

## 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

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**Abstract** Three species of *Ergasilus* Nordmann, 1832 are reported from the gills of *Salminus* spp. in Brazil. *Ergasilus salmini* Thatcher & Brazil-Sato, 2008 from *Salminus brasiliensis* Cuvier is redescribed, based on examination of paratypes. The study revealed morphological differences from the original description, especially in the morphology of the cephalothorax and the ornamentation of antenna, antennule and legs. *Ergasilus lacusauratus* n. sp. described from *S. brasiliensis* in lake Lagoa Dourada (Paraná) differs from the only known species from this host group, *E. salmini*, in the shape and size of the cephalothorax and the general morphology of the egg-sacs. *Ergasilus*

*sinefalcatus* n. sp. from *S. franciscanus* Lima & Britsky in River São Francisco (Minas Gerais) closely resembles *E. pitalicus*, *E. coatiarus* and *E. leporinidis* in the lack of a pectinate seta on the first exopodal segment, a feature common in species of *Ergasilus* in the Neotropics. *Ergasilus sinefalcatus* n. sp. differs from these species in the presence of a spiniform process on the coxae of legs 2, 3 and 4, an ornament never reported from freshwater species of *Ergasilus* in South America.

### Introduction

*Ergasilus* Nordmann, 1832 is the most species-rich genus of Ergasilidae Nordmann, 1832 (Copepoda), containing approximately two-thirds of the described species in the family (El-Rashidy & Boxshall, 2002). About three-quarters of the known ergasilids, i.e. 179 according to Boxshall & Defaye (2008), are found in freshwater habitats (Araujo & Varela, 1998). Boxshall & Defaye (2008) also indicated that the Neotropical region has the largest number of species of the family, with 63 species distributed in 16 genera, of which 13 are endemic (e.g. Boeger & Thatcher, 1990; Montú & Boxshall, 2002; Rosim, Boxshall & Ceccarelli, 2013). Within the Neotropics, 18 freshwater species of *Ergasilus* are known from the gills of teleosts and one species of ray: *Ergasilus bryconis* Thatcher, 1981; *E. callophysus* Thatcher & Boeger, 1984; *E. chelangulatus* Thatcher & Brasil-Sato, 2008;

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*E. coatiarus* Araujo & Varella, 1998; *E. colomesus* Thatcher & Boeger, 1983; *E. holobryconis* Malta & Varella, 1986; *E. hydrolycus* Thatcher, Boeger & Robertson, 1984; *E. hypophthalmi* Boeger, Martins & Thatcher, 1993; *E. iheringi* Tidd, 1943; *E. jaraquensis* Thatcher & Robertson, 1981; *E. leporinidis* Thatcher, 1981; *E. pitalicus* Thatcher, 1984; *E. salmini* Thatcher & Brasil-Sato, 2008; *E. thatcheri* Engers, Boeger & Thatcher, 2000; *E. triangularis* Malta, 1994; *E. turucuyus* Malta & Varella, 1996; *E. trygonophilus* Domingues & Marques, 2010; *E. urupaensis* Malta, 1993 and *E. yumaricus* Malta & Varella, 1995.

Presently, only one species of *Ergasilus*, *E. salmini*, is known from a species of *Salminus* Agassiz (Teleostei: Characidae), a characiform with great sport-fishing value in South America (Thatcher & Brasil-Sato, 2008). According to Lima & Britski (2007), there are currently four known species of *Salminus*: *S. affinis* Stendachner, *S. hilarii* Valenciennes, *S. brasiliensis* Cuvier (senior synonym of *S. maxillosus* Valenciennes and *S. brevidens* Cuvier) and *S. franciscanus* Lima & Britsky (endemic to the River São Francisco). Collections of parasites from the gills of *S. brasiliensis* and *S. franciscanus* revealed the presence of two new species of *Ergasilus*. Further, the study of the previously described *E. salmini* made it clear that a redescription is necessary. This paper provides a redescription of *E. salmini* and describes the two new species.

## Materials and methods

Two species of *Salminus* were collected and analysed. Specimens of *S. brasiliensis* were collected in lake Lagoa Dourada, municipality of Ponta Grossa, state of Paraná, Brazil (25°14'25.30"S, 50°2'58.73"W) in August 1993. Specimens of *S. franciscanus* were collected in River São Francisco, in the municipality of Três Lagoas, state of Minas Gerais (18°12'21.12"S, 45°15'37.39"W), Brazil. In all cases, the gills were removed and fixed in 5% formalin. In the laboratory, copepods were removed from the gill filaments, cleared in lactic acid and mounted in Hoyer's mounting medium (prepared according to Humason, 1979). When necessary, specimens were dissected prior to mounting with the help of glass probes.

Drawings were prepared with the aid of an Olympus BX51 microscope with DIC illumination and

camera lucida. All measurements are in micrometres and are presented as the range followed by the mean and the number of specimens measured in parenthesis. Holotypes, paratypes and vouchers are deposited in the Museu de Zoologia da Universidade de São Paulo (MZUSP).

## *Ergasilus salmini* Thatcher & Brazil-Sato, 2008

*Type-host*: *Salminus franciscanus* Lima & Britski.

*Type-locality*: River São Francisco, downstream from Três Marias Dam, State of Minas Gerais (18°12'21.12"S, 45°15'37.39"W), Brazil.

*Site on host*: Gill filaments.

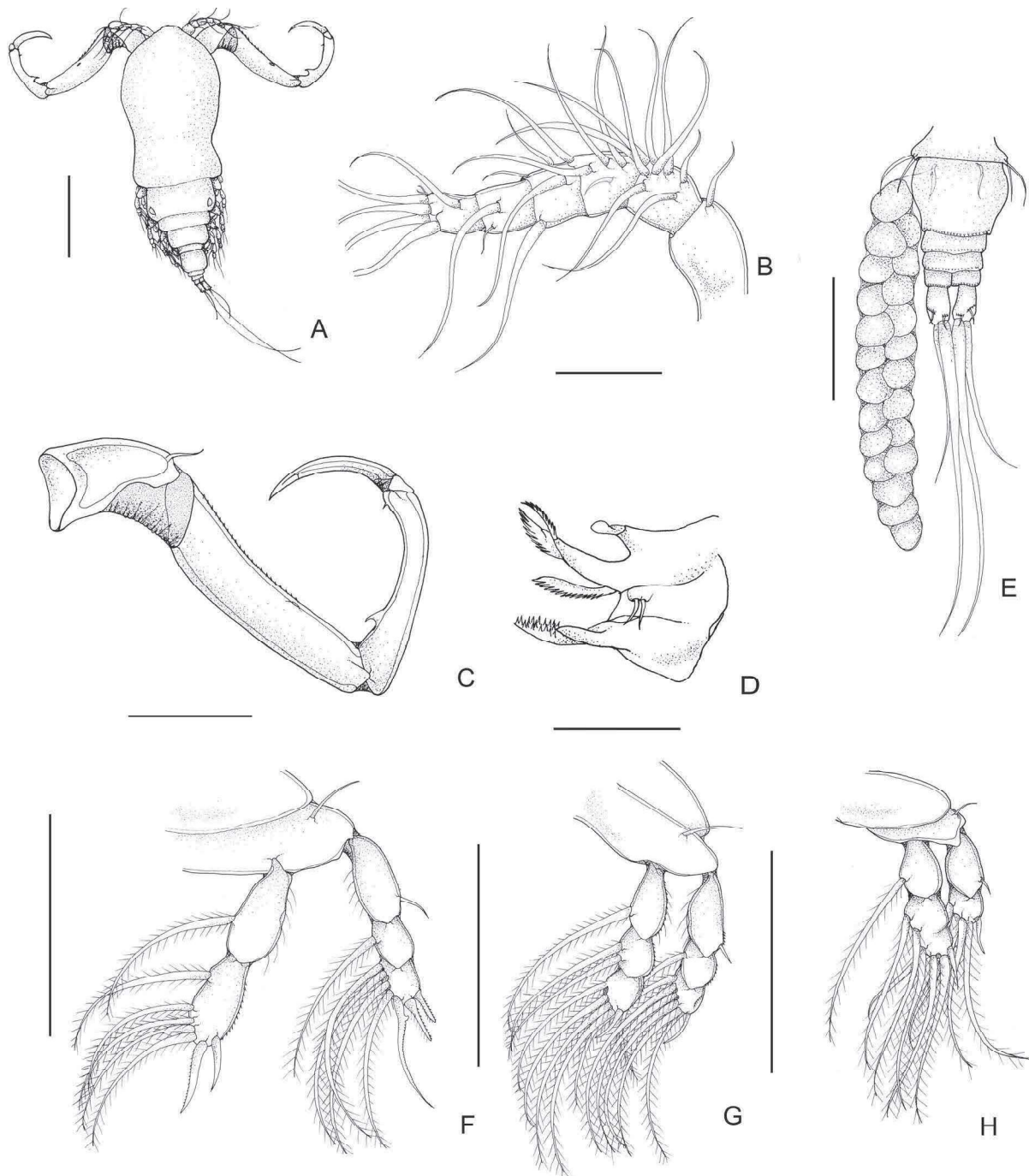
*Type-material studied*: Seven paratypes held in the private collection of Dr. Vernon E. Thatcher, now deposited in the MZUSP under accession numbers MZUSP 32792–32798.

## Description (Fig. 1A–H)

*Adult female* [Based on 7 specimens.] Body length from anterior margin of prosome to posterior of caudal rami 692–776 (741; n = 3). Body comprising prosome and urosome; prosome consisting of non-inflated cephalosome, lacking anterior projection and 4 pedigerous somites. Cephalosome and first pedigerous somite partly fused. Cephalothorax length less than twice width, more than half body length. Urosome consisting of fifth pedigerous somite, genital double-somite, and 3 free abdominal somites. Genital double-somite barrel-shaped, narrowing posteriorly, with ventral surface ornate with spinules along posterior and postero-lateral margins. Abdominal somites with row of spinules on postero-ventral margins; third abdominal somite bipartite. Caudal rami longer than wide, each armed with long medial seta, shorter lateral median seta and 2 smaller (lateral and ventral) setae; row of spinules present ventrally, immediately anterior to smaller setae. Egg-sacs 2, many times longer than wide, each composed of 2–3 rows of eggs.

Antennule 6-segmented, tapering distally, aesthetascs present on fifth and sixth segments. Setal formula: 1:9:5:5:1+1 ae:5+2 ae.

Antenna comprising coxobasis, 3-segmented endopod and terminal claw. Coxobasis short, with small distal seta at inner distal corner; membrane between



**Fig. 1** *Ergasilus salmini*, adult female. A, Dorsal view; B, Antennule; C, Antenna; D, Mouthparts; E, Abdomen, caudal rami and egg-sac; F, Leg I; G, Leg II; H, Leg IV. Scale-bars: A, 250 µm; B, 50 µm; C, E–H, 100 µm; D, 25 µm

coxobasis and first endopodal segment not inflated. First endopodal segment nearly 3× longer than coxobasis, with spinules on internal margin and submedian sensillum lacking cuticular elevation.

Second segment weakly-curved, shorter than first segment, with 2 sensilla; proximal sensillum conspicuous. Third segment lacking seta. Claw evenly curved, with small pit (fossa) on concave margin.

Mouthparts comprising mandible, maxillule and maxilla; maxilliped absent. Mandible with anterior, middle and posterior blades; middle blade with teeth along posterior edge. Maxillule bearing 2 setal elements. Maxilla lacking spinulate setae; basis partially toothed on convex margin.

Swimming legs 1–4 biramous, each with 2-segmented protopod comprising coxa and basis; interpodal plates of all legs lacking spinules. Armature of legs (spines, Roman numerals; setae, Arabic numerals) as follows:

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

\*Pectinated seta

Leg 1. Coxa with smooth margins, lacking spinules; basis with smooth margins, lacking spinules, with outer seta. Exopod 3-segmented; first segment with pilose inner margin and distal spine on outer margin, lacking spinules and seta; second segment lacking spinules and distal spine, with single seta; third segment lacking spinules, with 1 pectinated, falciform seta and 4 pilose setae, plus 2 distal spinulated spines. Endopod 2-segmented; first segment lacking spinules, with pilose outer margin and single seta; second segment with spinules on entire outer margin, without rosette-like array of blunt spinules, with 5 setae, plus 2 weakly curved spines, only inner spine spinulated.

Legs 2 and 3 similar. Coxa lacking spinous process; basis with smooth margins, lacking spinules, with outer seta. Exopod 3-segmented; first segment pilose on inner margin with spinules on outer margin and non-spinulated distal spine, lacking seta; second segment with spinules on entire outer margin, with single seta, lacking distal spine; third segment with spinules on entire outer margin, with 6 setae, plus non-spinulated spine. Endopod 3-segmented; first segment pilose and with spinules on entire outer margin and single seta; second segment non-pilose, with spinules on entire outer margin, with 2 setae, lacking distal spine; third segment with spinules on entire outer margin, with 4 setae, plus distal non-spinulated spine.

Leg 4. Coxa lacking spinous process; basis with outer seta, lacking spinules. Exopod 2-segmented; first

segment non-pilose, lacking spinules and seta, with non-spinulated distal spine; second segment lacking spinules, with 4 setae, plus distal non-spinulated spine. Endopod 2-segmented, second segment composed by partially fused segments; first segment non-pilose, lacking spinules, with single seta; second segment lacking spinules, with 5 setae, plus distal non-spinulated spine and row of spinules at the apparent line of fusion.

Leg 5. Reduced to 2 setae, 1 on small papilla.

#### Remarks

Re-examination of paratypes of *E. salmini* revealed some morphological differences from the original description. For instance, the cephalothorax and first pedigerous somite are partially fused (these segments were reported as unfused by Thatcher & Brazil-Sato, 2008). Most other discrepancies from the original description are related to the presence/absence of sensilla, setae, spines and spinules, which are reported here for the first time. Among the most significant features not reported in the original description but identified in the present redescription, are the following: antenna (seta on the coxobasis; sensillum on the first endopodal segment; sensillum on the proximal region of the second endopodal segment; serrate internal margin of the first endopodal segment); antennule with 21 setae and 2 aesthetascs; legs 1–6 [outer seta on the basis; spine on the first endopodal segment; spinulation on spines of the third endopodal segment; five setae on the third endopodal segment (only four reported in the original description)]; legs 2–3 (outer seta present on the basis; spine on the first endopodal segment); leg 4 (outer seta present on the basis; spine on the first endopodal segment; two-segmented endopod, the last segment composed of two partially fused segments; first endopodal segment bearing an inner seta; second endopodal segment bearing five setae (only three reported in the original description)).

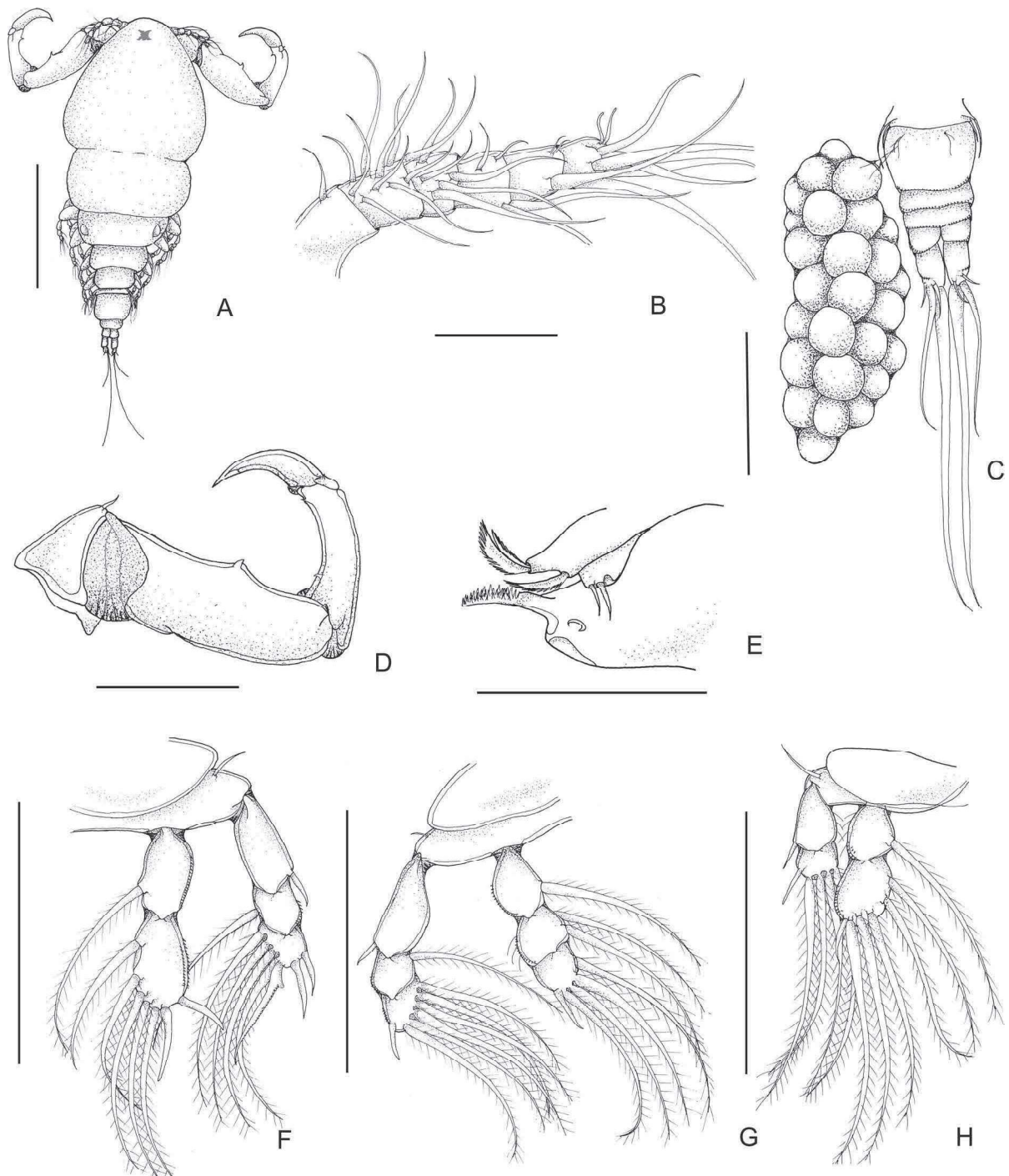
#### *Ergasilus lacusauratus* n. sp.

*Type-host*: *Salminus brasiliensis* (Cuvier).

*Type-locality*: Lake Lagoa Dourada, municipality Ponta Grossa, State of Paraná (25°14'25.30"S, 50°2'58.73"W), Brazil.

*Site on host*: Gill filaments.





**Fig. 2** *Ergasilus lacusauratus* n. sp., adult female. A, Dorsal view; B, Antennule; C, Abdomen, caudal rami and egg-sac; D, Antenna; E, Mouthparts; F, Leg I; G, Leg II; H, Leg IV. Scale-bars: A, 250  $\mu$ m; B, 50  $\mu$ m; C, D, F–H, 100  $\mu$ m; E, 30  $\mu$ m

*Male*: Unknown.

*Type-material*: Holotype female (MZUSP 32762); paratypes (7 females; MZUSP 32763–32769).

*Etymology*: The specific name is derived from the Latin *lacus* (lake) and *auratus* (golden) and refers to the type-locality of the species, the *Lagoa Dourada* (Golden Lake).

#### Description (Fig. 2A–H)

*Adult female* [Based on 8 specimens.] Body length from anterior margin of prosome to posterior of caudal rami 667–816 (743; n = 7). Body comprising prosome and urosome; prosome consisting of cephalosome lacking anterior projection and 4 pedigerous somites. Cephalosome and first pedigerous segment not fused. Cephalothorax length less than twice width, 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 barrel-shaped, narrowing posteriorly, with ventral surface ornate with acute spinules along posterior and postero-lateral margin. Abdominal segments with spinule rows on postero-ventral margins. Caudal rami longer than wide, each armed with long medial seta, median lateral seta and 2 smaller (lateral and ventral) setae; spinule rows present ventrally, anterior to setae. Egg-sacs 2, robust, each composed of up to 5 longitudinal rows of eggs.

Antennule 6-segmented, tapering distally, aesthetascs present on sixth segment. Setal formula: 1:10:5:4:1+2ae:5+2ae.

Antenna comprising coxobasis and 3-segmented endopod bearing terminal claw. Coxobasis short, with small distal seta at inner distal margin; membrane between coxobasis and first endopodal segment not inflated. Length/width ratio of first endopodal segment <3; internal margin lacking spinules; sensillum near mid-length, lacking cuticular elevation. Second segment evenly curved, shorter than first segment, with 2 sensilla. Third segment greatly reduced, with single seta. Claw evenly curved with small sub-distal pit (fossa) on concave margin.

Mouthparts comprising mandible, maxillule and maxilla; maxilliped absent. Mandible with anterior, middle, and posterior blades, middle blade with teeth along posterior edge. Maxillule bearing 2 setal elements. Basis of maxilla partially toothed on convex margin, spinulate setae on maxilla absent.

Swimming legs 1–4 biramous, each with 2-segmented protopod comprising coxa and basis; interpodal plates of all legs lacking spinules. Armature of legs (spines, Roman numerals; setae, Arabic numerals) as follows:

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

\*Pectinated seta

Leg 1. Coxa lacking spinous process; basis with smooth margins, lacking spinules, with outer seta. Exopod 3-segmented; first segment non-pilose, lacking spinules and seta, with distal spine on outer margin; second segment with distal spinules on outer margin and single seta, lacking distal spine; third segment without spinules, with 1 pectinated, falciform seta, and 4 pilose setae, plus 2 distal non-spinulated spines. Endopod 2-segmented; first segment non-pilose, with spinules on entire outer margin and single seta; second segment with spinules on entire outer margin, without rosette-like array of blunt spinules, with 5 setae, plus 2 spines, non-spinulated.

Legs 2 and 3 similar. Coxa lacking spinous process; basis lacking spinules, with outer seta. Exopod 3-segmented; first segment non-pilose, lacking spinules and seta, distal spine non-spinulated; second segment with spinules on distal outer margin, with single seta, lacking distal spine; third segment with spinules on entire outer margin, 6 setae and non-spinulated spine. Endopod 3-segmented; first segment non-pilose, with spinules on entire outer margin and single seta; second segment pilose, with spinules on entire outer margin, with 2 setae, lacking distal spine; third segment lacking spinules, with 4 setae and non-spinulated distal spine.

Leg 4. Coxa lacking spinous process; basis with outer seta, lacking spinules. Exopod 2-segmented; first segment pilose on inner margin, lacking spinules and seta, with non-spinulated distal spine; second segment lacking spinules, with 4 setae, plus distal non-spinulated spine. Endopod 2-segmented; first segment pilose with spinules distally on outer margin, with single seta; second segment with spinules distally on

outer margin, with 5 setae, plus distal non-spinulated spine.

Leg 5. Reduced to 2 setae, one on small papilla.

#### Remarks

The new species differs from the only known species of *Ergasilus* parasitic in a species of *Salminus*, *E. salmini*, in (i) the morphology of the cephalothorax (inflated in the new species); (ii) the possession of a more robust antenna lacking spinules on the inner margin of the first endopodal segment; (iii) the possession of more robust egg-sacs, with multiple rows of eggs; and (iv) the 2-segmented endopod of leg 4 (*vs* partially segmented, i.e. incompletely fused ancestral endopodal segments 2–3 in *E. salmini*). As most species of *Ergasilus*, the new species has a pectinated seta on the first pair of legs.

*Ergasilus lacusauratus* n. sp. is similar to *E. turucuyus* in the relative size and shape of the cephalothorax and the morphology of the antenna (both with robust first endopodal segment and sensillum near mid-length). However, in *E. turucuyus* the first endopodal segment of the antenna is comparatively shorter than in *E. lacusauratus*. These two species also differ in the morphology of leg 4. *Ergasilus lacusauratus* possesses a distal outer spine on the first exopodal segment, not observed in *E. turucuyus*. Aesthetascs were observed only on the sixth segment of the antennule in the new species whereas in most of the species these are located on the fifth and sixth segments. Further, the available specimens of *E. lacusauratus* n. sp. possess shorter and more robust egg-sacs than the known species of *Ergasilus* from Brazil.

#### *Ergasilus sinefalcatus* n. sp.

*Type-host*: *Salminus franciscanus* Lima & Britski, 2007.

*Type-locality*: River São Francisco, downstream from Três Marias Dam, State of Minas Gerais, (18°12'21.12"S, 45°15'37.39"W), Brazil.

*Site on host*: Gill filaments.

*Male*: Unknown.

*Type-material*: Holotype female (MZUSP 32753); paratypes (8 females; MZUSP 32754–32761).

*Etymology*: The specific epithet is derived from the Latin *sine* (without) and *falcem* (sickle) and makes allusion to the fact that this is one of the few species of Neotropical *Ergasilus* lacking a falciform seta (pectinate seta) on the first endopodal segment.

#### Description (Fig. 3A–H)

*Adult female* [Based on 9 specimens.] Body length from anterior margin of prosome to posterior of caudal rami 706–1,120 (1,003; n = 8). Body comprising prosome and urosome; prosome consisting of non-inflated cephalosome, lacking anterior projection and 4 pedigerous somites. Cephalosome and first pedigerous segment not fused. Cephalothorax length less than twice width, nearly half body length. Urosome consisting of fifth pedigerous somite, genital double-somite and 3 free abdominal somites; third abdominal somite bipartite. Genital double-somite barrel-shaped, narrowing posteriorly, with ventral surface ornate with spinules along postero-ventral margin. Abdominal segments with spinule rows on postero-ventral margins. Caudal rami longer than wide, each armed with long medial seta, shorter median lateral seta, and 2 smaller (lateral and ventral) setae; spinule rows present ventrally, anterior to seta. Egg-sacs 2, each composed by up to 4 longitudinal rows of eggs.

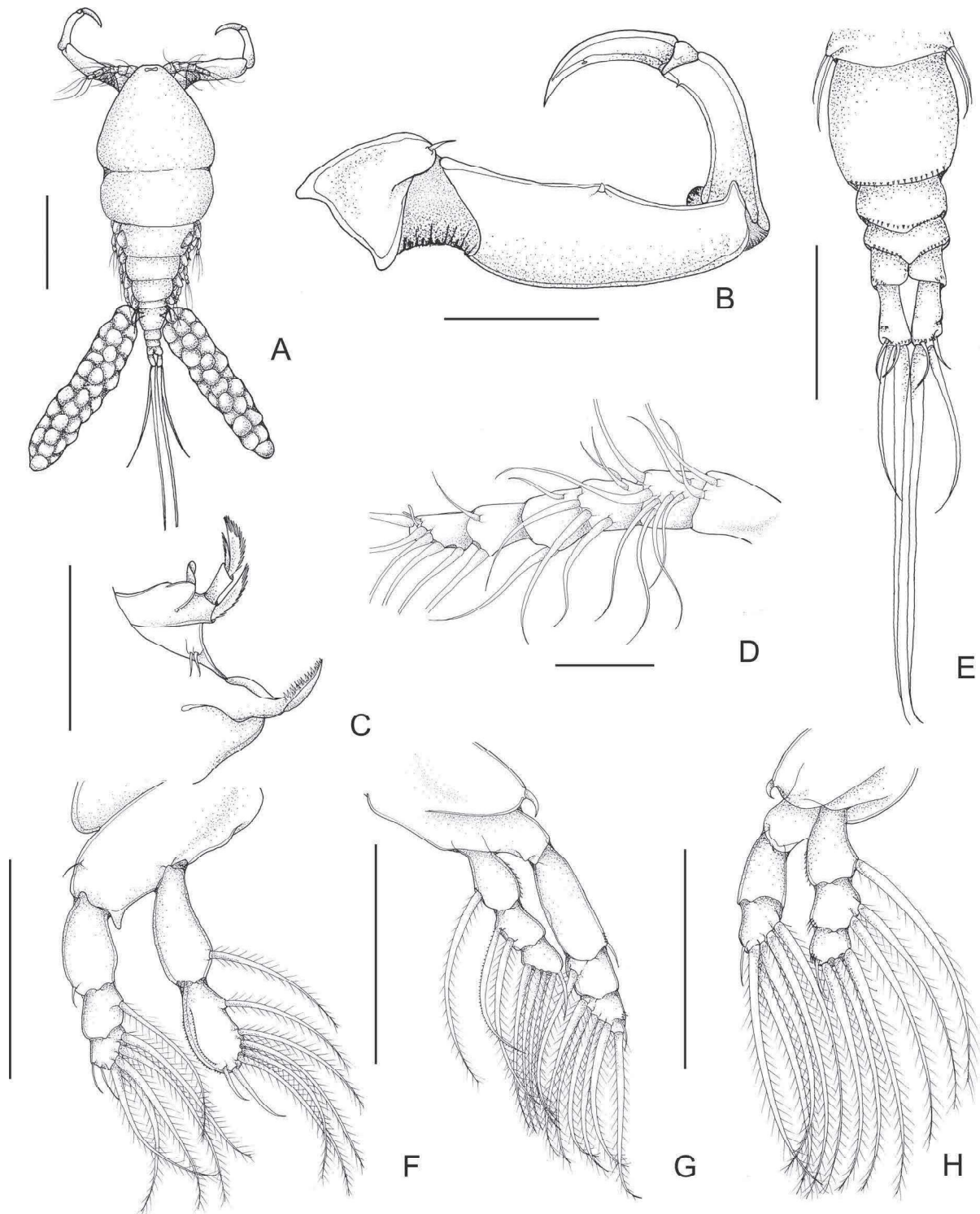
Antennule 6-segmented, tapering distally, aesthetascs present on sixth segment. Setal formula: 1:11:5:3+1 ae:1+2 ae: 5+2 ae.

Antenna comprising coxobasis and 3-segmented endopod bearing terminal claw. Coxobasis short, with small distal seta at inner distal margin; membrane between coxa and first endopodal segment not inflated. Length/width ratio of first endopodal segment >3; internal margin lacking spinules and sensillum near mid-length, without cuticular elevation. Second segment evenly curved, shorter than first segment, with single subterminal sensillum. Third segment lacking seta. Claw evenly curved, with small subdistal pit (fossa) on concave margin.

Mouthparts comprising mandible, maxillule and maxilla; maxilliped absent. Mandible with anterior, middle and posterior blades, middle blade with teeth along posterior edge. Maxillule bearing 2 setal elements. Maxilla lacking spinulate setae; basis partially toothed on convex margin.

Swimming legs 1–4 biramous, each with 2-segmented protopod comprising coxa and basis; interpodal plates of





**Fig. 3** *Ergasilus sinefalcatus* n. sp., adult female. A, Dorsal view; B, Antenna; C, Mouthparts; D, Antennule; E, Abdomen and caudal rami; F, Leg I; G, Leg II; H, Leg IV. Scale-bars: A, 250  $\mu$ m; B, 50  $\mu$ m; C, D, F–H, 100  $\mu$ m; E, 30  $\mu$ m



all legs lacking spinules. Armature of legs (spines, Roman numerals; setae, Arabic numerals) as follows:

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

Leg 1. Coxa lacking spinous process; basis with conspicuous bluntly-pointed projection at base of exopod, lacking spinules, with outer seta. Exopod 3-segmented; first segment non-pilose, lacking spinules and seta, with distal spine; second segment lacking spinules and distal spine, with single seta; third segment lacking spinules and pectinated seta, with 5 pilose setae, plus 2 distal non-spinulated spines. Endopod 2-segmented; first segment non-pilose, lacking spinules, with single seta; second segment with spinules on entire outer margin and submarginal row of spinules, without rosette-like array of blunt spinules, with 5 setae, plus 2 non-spinulated spines (1 long and 1 short).

Legs 2 and 3 similar. Coxa with spiniform process; basis lacking spinules and seta. Exopod 3-segmented; first segment twice as long as wide, non-pilose, with spinules distally on outer margin, lacking seta, distal spine non-spinulated; second segment lacking spinules and distal spine, with single seta; third segment with spinules distally on outer margin, with 6 setae, plus spine lacking spinules. Endopod 3-segmented; first segment non-pilose, with spinules on entire outer margin and single seta; second segment non-pilose, lacking spinules and distal spines, with 2 setae; third segment lacking spinules, with 4 setae, plus distal non-spinulated spine.

Leg 4. Coxa with spiniform process; basis lacking spinules and seta. Exopod 2-segmented; first segment non-pilose, lacking spinules, seta and spine; second segment lacking spinules, with 5 setae, plus distal non-spinulated spine. Endopod 3-segmented; first segment non-pilose, with spinules on entire distal half of outer margin and single seta; second segment with long spinules distally on outer margin and 2 setae, lacking distal spine; third segment non-pilose, with spinules distally on outer margin and 3 setae, plus distal spine.

Leg 5. Reduced to 2 setae, 1 on small papilla.

## Remarks

Similar to *E. coatiarus*, *E. iheringi*, *E. leporinidis*, and *E. pitalicus*, the new species does not possess a pinnate (falciform) seta on the exopod of the first pair of legs, a feature common to most species of the genus in the Neotropics. However, the new species can be easily differentiated from these and all other Neotropical species of *Ergasilus* by the presence of a robust spiniform process on the coxae of legs 2, 3 and 4.

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