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A new species of *Ergasilus* (Copepoda: Ergasilidae) from *Geophagus altifrons* and *G. argyrostictus* (Perciformes: Cichlidae) in the Brazilian Amazon

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Abstract

A new species of ergasilid copepod, *Ergasilus xinguensis* n. sp**.**, is described from females found on the gills of two cichlid fishes, *Geophagus argyrostictus* (Kullander, 1991) (type host) and *G. altifrons* (Heckel, 1840), from the Brazilian Amazon. The new species can be distinguished from congeners by the unique combination of the following characteristics: the cephalothorax is not inflated and is slightly constricted, the first antennulary segment bears 3 setae, maxillule with 3 unequal outer setae without minute process medially, maxilla has a large syncoxa with one seta near its basis, first and fourth legs are with a 3-segmented endopod, base of the exopod in leg 2 with a conspicuous bluntly-pointed projection and caudal ramus with two rows of curved conical spinules on ventral surface. The new species is the second member of *Ergasilus* von Nordmann, 1832 found on cichlids of the genus *Geophagus* (Heckel).

Keywords

Copepoda, Ergasilidae, *Ergasilus*, Cichlidae, *Geophagus*, Xingu River, Brazil

Introduction

The Ergasilidae von Nordmann, 1832 is one of the biggest families in the order Cyclopoida Burmeister, 1835, with most species found on freshwater fishes. Only adult females of ergasilids are parasitic on gills, fins, inside the nasal fossae, embedded in host tissues or in the urinary bladder of actinopterygian fishes, and rarely on the gills of elasmobranchs and bivalve molluscs (Kabata 1979; Boxshall and Halsey 2004; Rosim *et al.* 2013).

The ergasilids comprise about 270 described species distributed in 27 genera throughout the world, with *Ergasilus* being the most species-rich genus containing approximately two-thirds of the described species in the family (Boxshall and Montú 1997; El-Rashidy and Boxshall, 2002; Rosim *et al.* 2013). According to Boxshall and Defaye (2008), the Neotropical region has the second highest richness of freshwater copepods globally, with ergasilids representing about 11% of the total richness (16 genera) in this region. However, some authors assume that only a small proportion of existing ergasilids is currently known (Montú and Boxshall 2002; Rosim *et al.* 2013; Marques *et al.* 2015).

Twenty two freshwater species of *Ergasilus* are known from the gills of Neotropical teleosts and one species of ray. Two species of *Ergasilus* have been reported from cichlid fishes in the Neotropics, namely *E. coatiarus* Araújo and Varella, 1998 from *Cichla monoculus* (Bloch and Schneider, 1801), *C. orinocensis* (Humboldt, 1833) and *C. temensis* (Humboldt, 1821) in the Amazon basin, and *E. pitalicus* Thatcher, 1984 from *Cichlasoma* sp. in the Pital River, Colombia. In addition, *Ergasilus* sp. has been reported from *Cichlasoma trimaculatum* (Günther 1867) in Tres Palos Lagoon, Guerrero, Mexico (Thatcher 1984a; Violante-González *et al*. 2008; Morales-Serna *et al*. 2012; Luque *et al*. 2013).

During a parasitological survey of metazoan parasites of freshwater fishes in the Brazilian Amazon, ectoparasitic copepods of the genus *Ergasilus* were found on two species of

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Geophagus, namely *G. argyrostictus* (Kullander, 1991) and *G. altifrons* (Heckel, 1840) (Perciformes: Cichlidae). A morphological study of these specimens has revealed that they represent an as yet unknown species of *Ergasilus*, which is described herein.

Materials and Methods

Copepods were collected from the gills of *G. argyrostictus* and *Geophagus altifrons* caught in the Xingu River around Altamira, State of Pará, Brazil (3°12´S, 52°12´W). Gills were placed in Petri dishes with tap water and examined for copepods using dissecting microscope. Copepods found were fixed and preserved in 70% ethanol. Drawings were made with the aid of an Olympus BX53 microscope (Olympus Corporation, Tokyo, Japan) equipped with a drawing tube. Measurements are in micrometres (μm) unless otherwise stated and are presented as a range of values of specimens from type host, with data on specimens from *G. altifrons* in parentheses. Type specimens of the new species are deposited in the Crustacea Collection of the National Museum of Rio de Janeiro (MNRJ), Brazil. Terminology follows Boxshall and Halsey (2004). The scientific names of fish hosts follow Froese and Pauly (2015).

