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ORIGINAL ARTICLE

An update for cladoceran fauna (Crustacea, Branchiopoda) from Lake Paranoá, Central Brazil, with the first description of a male of *Leydigiopsis ornata* Daday, 1905

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ABSTRACT

Until recently, Lake Paranoá was considered the most thoroughly studied aquatic environment in relation to cladocerans in the Federal District. However, in new samplings carried out during the dry and rainy seasons of 2014, we found 10 new records of species. These species were presumed to occur in Lake Paranoá because of their range of geographical distribution. The male of *Leydigiopsis ornata* Daday, 1905 is described for the first time, adding new morphological traits to a recent redescription of the species. The presence of three rows of setulae on the labral keel is unique to the *L. ornata* male. As is the case in females, the male of *L. ornata* is mainly differentiated from *L. megalops* Sars, 1901 and *L. curvirostris* Sars, 1901 by the morphology of the postabdomen.

KEY WORDS

Acroperus, Ephemeroporus, male morphology, *Nicsmirnovius, Parvalona.*

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Introduction

Until recently, Lake Paranoá was considered the most thoroughly studied aquatic environment in relation to cladocerans in the Federal District, with species reported since the 1970s. The paper published by Elmoor-Loureiro *et al.* (2004) might be considered a benchmark for knowledge of this group of microcrustaceans in Lake Paranoá, because it sheds light on the trophic history of the lake and suggests a possible relationship with the increase in the number of species reported, which has almost doubled.

More recently, