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A new species of *Pseudovaigamus* Amado, Ho & Rocha, 1984 (Cyclopoida: Ergasilidae) from the teleost *Pimelodus maculatus* Lacepède, 1803

RODRIGO B. NARCISO[1,3], GILMAR PERBICHE-NEVES[2] & REINALDO JOSÉ DA SILVA[1]
[1]*São Paulo State University (Unesp), Institute of Biosciences, Botucatu, Brazil*
[2]*Federal University of São Carlos (Ufuscar), Department of Hydrobiology, São Carlos, Brazil*
[3]*Corresponding author:* [1,3] *rodrigoparasitologia@gmail.com;* *https://orcid.org/0000-0002-8295-4742*
[2] *gilmarperbiche83@gmail.com;* *https://orcid.org/0000-0002-5025-2703*
[1] *reinaldo.silva@unesp.br;* *https://orcid.org/0000-0002-3426-6873*

Abstract

A new species of the copepod genus *Pseudovaigamus* Amado, Ho & Rocha, 1984 is described herein based on parasitic adult females found attached to the gills of the freshwater teleost *Pimelodus maculatus* Lacepède, 1803, sampled in two tributaries (Veados and Paranapananema Rivers) of the Jurumirim Reservoir, Upper Paranapanema River, São Paulo State, Brazil. The new copepod was identified as an undescribed species of *Pseudovaigamus* because it shares with the type-species, *Pseudovaigamus spinicephalus* (Thatcher & Robertson, 1984), the combination of first leg with 2-segmented endopod, fourth leg with 3-segmented endopod and 2-segmented exopod, and cephalothorax armed with dorsolateral stylets (or retrostylets). However, the new copepod differs from its congener in having a trifid rostral spine, retrostylets with long spatulate process, 5-segmented antennule, and caudal rami simple or lacking any distal lobe. We erected a new species, *Pseudovaigamus tridentatus* **n. sp.**. It is the first report of a *Pseudovaigamus* found on a freshwater fish in Brazil.

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

Introduction

Thatcher & Robertson (1984) described (based on morphological and morphometric data) two copepod species (*Vaigamus retrobarbatus* Thatcher & Robertson, 1984 and *Vaigamus spinicephalus* Thatcher & Robertson, 1984) from specimens (males and females) collected from plankton samples in Marchantaria Island, Amazonas State, Brazil and Tocantins River, Pará State, Brazil, respectively . Besides proposing a new genus, *Vaigamus* Thatcher & Robertson, 1984, the authors also proposed a new parasitic copepod family, Vaigamidae to accommodate the two described species. According to the authors, members of the Vaigamidae share several diagnostic features with ergasilids, e.g. general body plan, absence of maxillipeds in adult females, number and shape of legs, antennules, and antennae (Thatcher & Robertson 1984). However, vaigamids were not included as members of Ergasilidae because of the presence of paired dorsolateral stylets on the cephalothorax and rostrum armed with a rostral spine, which are both absent in ergasilids (Thatcher & Robertson 1984).

The family status of Vaigamidae was questioned by Amado *et al*. (1995). When assessing the relationship between vaigamids and ergasilids, the authors verified that all vaigamids (including *Gamidactylus* Thatcher & Boeger, 1984; *Gamispatulus* Thatcher & Boeger, 1984; *Gamispinus* Thatcher & Boeger, 1984; and *Vaigamus*) formed a monophyletic group within Ergasilidae (see fig. 1 in Amado *et al*. 1995), leading to the synonymization of both families (Amado *et al*. 1995). In the same study, the authors also evaluated the relationship between *V. retrobarbatus* and *V. spinicephalus* and proposed a new genus, *Pseudovaigamus* Amado, Ho & Rocha, 1995 to allocate *V. spinicephalus* because of the differences on their fourth leg (i.e. fourth leg with endopod 2-segmented and exopod 1-segmented in *V. retrobarbatus* vs endopod 3-segmented and exopod 2-segmented in *V. spinicephalus*) (Amado *et al*. 1995). Currently, vaigamids are a subgroup of five genera within the Ergasilidae, *Pseudovaigamus* remains as a valid taxon and, since its description, specimens of *Pseudovaigamus spinicephalus* (Thatcher & Robertson, 1984)

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(type-species) have not been found in any other aquatic systems or any host species, leaving this genus to have a "free-living" status (see checklist in Luque *et al*. 2013).

During the survey of the fishes from two tributaries (Veados and Paranapanema Rivers) of the Jurumirim Reservoir, Upper Paranapanema River, São Paulo State, Brazil, we found several ergasilids parasitizing the gills of the freshwater catfish, *Pimelodus maculatus* Lacepède, 1803. A morphological analysis of these copepods indicates that they represent an undescribed species of *Pseudovaigamus*, which is herein described based on female specimens.

Material and Methods

Ninety-one specimens of *P. maculatus* were collected during a sampling survey in 2011 and 2012 from two tributaries from the Jurumirim Reservoir, São Paulo State, Brazil: (1) Paranapanema River (23°29'16.54" S, 48°37'12.88" W), municipality of Angatuba; and (2) Veados River (23°16'2.49" S, 48°38'15.72" W), municipality of Itatinga. 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 (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 gills were then removed and examined for copepods using a stereomicroscope. Copepods found were carefully removed from the gills using entomological needles and then stored in 70% ethanol. Some copepod specimens were selected and cleared in lactic acid and then mounted in Hoyer's medium in a semi-permanent slide. Whenever necessary, some specimens were also dissected in glycerol medium, and then each part was mounted on individual slides. Coverslips were sealed with transparent nail varnish.

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 the 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. Anatomical terms used followed Boxshall & Montú (1997) and Boxshall & Halsey (2004). The same sources were also used to identify copepod specimens to family and genus level. Abbreviations used throughout the description 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 claw is considered an armature element derived from the third endopodal segment (El-Rashidy & Boxshall 1999). Ecological descriptors such as prevalence and mean intensity were calculated following Bush *et al*. (1997).

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

Abbreviation	Meaning
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

Holotype and paratypes were deposited in: (1) the Zoological Collection of the Museu de Zoologia da Universidade de São Paulo (MZUSP), municipality of São Paulo, São Paulo State, Brazil; and (2) 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 *Pseudovaigamus* Amado, Ho & Rocha, 1995

***Pseudovaigamus tridentatus* n. sp.**
(Figs 1–4)

Host. *Pimelodus maculatus* Lacepède, 1803 (Siluriformes: Pimelodidae).

Locality. Paranapanema River, Jurumirim Reservoir, Upper Paranapanema River (23° 29'16.54" S, 48° 37'12.88" W), municipality of Angatuba, São Paulo State, Brazil.

Additional 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.

Site in host. Gill.

Specimens deposited. Holotype MZUSP 41553 (adult female) and Paratypes MZUSP 41554 to MZUSP 41562 (9 adult females) in the the Zoological Collection of the Museu de Zoologia da Universidade de São Paulo (MZUSP), municipality of São Paulo, São Paulo State, Brazil; and Paratypes INPA 2531 to INPA 2534 (5 adult females) in the Invertebrate Collection of the Instituto Nacional de Pesquisas da Amazônia (INPA), municipality of Manaus, Amazonas State, Brazil.

Prevalence and mean intensity on the gill filaments: eight of 91 analyzed fish (or 8,8%) and 4,2 ± 1,8 (1–14) copepods per infected fish.

Etymology. The specific name is derived from the Latin word, *tridentis* (= trident) in reference to the trifid rostral spine that resembles the cutting edge of that old melee weapon.

Differential diagnosis. Trifid rostral spine, armed with a long middle spine and two curved lateral spines. Retrostylets with the innermost portion extending posteriorly to form a spatulate process. Antennule 5-segmented; first segment with a groove on posterior margin. Caudal rami simple, lacking any distal lobe. Second endopodal segment of P1 and third exopodal segment of P1–P2 armed with dilated spine.

Description of adult female. Based on 15 adult females, 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 three free pedigerous somites (PS-2 to PS-4). Cephalothorax bullet-shaped (Fig. 1A), decreasing in width anteriorly, maximum width at level of restrostylet tip (Table 2); dorsal surface with several pores and bristles symmetrically distributed and one circular integumental window (located at level of rostrum's middle spine) (arrowed in Fig. 1A); and armed with paired dorsolateral stylets (= retrostylets). Rostrum forming trifid rostral spine and ornamented with several pores and bristles on ventral surface (Fig. 1B); middle spine long, about three times longer than lateral spines, straight and sharply posteriorly; lateral spine strongly curved, with sharp tip. Retrostylets double (Fig 1C) carrying lateral stylet process and medial spatulate process; stylet process slightly curved, with sharply tip; spatulate process slightly longer than stylet, with rounded tip; dorsal surface ornamented with two bristles on lateral margin and one medial pore. Free pedigerous somites decreasing gradually in width from anterior to posterior (Fig. 1A); PS-2 with paired integumental windows laterally on tergite (arrowed in Fig. 1D); dorsal surface ornamented with central pair of pores and two bristles on both lateral margins; PS-3 lacking any integumental window, dorsally ornamented with central pair of pores and three bristles on both lateral margins; PS-4 lacking any integumental window, central pores absent, dorsally ornamented with one bristle on both lateral margins.

Urosome consisting of PS-5, genital double-somite, and three free abdominal somites (AS-1 to AS-3) (Fig. 2A). PS-5 reduced (Fig. 2A), shorter and narrower than prosome somites, unornamented. Genital double-somite (Fig. 2A), about 1.5 times wider than long, bearing slit-like genital apertures dorsally, ornamented with posterior spinules on both lateral margins. Abdominal somites decreasing in width from anterior to posterior, each somite ornamented with posterior spinules on both lateral margins; AS-3 (= anal somite) deeply incised posteriorly (= anus), ornamented with pair of pores on dorsal surface; pores located immediately next to anus (Fig. 2A).

Caudal rami (Fig. 2A) about 1.5 times longer than wide; each ramus ornamented with one spinule on posterolateral margin (located immediately next to seta 1), and armed with four bare setae: seta 1 and 3 shortest, both setae inserted on ventral surface; seta 2 and 4 both inserted on posterior margin; seta 4 longest, about 2 times longer than seta 2 (Table 2).

Antennule 5-segmented (Fig. 1F); first segment with groove on posterior margin; setal formula: 10, 4, 4, 2, 7 (total 27; aesthetascs not distinguished from setae). Antennna 4-segmented (Fig. 1E) comprising coxobasis and 3-segmented enp; coxobasis (= first segment) broad, ornamented with bare seta; enp-1 (= second segment) longest, about 2 times longer than other antennary segments, straight, unornamented; enp-2 (= third segment) straight, unornamented; enp-3 (= fourth segment) reduced, unornamented; and one terminal claw; claw strongly curved, with fossa on concave margin (arrowed in Fig. 1E).

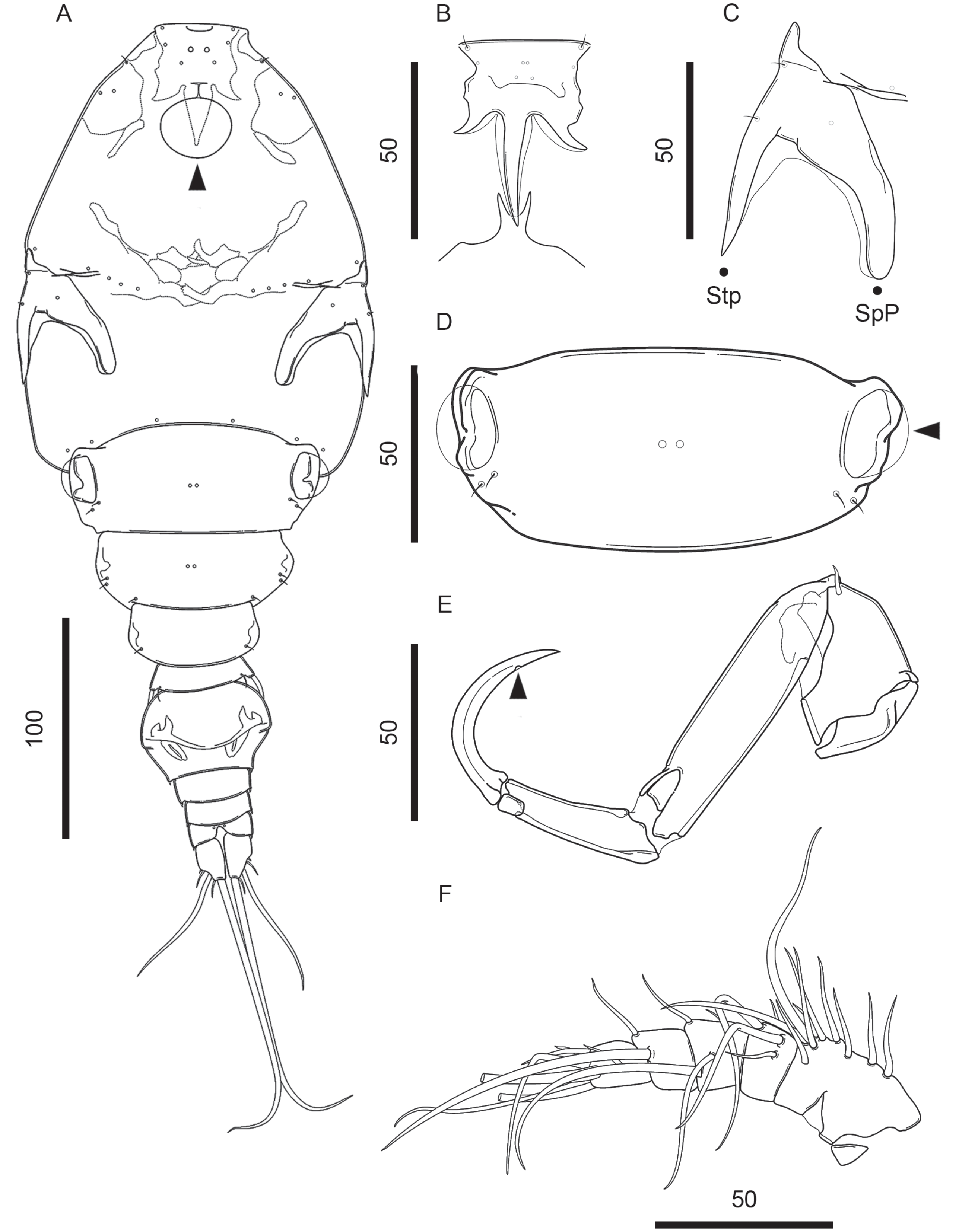

FIGURE 1. *Pseudovaigamus tridentatus* **n. sp.**—adult female. **A** body, dorsal view, cephalosome with circular integumental window (arrowhead). **B** rostral spine, ventral view. **C** retrostylet, dorsal view. **D** second pedigerous somite, dorsal view, with paired integumental windows laterally on tergite (arrowhead). **E** antenna, antennary claw with fossa on concave margin (arrowhead). **F** antennule. SpP = spatulate process. Stp = stylet process. Scale bars in µm.

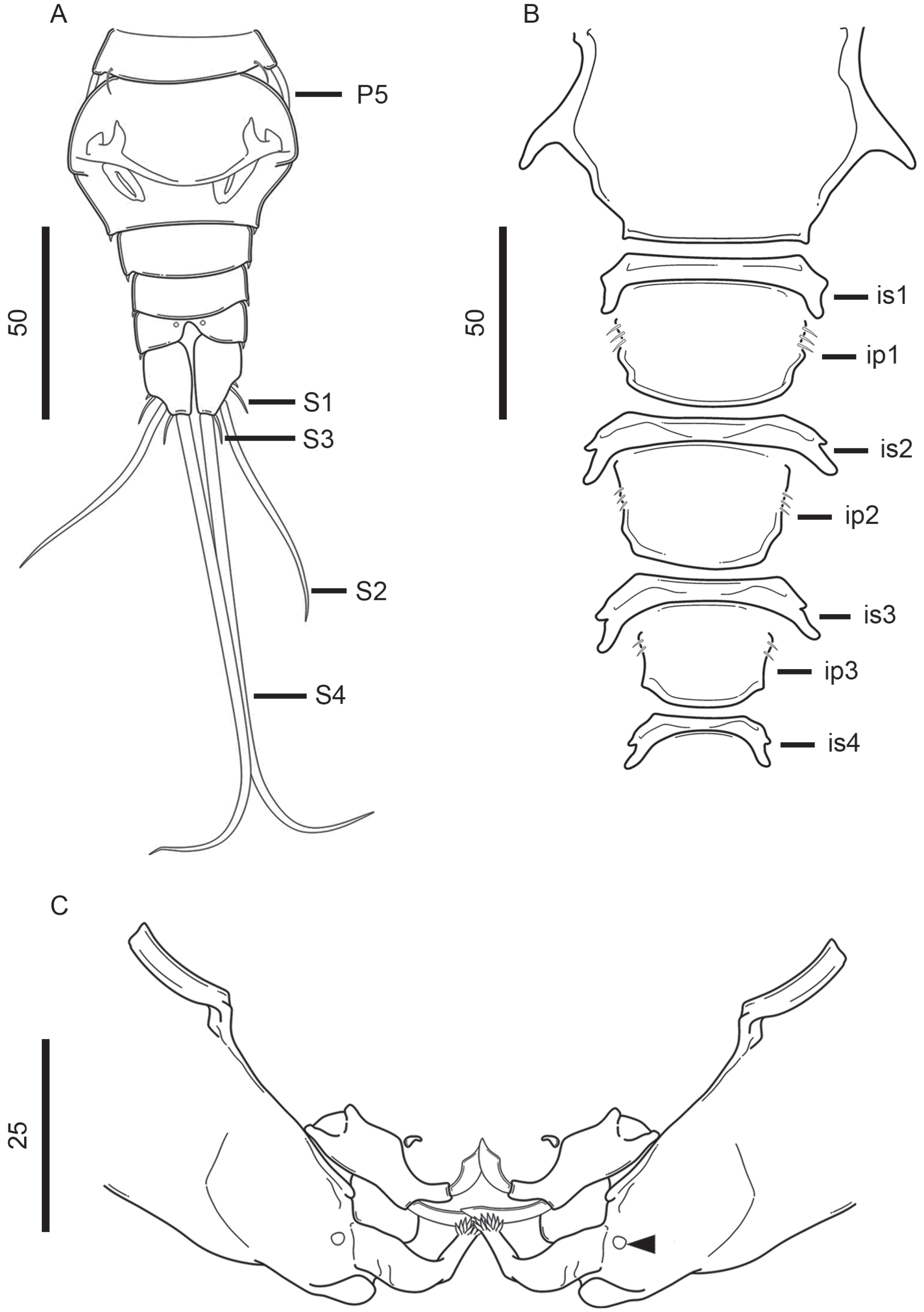

FIGURE 2. *Pseudovaigamus tridentatus* **n. sp.**—adult female. **A** urosome, dorsal view. **B** intercoxal sclerites and intercoxal plates, ventral view. **C** buccal apparatus. is1 to is4 = first to fourth intercoxal sclerites. ip1 to ip3 = first to third intercoxal plates. P5 = fifth leg. S1 = seta 1. S2 = seta 2. S3 = seta 3. S4 = seta 4. Scale bars in µm.

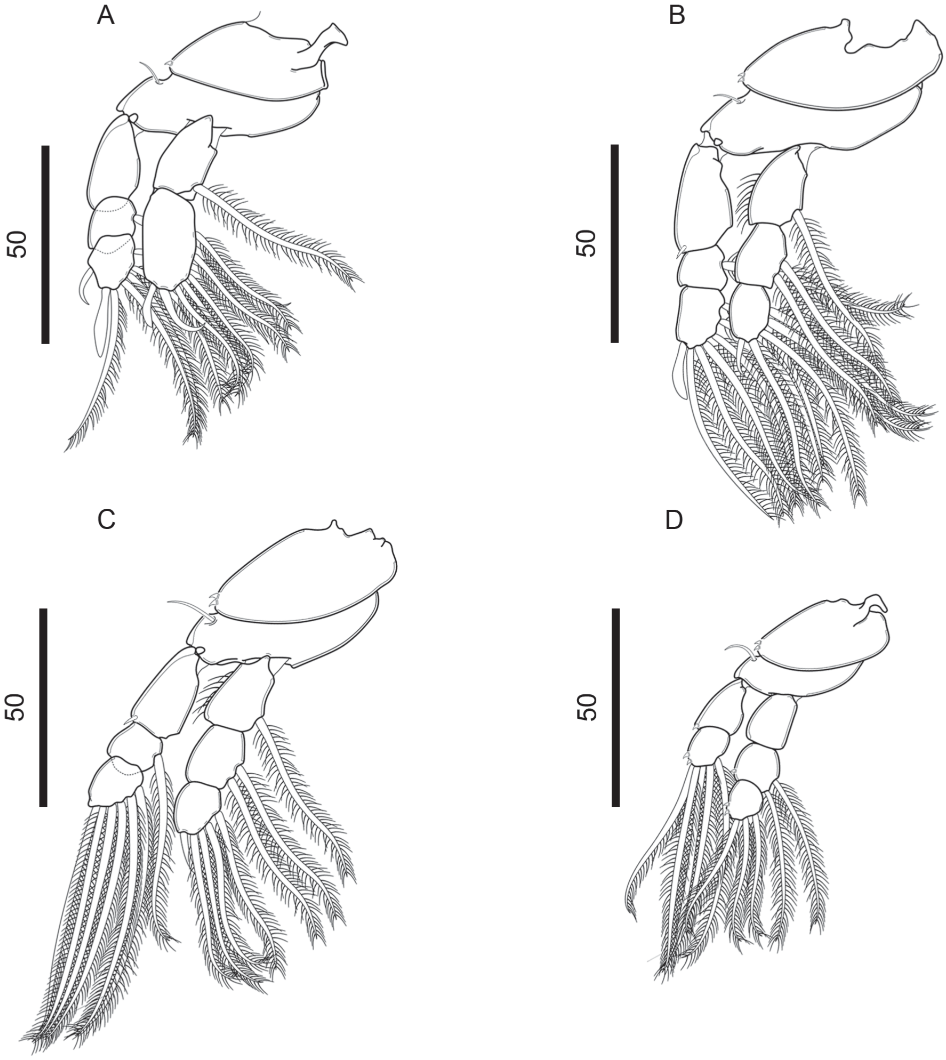

FIGURE 3. *Pseudovaigamus tridentatus* **n. sp.**—adult female. **A** leg 1. **B** leg 2. **C** leg 3. **D** leg 4. Scale bars in µm.