Results

Order Cyclopoida Burmeister, 1835
Family Ergasilidae von Nordmann, 1832
***Ergasilus xinguensis* n. sp.** (Figs. 1–3)

Adult female (based on 6 specimens from *G. argyrostictus* and 2 specimens from G. *altifrons*). Body length from anterior margin of prosome to posterior of caudal rami 797–939 (786–807). Body comprising prosome and urosome (Fig. 1A); prosome consisting of cephalosome, with antennule and antenna visible in dorsal view and 4 pedigerous somites. Cephalosome and first pedigerous somite fused. Cephalothorax longer than wide, 449–471 (456–463) long, 350–379 (311–350) wide, not inflated and slightly constricted, comprising more than half body length. Urosome consisting of fifth pedigerous somite, genital double-somite, and 3 free abdominal somites; third abdominal somite bipartite. Genital double-somite (Fig. 2A) wider than long, 65–78 (74–82) long, 77–97 (77–78) wide, with ventral surface ornate with 2 rows of acute spinules along posterior margin. Free abdominal somites decreasing in width posteriorly; first and second nearly equal in length; anal somite bipartite, smaller than previous two. Posteroventral margin of abdominal somites ornamented with 2 rows of spinules (first and second somites) or a row (anal somite).

Caudal rami nearly equal in length to anal somite; 2 rows of curved conical spinules on ventral surface extending near posterior and medial margins; each ramus armed with large medial seta, 2 setae ventrally and seta at outer corner. Two egg-sacs (Fig. 2B), much longer than wide, each composed of 2–4 rows of eggs.

Antennule 6-segmented (Fig. 1D), tapering distally, aesthetascs present on third, fifth and sixth segments; setal formula as follows: 3: 11: 5 + ae: 4: 2 + ae: 5 + ae: all setae naked.

Antenna comprising coxobasis, 3-segmented endopod with curved terminal claw (Fig. 1B). Coxobasis short, widest proximally; membrane between coxobasis and first endopodal segment not inflated. First endopodal segment nearly 3× longer than coxobasis; armed with peg seta on internal margin. Second endopodal segment slightly curved, about 2× longer than coxobasis, armed with one curved spiniform element proximally and one distally on inner margin. Third endopodal segment small, bearing long claw nearly as long as second endopodal segment.

Mouthparts comprising mandible, maxillule and maxilla; maxilliped absent (Fig. 1C). Mandible unsegmented, bearing anterior, middle and posterior blades; anterior blade small, with teeth along anterior margin; middle and posterior blade with smooth teeth along posterior margin. Maxillule small, bearing 3 unequal outer setae. Maxilla comprising large syncoxa with one seta near basis; second segment (basis), bearing long, sharp teeth anteriorly and spinulate seta located at middle of basis.

Swimming legs 1–4 biramous (Fig. 3A–D), each with 2-segmented protopod comprising coxa and basis; interpodal plates (Fig. 2D) with a row of spinules (legs 1 and 2) or lacking spinules (legs 3 and 4). Coxa of all legs with smooth margins, lacking spinules. Basis with outer seta present on posterior surface of all legs, inner margin with a row of spinules (legs 1 and 4) or 2 rows (legs 2 and 3). Basis of leg 2 with conspicuous bluntly-pointed projection between bases of rami. All legs 3-segmented, except 2-segmented fourth exopod. Outer margins of both rami partly or completely covered with rows of spinules. Endopod of leg 4 with a row of spinules in posteroventral surface of each segment. Inner margin of first exopodal segment of legs 2, 3 and 4 setulate.

Armature of legs (spines, Roman numerals; setae, Arabic numerals) as follows:

	Coxa	**Basis**	**Exopod**	**Endopod**
Leg 1	0–0	1–0	I–0; I–1; II–5	0–1; 0–1; II–4
Leg 2	0–0	1–0	I–0; 0–1; 0–6	0–1; 0–2; I–4
Leg 3	0–0	1–0	I–0; 0–1; 0–6	0–1; 0–2; I–4
Leg 4	0–0	1–0	I–0; 0–5	0–1; 0–2; I–3

Fifth leg (Fig. 2C) short, bearing outer seta on protopod, 2 setae located distally (sub-apical slightly larger than apical) and one small seta laterally on free segment.

Male: Unknown

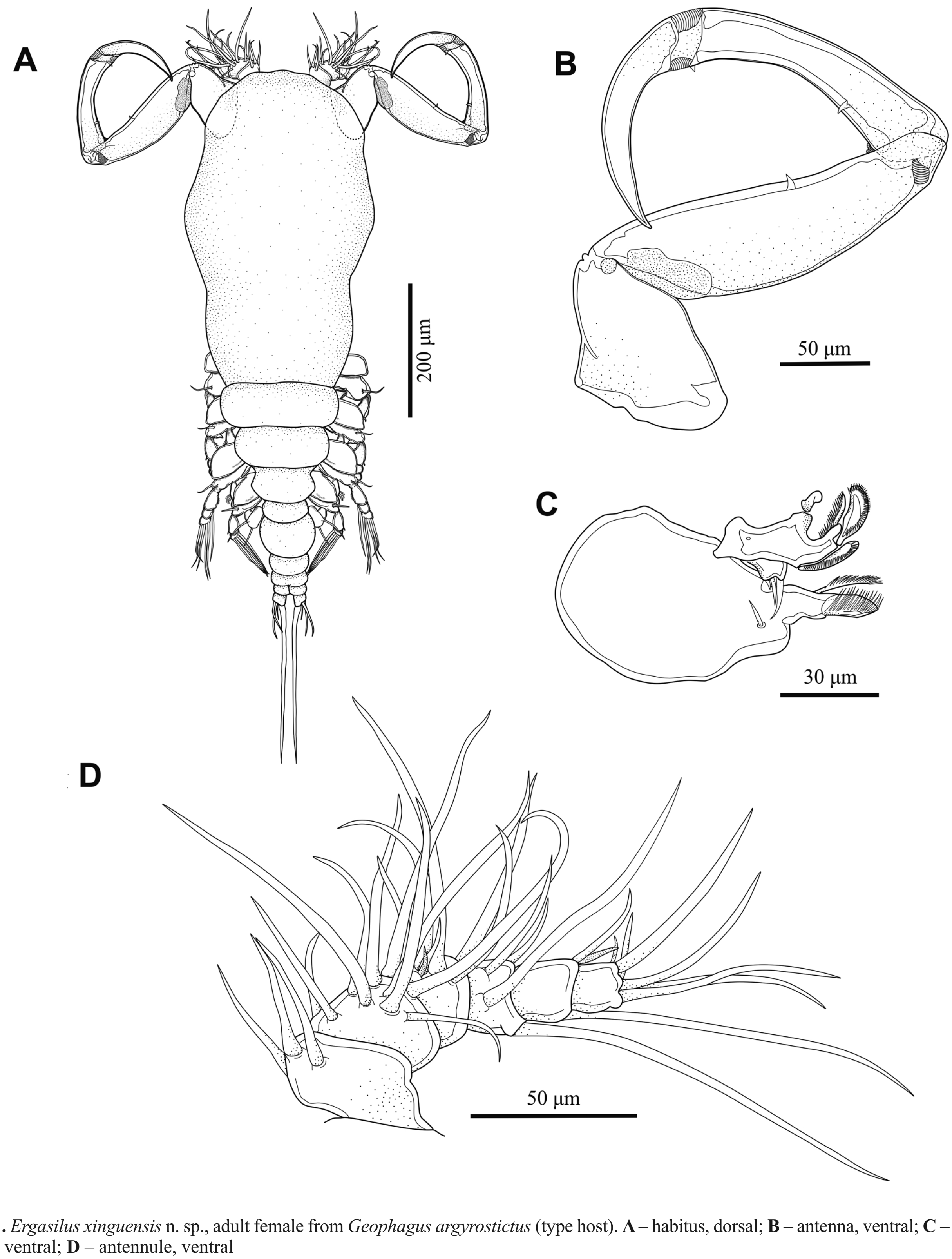

Fig. 1. *Ergasilus xinguensis* n. sp., adult female from *Geophagus argyrostictus* (type host). **A** – habitus, dorsal; **B** – antenna, ventral; **C** – mouthparts, ventral; **D** – antennule, ventral

Taxonomic summary

Type host: *Geophagus argyrostictus* Kullander.

Other host: *Geophagus altifrons* Heckel.

Site on host: Gill filaments.

Type-locality: Xingu River, Altamira (3°12‘S, 52°12‘W), State of Pará, Brazil.

Date of collection: 25 April 2013.

Prevalence: 18% in *Geophagus argyrostictus* (n = 11) and 6% in *Geophagus altifrons* (n = 16).

Mean intensity of infection: 1.5 in *Geophagus argyrostictus* and 11.0 in *Geophagus altifrons*.

Material deposited: Holotype ♀ (MNRJ-26133) and paratype ♀ (MNRJ-26134) from the gills of *Geophagus argyrostictus* (type host) and three paratypes ♀♀ (MNRJ-26135) from the gills of *G*. *altifrons* (Perciformes: Cichlidae).

Etymology: This species is named after the type locality from where it was collected, the Xingu River, a tributary of the Amazon River.

Remarks

Specimens found on two species of *Geophagus* belong to *Ergasilus* because they possess: (1) biramous leg 4 with a 2-segmented exopod and 3-segmented endopod, (2) 6-segmented antennule, (3) antenna with a single claw, (4) reduced maxillae, and (5) maxillipeds absent in females (Boxshall and Halsey 2004; Suárez-Morales and Santana-Piñeros 2008). The

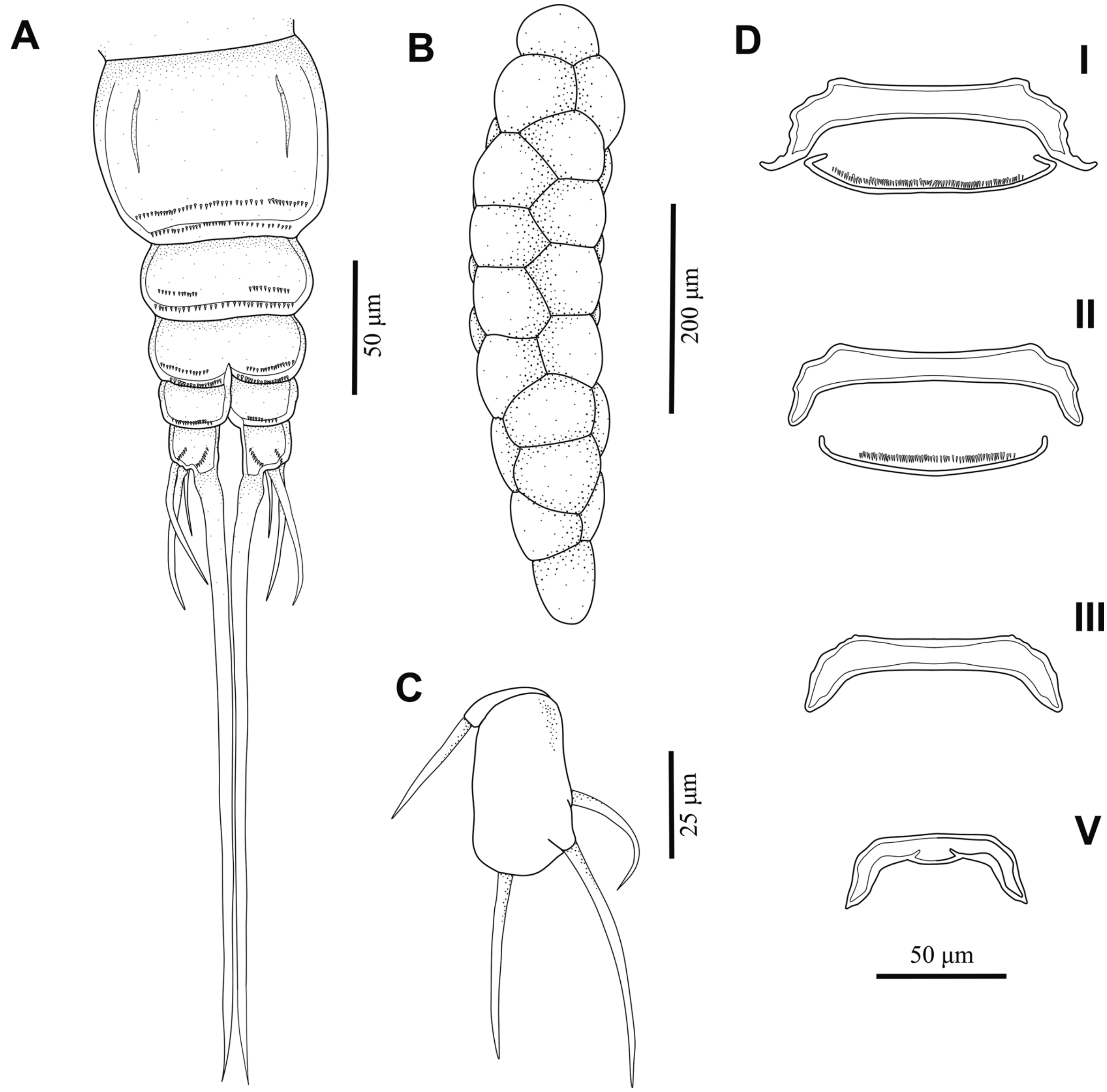

Fig. 2. *Ergasilus xinguensis* n. sp. adult female from *G. argyrostictus*. **A** – abdomen and caudal rami, ventral; **B** – egg sac, dorsal; **C** – leg 5, ventral; **D** – interpodal plates of legs 1 to 4 (numbered 1 to 4), ventral

new species, *E. xinguensis*, is mainly characterized by the presence of the first and fourth legs with a 3-segmented endopod and first antennulary segment with 3 setae. Of 22 species of *Ergasilus* parasitizing freshwater fishes in the Neotropics, only *E. colomesus* Thatcher and Boeger, 1983; *E. pitalicus* Thatcher, 1984; *E. trygonophilus* Domingues and Marques, 2010 and *E. sinefalcatus* Marques, Boeger and Brasil-Sato, 2015 have the fourth leg with a 3-segmented endopod, but only *E. pitalicus* is found in cichlids. All these species can be easily separated from *E. xinguensis* n. sp. by the possession of the first antennulary segment with a single seta and first leg with a 2-segmented endopod (Thatcher and Boeger 1983; Thatcher 1984a; Domingues and Marques 2010; Marques *et al*. 2015), whereas the new species possesses the first antennulary segment with 3 setae and first leg with a 3-segmented endopod. Another species parasitizing a Neotropical cichlid, *Ergasilus coatiarus* has the first leg with 2-segmented endopod.

