in freshwater aquaculture. *Zoological Studies*, 43 (2), 193–205.
Rosim, D.F., Mesquita, R.L.B. & Luque, J.L. (2010) Occurrence of *Gamispatulus schizodontis* Thatcher & Boeger, 1984 (Cyclopoida, Ergasilidae) in the nasal cavities of Erythrinidae fishes from Brazil. *Pan-American Journal of Aquatic Sciences*, 5 (1), 153–156.
Silva, W.M. & Perbiche-Neves, G. (2017) Trends in freshwater microcrustaceans studies in Brazil between 1990 and 2014. *Brazilian Journal of Biology*, 77 (3), 527–534.

https://doi.org/10.1590/1519-6984.17915
Takemoto, R.M., Pavanelli, G.C., Lizama, M.A.P., Lacerda, A.C.F., Yamada, F.H., Moreira, L.H.A., Ceschini, T.L. & Bellay, S. (2009) Diversity of parasites of fish from the Upper Paraná River floodplain, Brazil. *Brazilian Journal of Biology*, 69 (2), 691–705.
https://doi.org/10.1590/S1519-69842009000300023
Tavares-Dias, M., Araujo, C.S.O., Porto, S.M.A., Viana, G.M. & Monteiro, P.C. (2013) *Sanidade do Tambaqui Colossoma macropomum nas Fases de Larvicultura e Alevinagem*. Embrapa, Amapá, 42 pp.
Tavares-Dias, M., Dias-Junior, M.B.F., Florentino, A.C., Silva, L.M.A & Cunha, A.C.D. (2015) Distribution pattern of crustacean ectoparasites of freshwater fish from Brazil. *Brazilian Journal of Veterinary Parasitology*, 24 (2), 136–147.
https://doi.org/10.1590/S1984-29612015036
Tavernari, F.C., Takemoto, R.M., Guidelli, G.M., Lizama, M.A.P., Lacerda, A.C.F. & Pavanelli, G.C. (2009) Parasites of *Auchenipterus osteomystax* (Osteichthyes, Auchenipteridae) from two different environments, Rosana's reservoir and upper Paraná river floodplain, Brazil. *Acta Scientiarum, Biological Sciences*, 31 (1), 49–54.
https://doi.org/10.4025/actascibiolsci.v31i1.833
Thatcher, V.E. (1998) Copepods and fishes in the Brazilian Amazon. *Journal of Marine Systems*, 15 (1–4), 97–112.
https://doi.org/10.1016/S0924-7963(97)00043-2
Thatcher, V.E. (2006) *Amazon fish parasites*. Pensoft, Moscow, 508 pp.
Thatcher, V.E. & Boeger, W.A. (1984a) The parasitic crustaceans from the Brazilian Amazon. 15. *Gamispatulus schizodontis* gen. et sp. nov. (Copepoda: Poecilostomatoida: Vaigamidae) from the nasal fossae of *Schizodon fasciatus* AGASSIZ. *Amazoniana: Limnologia et Oecologia Regionalis Systematis Fluminis Amazonas*, 9 (1), 119–126.
Thatcher, V.E. & Boeger, W.A. (1984b) The parasitic crustaceans of fishes from the Brazilian Amazon. 13. *Gamidactylus jaraquensis* gen. et sp. nov. (Copepoda: Poecilostomatoida: Vaigamidae) from the nasal fossae of *Semaprochilodus insignis* (Schomburgk). *Amazoniana: Limnologia et Oecologia Regionalis Systematis Fluminis Amazonas*, 8 (3), 421–426.
Thatcher, V.E. & Boeger, W.A. (1984c) The parasitic Crustaceans of fishes from the Brazilian Amazon, 14, *Gamispinus diabolicus* gen. et sp. nov. (Copepoda: Poecilostomatoida: Vaigamidae) from the nasal fossae of *Ageneiosus brevifilis* VALENCIENNES. *Amazoniana: Limnologia et Oecologia Regionalis Systematis Fluminis Amazonas*, 8 (4), 505–510.
Thatcher, V.E. & Robertson, B.A. (1984) The parasitic crustaceans of fishes from the Brazilian Amazon. 11. Vaigamidae fam. nov. (Copepoda: Poecilostomatoida) with males and females of *Vaigamus retrobarbatus* gen. et sp. nov. *V. spinicephalus* sp. nov. from plankton. *Canadian Journal of zoology*, 62 (4), 716–729.
https://doi.org/10.1139/z84-102
Thatcher, V., Santos, M. & Brasil-Sato, M. (2008) *Gamidactylus piranhus* sp. nov. (Copepoda, Vaigamidae) from the nasal fossae of serrasalmid fishes from the Três Marias Reservoir, Upper São Francisco River, Minas Gerais State, Brazil. *Acta Parasitologica*, 53 (3), 284–288.
https://doi.org/10.2478/s11686-008-0034-7
Varella, A. (1994) *Gamidactylus bryconis* sp. n. (Copepoda, Poecilostomatoida, Vaigamidae) das fossas nasais de peixes, *Brycon pellegrini* Holly, 1929 e *B. melanopterus* (Cope, 1872) da Amazônia brasileira. *Acta Amazonica*, 24 (1–2), 145–152.
https://doi.org/10.1590/1809-43921994242152
Varella, A. & Malta, J.C.O. (1995) *Gamidactylus hoplius* sp. n. (Copepoda, Poecilostomatoida, Vaigamidae) das fossas nasais de *Hoplias malabaricus* (Bloch, 1794) (Characiformes, Erythrynidae) da Amazônia Brasileira. *Acta Amazonica*, 25 (3–4), 281–288.
https://doi.org/10.1590/1809-43921995253288
Varella, A.M.B., Morey, G.A.M. & Malta, J.C.O. (2019) *Ergasilus tipurus* n. sp. (Copepoda: Ergasilidae), A Parasite of Brazilian Amazon Fish Species. *Acta Parasitologica*, 64 (1), 187–194.
https://doi.org/10.2478/s11686-018-00020-w
Williams, E.H. & Bunkley-Williams, L. (2019) Life Cycle and Life History Strategies of Parasitic Crustacea. *In*: Smit, N., Bruce, N. & Hadfield, K. (Eds.), *Parasitic Crustacea*. Springer, Cham and Gewerbestrasse, pp. 179–266.
https://doi.org/10.1007/978-3-030-17385-2_5