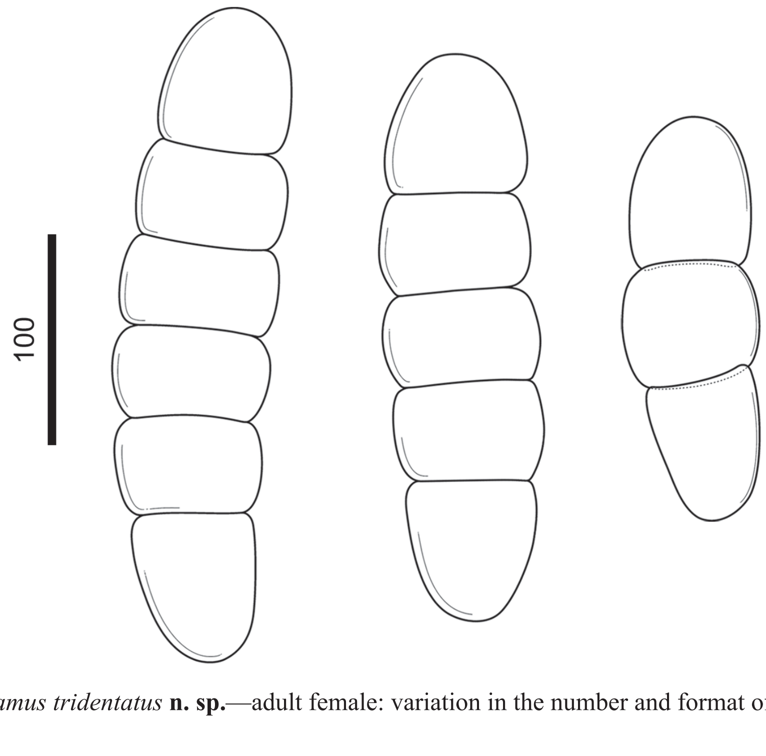

FIGURE 4. *Pseudovaigamus tridentatus* **n. sp.**—adult female: variation in the number and format of eggs Scale bars in µm.

TABLE 2. Measurements in micrometers (µm) of adult females of *Pseudovaigamus tridentatus* **n. sp.**

Character	Range (mean)
Total length [a]	362–383 (392)
Cephalothorax length	180–225 (200)
Cephalothorax width	153–185 (164,5)
Rostral spine length	55–67 (62)
Retrostylet length	65–79 (73)
Antennule length	91–108 (101)
Antenna segment 1 length	36–61 (52)
Antenna segment 2 length	87–100 (95)
Antenna segment 3 length	45–52,5 (48)
Antenna segment 4 length	7–10 (9)
Claw length [b]	55–64 (59)
Pedigerous somite 2 length	38–56 (43)
Pedigerous somite 2 width	110–124 (117)
Pedigerous somite 3 length	30–44 (38)
Pedigerous somite 3 width	85–95 (91)
Pedigerous somite 4 length	23–31 (25,5)
Pedigerous somite 4 width	55,5–68 (62)
Pedigerous somite 5 length	10–21 (14)
Pedigerous somite 5 width	44–61 (52)
Genital double-somite length	36–47 (41)
Genital double-somite width	59–65 (62)
Abdominal somite 1 length	9,5–13 (11)
Abdominal somite 1 width	36–42 (39)
Abdominal somite 2 length	10–12,5 (11)
Abdominal somite 2 width	32–40 (36)
Abdominal somite 3 length	11–15 (13)
Abdominal somite 3 width	28,5–36,5 (33)
Caudal ramus length	19–22,5 (21)
Caudal ramus width	12–16 (14)
Caudal ramus seta 1 length	7–12 (9,5)
Caudal ramus seta 2 length	47,5–67 (60)
Caudal ramus seta 3 length	8–12 (9)
Caudal ramus seta 4 length	116–141 (129)
Egg sac length	192–312 (258)
Egg sac width	66–78 (73)

[a] less caudal rami setae; [b] measured from the posterior margin to the tip

Buccal apparatus (Fig. 2C) comprising mandible, maxillule, and maxilla. Mandible armed with two blades (anterior and posterior blade); anterior blade widening distally, unornamented; posterior blade longer and thinner than previous blade, unornamented. Maxillule rounded, unornamented. Maxilla 2-segmented, comprising syncoxa (= first segment) and basis (= second segment); syncoxa broad, with subdistal pore (located immediately next to basis's insertion) (arrowed in Fig. 2C); basis narrowing distally, ornamented with multiple spinules.

P1 to P4 biramous (Figs. 3A–D), each leg comprising coxa, basis, endopod (= inner ramus), and exopod (= outer ramus). P1 (Fig. 3A); coxa ornamented with outer spinules; basis armed with bare outer seta; enp 2-segmented, both segments lacking any ornament on both margins; enp-1 (= proximal segment) armed with one plumose seta on inner margin; enp-2 (= distal segment) slightly longer than previous segment, armed with two distal spines (outer and inner spine); outer spine wider posteriorly, with rounded tip; inner spine about 1.5 times longer than previous spine, curved, with sharp tip; and five plumose setae on inner margin; exp 3-segmented, all segments lacking any ornament on both margins; exp-1 (= proximal segment) about 1.5 times longer than following segments, lacking any armament on outer margin; exp-2 (= middle segment) armed with one plumose seta on inner margin; exp-3 (= distal segment) armed with two spines (outer and inner spine); outer spine curved, with sharp tip; inner spine about 1.5 times longer than previous spine, wider posteriorly, with rounded tip; and five plumose setae on inner margin.

P2 (Fig. 3B); coxa ornamented with two outer spinules; basis armed with bare outer seta; enp 3-segmented; enp-1 (= proximal segment) ornamented with bristles along outer margin, armed with one plumose seta on inner margin; enp-2 (= middle segment) unornamented, armed with two plumose setae on inner margin; enp-3 (= middle segment) unornamented, slightly rounded, armed with single distal spine; spine curved, with sharp tip; and four plumose setae; exp 2-segmented, all segments lacking any ornament on both margins; exp-1 (= proximal segment) about 1.5 times longer than following segments, armed with single distal spine on outer margin; exp-2 (= middle segment) armed with one plumose seta on inner margin; exp-3 (= distal segment) armed with single distal spine; spine wider posteriorly, with rounded tip; and six plumose setae.

P3 (Fig. 3C) with same ornamentation and armament described for P2, except for exp-3 that on P3 lacks any spine.

P4 (Fig. 3D); coxa ornamented with two outer spinules, basis with bare outer seta; enp 3-segmented, all segments lacking any ornamented on both margins; enp-1 (= proximal segment) lacking any spine or seta on both margins; enp-2 (= middle segment) armed with minute spine on outer margin; spine smaller than those present on previous legs; and two plumose setae on inner margin; enp-3 (= distal segment) armed with two minute spines and three plumose setae; exp 2-segmented, both segments lacking any ornamented on both margins; exp-1 (= proximal segment) armed with minute spine on outer margin; exp-2 (= distal segment) armed with two minute spines and five plumose setae.

P5 reduced and represented by two bare setae (= ventrolateral and dorsal seta) (Fig. 2A); ventrolateral seta bigger and longer than dorsal seta; dorsal seta inserted on dorsal surface. Spine and setal formula of biramous legs is presented in Table 3.

TABLE 3. Armature of swimming legs of *Pseudovaigamus tridentatus* **n. sp.**—adult female. (Roman numeral = spines; Arabic numerals = setae). P1-P4 = first to fourth swimming leg

Swimming leg	Coxa	Basis	Endopod	Exopod
P1	I-0	1-0	0-1; II-5	0-0; 0-1; II-5
P2	II-0	1-0	0-1; 0-2; I-4	I-0; 0-1; I-6
P3	II-0	1-0	0-1; 0-2; I-4	I-0; 0-1; 0-6
P4	II-0	1-0	0-0; I-2; II-3	I-0; II-5

Intercoxal sclerites slender, unornamented, with both ends directed posteriorly (Fig. 2B). Intercoxal plates from P1 to P3 ornamented with spinules on lateral margins (Fig. 2B); intercoxal plate of P4, absent (Fig. 2B).

Egg sacs paired, uniseriate (Fig. 4). Number of eggs per sac ranging from 3 to 6. First and last eggs in each sac differ from intermediate eggs; first and last eggs subtriangular, about 1.5 times longer than wide; intermediate eggs thinner than previous eggs, subrectangular (Fig. 4).

Remarks. The new copepod was identified as a member of the Ergasilidae family by having: uniramous 4-segmented antennae comprising coxobasis (= first segment), 3-segmented enp (= second to fourth segments) and terminal claw; mandible bearing two blades; maxilla 2-segmented with basis (= second segment) ornamented with distal spinules; and P4 exp 2-segmented. Furthermore, it was also recognized as a member of this family based on the absence of maxillipeds on parasitic adult females (Boxshall & Halsey 2004). Within the Ergasilidae, the new copepod can be readily distinguished from other ergasilids, with exception of those of the vaigamid subgroup (i.e. monophyletic group within Ergasilidae composed of five genera: *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 retrostylets (Narciso & Silva 2020).

Among the five vaigamid genera, the new copepod was identified as a new member of the monotypic genus *Pseudovaigamus* for possessing P4 with 3-segmented enp and 2-segmented exp (rather than P4 with 2-segmented enp and 1-segmented exp as in other vaigamid species). Additionally, the new copepod was also identified as a member of *Pseudovaigamus* since it shares with the type-species, *P. spinicephalus*, the following combination of features: (1) rostrum armed with rostral spine (rather than rostrum lacking rostral spine as in members of *Gamidactylus* and *Gamispinus*); (2) antenna armed with single terminal claw (rather than two terminal claws as in members of *Gamidactylus*, *Gamispatulus,* and *Gamispinus*); and (3) second and third antennary segments unornamented (rather than carrying multiple spinules on inner and/or outer margin as in members of *Gamidactylus*, *Gamispatulus,* and *Gamispinus*). Although *Pseudovaigamus* shares several similarities with *Vaigamus*, the segmentation pattern of P4 (described above) exhibited by *Pseudovaigamus* species (including the new species described herein) allows the differentiation between the two genera (Amado *et al*. 1995).

The new copepod *Pseudovaigamus tridentatus* **n. sp.** differs from its congener in several features. The rostral spine present in *P. tridentatus* **n. sp.** is trifid (comprising long and straight middle spine, and two lateral curved spines), whereas in *P. spinicephalus* it is simple (or carrying only the middle spine). The number of antennule segments is different: in *P. tridentatus* **n. sp.** antennule is 5-segmented, whereas in *P. spinicephalus* it is 6-segmented. Moreover, the rostral spine in *P. spinicephalus* is characterized by having a subbasal swelling which is absent in the new species. The morphology of retrostylets is also different: in *Pseudovaigamus tridentatus* **n. sp.** the innermost portion of this structure extends posteriorly forming a "spatulate" process similar in size to the stylet, whereas in *P. spinicephalus*, even though it carries a similar process (not quoted in the text of the original description), the spatulate process in this species is much smaller than the stylet (see Fig. 5 for a comparison). Another difference between both species is the morphology of caudal rami: in *P. spinicephalus* each ramus carries a distal lobe covered with multiples spinules, such lobe was not seen in the new species (Fig. 2A). Finally, the armature of legs in *P. tridentatus* **n. sp.** differs in several aspects from those present in *P. spinicephalus*, as follow: (1) coxa from P1 to P4 carries one or two lateral spinules in *P. tridentatus* **n. sp.** vs coxa unornamented as in *P. spinicephalus*; (2) P1 exp-1 lacks any spine on outer margin in *P. tridentatus* **n. sp.** vs carrying one distal spine on outer margin as in *P. spinicephalus*; (3) distal spines from P1 to P3 exp-3 and P1 enp-2 become wider distally in *P. tridentatus* **n. sp.** vs spines narrowing posteriorly and with sharp tip as in *P. spinicephalus*; and (4) P4 enp-1 lacks any armature element (e.g. spine and/or seta) in *P. tridentatus* **n. sp.**, whereas in *P. spinicephalus* it carries one plumose seta on inner margin (see Fig. 34 in Thatcher & Robertson 1984). Based on the morphological differences described above, we propose herein a new species, *P. tridentatus* **n. sp.**, to the ergasilid genus *Pseudovaigamus*.