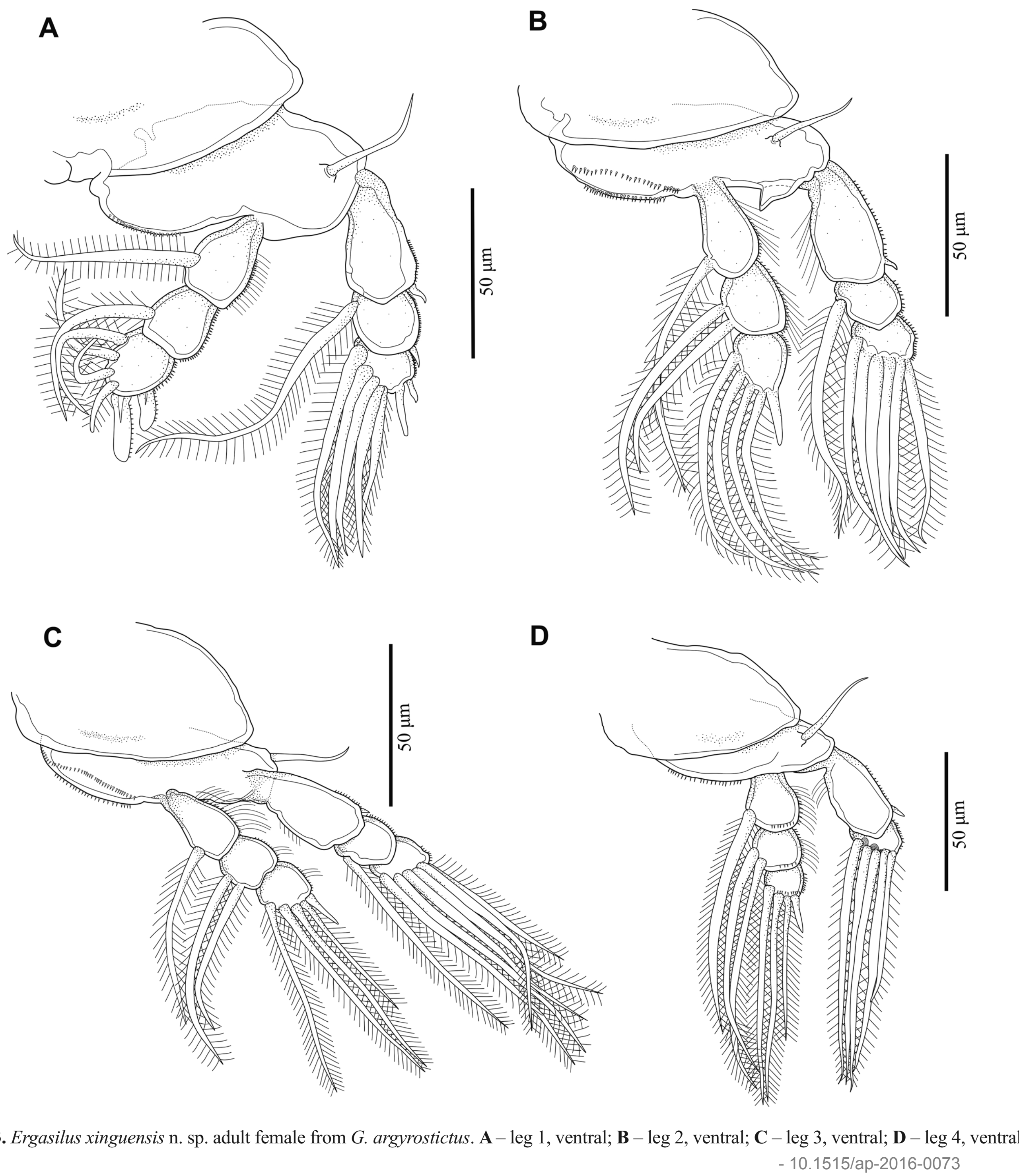

Fig. 3. *Ergasilus xinguensis* n. sp. adult female from *G. argyrostictus*. **A** – leg 1, ventral; **B** – leg 2, ventral; **C** – leg 3, ventral; **D** – leg 4, ventral

A recently described species, *E. sinefalcatus* from *Salminus franciscanus* (Lima and Britski, 2007) in the São Francisco River, Brazil, also has the first leg with a 2-segmented endopod and fourth leg with 3-segmented endopod, but the number of seta(e) in the first antennulary segment presented in the morphological description differs from that in drawing (see Fig. 3 in Marques *et al*. 2015).

It should be noted that the presence of the first and fourth legs with a 3-segmented endopod as observed in the new species, is also typical of seven brackish-water species of *Ergasilus* in South America and *E. sieboldi* von Nordmann, 1832, a cosmopolitan parasite of freshwater fishes (Yamaguti 1939; Kabata 1979; Amado and Rocha 2001). However, the new species differs from these parasites in the presence of a conspicuous bluntly-pointed projection between bases of rami in Leg 2 and by form of the cephalothorax, which is not inflated, but it is slightly constricted. *Ergasilus xinguensis* n.sp. can also be distinguished from all, except *E. lizae* Krøyer, 1863 in the absence of seta in the syncoxa in maxilla, whereas the new species possesses a seta, near basis.

In addition, the new species differs from *E. atafonensis* Amado and Rocha, 1995 from *Mugil curema* in Rio de Janeiro, Brazil and *E. orientalis* Yamaguti, 1939 from *Acanthogobius flavimanus* and *Atherina bleekeri* in Japan by the absence of an inflate membrane between the coxobasis and the first segment of endopod, from *E. bahiensis* Amado and Rocha, 1995 from *Mugil curema* in Bahia, Brazil and *E. sieboldi* Nordmann, 1832 by all coxa nude, and from *E. parabahiensis* El-Rashidy and Boxshall, 1999 from *Agonostomus monticola* in Guyana by the maxilla and maxillule lacking spinules. It differs from *E. sergipensis* Amado and Rocha, 2001 in Sergipe, Brazil and *E. xenomelanirisi* Carvalho, 1955 from *Xenomelanirisi brasiliensis* in São Paulo, Brazil by the basis ornamented with rows of spinules on the inner margin.

Finally, among the brackish-water species of *Ergasilus*, the new species closely resembles *E. lizae*, a world widely distributed parasite of mullets (Mugilidae) by the shared presence of seta in the syncoxa in maxilla and a conspicuous bluntly-pointed projection between bases of rami in leg 2. El-Rashidy (1999) re-examinated the lectotype and paralectotype of *E. lizae* from Copenhagen Museum providing new information about its morphology that allowed a detailed comparison with the new species. The adult female of *E. lizae* can be differentiated from the new species by the cephalothorax inflated and clearly constricted (not inflated and slightly constricted in *E. xinguensis* n. sp.), genital double-somite ornamented with several rows of spinules on ventral surface (genital double-somite ornamented with 2 rows of spinules along posterior margin in the new species), armature of the antennule 3: 13: 5+ae: 4+ae: 2+ae: 7+ae, (3: 10: 5 + ae: 4: 2 + ae: 5 + ae in the new species), maxillule with three unequal outer setae and minute medial process (three unequal outer setae without minute process in the new species), syncoxa ornamented with a rows of spinules (without spinules in the new species), coxa on leg 1 and leg 2 ornamented with a row of spinules along outer margin (without spinules in all coxa in the new species), basis on leg 1 without spinules along inner margin (a row of spinules in the new species), and caudal ramus without spinules on ventral surface (two rows of curved conical spinules in the new species).

Discussion

At present, 774 species of copepods, 189 species of isopods and 133 species of branchiurans are known to parasitize marine and freshwater fishes in the Neotropical Region (Luque and Poulin 2007; Morales-Serna *et al*. 2012). A total of 1.338 host-parasite associations among crustaceans and fishes have been reported, with the highest number of records from Brazil (Luque *et al*. 2013). In contrast, records of parasitic copepods from cichlid fishes in Brazil are scarce, even though they represent one of the common groups of freshwater fishes.

Most of the 56 freshwater species of ergasilids found in Brazil occur on fish of the families Anostomidae, Characidae, Pimelodidae and Prochilodontidae (Tavares-Dias *et al.* 2015). In addition to *E. coatiarus* Araújo and Varella, 1998, *E. pitalicus* Thatcher, 1984 and *E. xinguensis* described in this paper, another two parasitic copepods are known from cichlids in Brazil, *Acusicola tucunarense* Thatcher, 1984 from *Cichla ocellaris* (Bloch and Schneider, 1801) in the Amazon River basin, and *Urogasilus brasiliensis* Rosim, Boxshall and Ceccarelli, 2013 from *Cichla piquiti* (Kullander and Ferreira 2006 in the Araguaia River basin (Thatcher 1984b; Luque and Tavares 2007; Luque *et al*. 2013; Rosim *et al*. 2013). However, only a small proportion of cichlids has been examined for parasites and thus it is probable that the fauna of ergasilids on these fish hosts is much richer.

Neotropical cichlids originated in Africa (Murray 2001; Poletto *et al*. 2010), where they have diversified considerably, with different behavior adapted to different environments (Keenleyside 1991). Oldewage (1988) listed 13 species of African ergasilids; they can be distinguished easily from *E. xinguensis* by different patterns of ornamentation on cephalothorax.

Twenty six species of *Geophagus* are known in South America and one in Central America (Froese and Pauly 2015), but most of them have not been studied for parasites. The discovery of *E. xinguensis* not only represents the first species of a parasitic copepod reported from *G. argyrostictus* and *G. altifrons*, but also the second record of an ergasilid on *Geophagus* spp. in the Neotropics. Formerly, *E. lizae* was recorded as parasite of *G. brasiliensis* from southern Brazil (Rassier *et al.* 2015).

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