Discussion

The antennules of adult ergasilids are short, uniramous, and have a maximum number of segments equal to six (most ergasilids) (El-Rashidy 1999). Comparing with the standard antennule (7-segmented) proposed by Boxshall & Huys (1998) for the members Poecilostomatoida (currently included within the suborder Ergasilida) we verified that during the development in ergasilids (mainly in the transition from copepodite V to adult) there is a failure in the expression of the segmentation between the segments 3 and 4 of the standard antennule (El-Rashidy 1999). A second failure also occurs in Ergasilidae, in these species (including the new species proposed herein) the antennules of adults consist of five segments (El-Rashidy 1999). This second failure, similarly to the first, probably occurs due to the non-expression of the segmentation between segments 2 and 3 of the standard antennule (El-Rashidy 1999). Huys & Boxshall (1991) proposed that such compound segments (or fused segments) can arise from two different processes: first, as a result of non-separation during the development, and second as a result of a subsequent merger. The first hypothesis, in addition to being the most parsimonious, is also corroborated in Ergasilidae by the available data on the life cycle of some ergasilids (Urawa *et al*. 1980; Alston *et al*. 1996; Kim 2004), which indicate that the separation of the first and largest segment (i.e. equivalent to ancestral segments I to XX) of the antennule (present from the first copepodite stage to the fifth) occurs in the transition from the last phase of copepodite (= copepodite V) to adult phase. The new species has a separation in the first segment, but this is not complete and is represented by a groove in the posterior margin of that segment (see Fig. 1F). Although the number of antennule segments is commonly used to differentiate genera, this was not considered sufficient herein to separate the new species into another genus since it shares several features with the type-species (e.g. number of claws, possession of rostral spine, segmentation of the third leg) and variations in the number of antennule segments have already been registered within other ergasilid genera such as *Ergasilus* von Nordmann, 1832 and more recently in *Rhinergasilus* Boeger & Thatcher, 1988 (i.e. 5-segmented in *Rhinergasilus piranhus* Boeger & Thatcher, 1988- type-species and 6-segmented in *Rhinergasilus digitus* Narciso, Brandao, Perbiche-Neves & Silva, 2020, and *Rhinergasilus unguilongus* Narciso, Perbiche-Neves & Silva, 2020). *Rhinergasilus piranhus* as well as the new species is small (i.e. about half the size of its congeners) and has the first antennule segment incompletely divided (Boeger & Thatcher 1988).

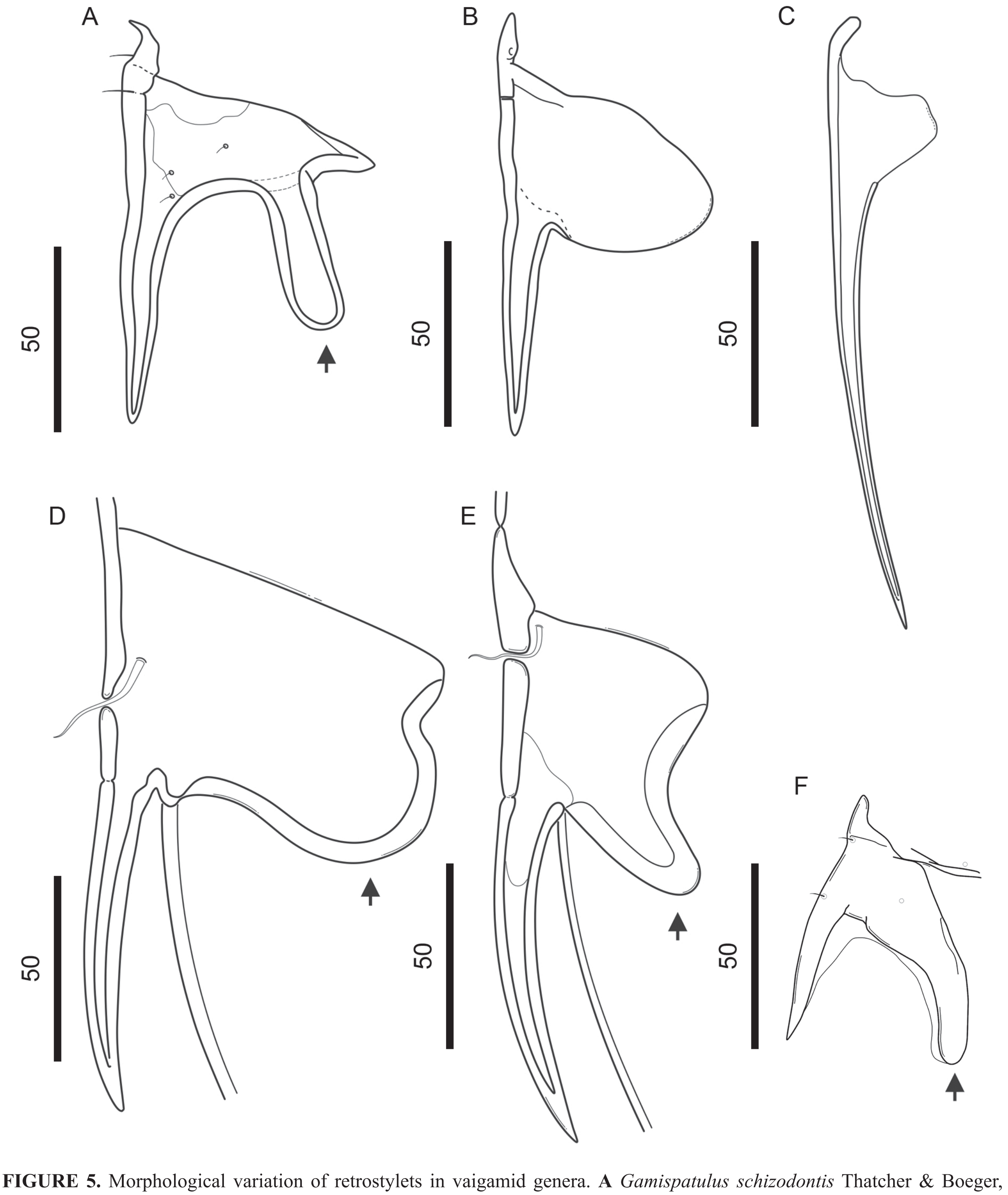

FIGURE 5. Morphological variation of retrostylets in vaigamid genera. **A** *Gamispatulus schizodontis* Thatcher & Boeger, 1984 from Thatcher & Boeger (1984a), with spatulate process (seta). **B** *Gamispinus diabolicus* Thatcher & Boeger, 1984 from Thatcher & Boeger (1984b). **C** *Gamidactylus piranhus* Thatcher, Santos & Brasil-Sato, 2008 from Thatcher *et al*. (2008). **D** *Vaigamus retrobarbatus* Thatcher & Robertson, 1984 from Thatcher & Robertson (1984), with innermost portion extending posteriorly (seta). **E** *Pseudovaigamus spinicephalus* (Thatcher & Robertson, 1984) from Thatcher & Robertson (1984), with innermost portion extending posteriorly (seta). **F** *Pseudovaigamus tridentatus* **n. sp**., with innermost portion extending posteriorly (seta). Scale bars in µm.

The possession of cephalothorax equipped with dorsolateral retrostylets is considered an important diagnostic feature for the subgroup of vaigamids, being present in all known species (Narciso & Silva 2020). Despite their importance, these structures are generally not very detailed in their descriptions or even mentioned during the species differentiation, excepting *Gamispatulus schizodontis* Thatcher & Boeger, 1984 for presenting retrostylets with accessory spatulate processes (hitherto exclusive of this species) (Thatcher & Boeger 1984). The new species has the medial portion of its retrostylet protruded posteriorly forming "spatular projections" similar to those found in *G. schizodontis*, however, these projections have a different shape (see Fig. 5 for comparison) and are located at the end of this structure (instead of being central as in *G. schizodontis*). Previous differences indicate that both spatular projections are likely to have different origins in the two species. On the other hand, the retrostylet presented in the original description of *P. spinicephalus* (see Fig. 26 in Thatcher & Robertson 1984) shows a similar, but smaller, spatular projection than that present in the new species. Despite having such projection, it was not mentioned in the original description of *P. spinicephalus*, or even was mentioned after its transfer from *Vaigamus* to *Pseudovaigamus* by Amado *et al*. (1995). Due to the presence of this projection in the retrostylet of the type species and for sharing other diagnostic characteristics (mentioned above) that the new species was allocated in *Pseudovaigamus* instead of *Gamispatulus*. More detailed characterization of the retrostylets may be very useful for distinguishing and/or establishing better phylogenetic relationships within and between species of vaigamids, mainly as the number of new species described for this group increases.

The genus *Pseudovaigamus* was originally proposed based on specimens (including adult males and ovigerous females) collected from plankton samples from the Tocantins River, Pará State, Brazil (Thatcher & Robertson 1984). Since the description of *P. spinicephalus* by Thatcher & Robertson (1984), other vaigamids have been found in the northern region as well as in other regions of the country (e.g. South and Southeast), but so far this species has no known hosts or has already been registered in another location (Narciso & Silva 2020). São Paulo State is considered the Brazilian region with the largest number of studies about microcrustaceans (Silva & Perbiche-Neves 2017). Recent descriptions of new ergasilids indicate that this state has great potential for discoveries of new taxa (Narciso & Silva 2020). Our findings contribute to an increase in knowledge about this genus through the registration for the first time of a *Pseudovaigamus* species attached to a fish host and expand the geographical distribution of this genus beyond the northern region of Brazil (i.e. first report of *Pseudovaigamus* in São Paulo State, Brazil).

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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

Alston, S., Boxshall, G.A. & Lewis, J.W. (1996) The life-cycle of *Ergasilus briani* Markewitsch, 1993 (Copepoda: Poecilostomatoida). *Systematic Parasitology*, 35, 79–110. https://doi.org/10.1007/BF00009818

Boeger, W.A. & Thatcher, V.E. (1988) *Rhinergasilus piranhus* gen. et sp. n. (Copepoda, Poecilostomatoida, Ergasilidae) from the Nasal Cavities of Piranha Caju, *Sermsalmus nattereri*, in the Central Amazon. *Proceedings of the Helminthological Society of Washington*, 55 (1), 87–90.

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. & Huys, R. (1998) The ontogeny and phylogeny of copepod antennules. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 353 (1369), 765–786. https://doi.org/10.1098/rstb.1998.0242

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

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

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

Huys, R. & Boxshall, G.A. (1991) *Copepod evolution*. Ray Society, London, 476 pp.

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

Kim, I.H. (2004) Copepodid stages of *Ergasilus hypomesi* Yamaguti (Copepoda, Poecilostomatoida, Ergasilidae) from a brackish lake in Korea. *Korean Journal of Biological Sciences*, 8 (1), 1–12.
https://doi.org/10.1080/12265071.2004.9647727

Narciso, R.B. & Silva, R.J. (2020) Two *Gamispatulus* Thatcher & Boger, 1984 (Cyclopoida: Ergasilidae) from *Schizodon intermedius* Garavello & Britski (Actinopterygii: Anostomidae), with description of a new species. *Zootaxa*, 4803 (6), 463–482.
https://doi.org/10.11646/zootaxa.4803.3.3

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

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, 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

Urawa, S., Muroga, K. & Kasahara, S. (1980) Studies on *Neoergasilus japonicus* (Copepoda: Ergasilidae), a Parasite of Freshwater Fishes – 11 Development in Copepodid Stage. *Journal of the Faculty of Applied Biological Science, Hiroshima University*, 19, 21–38.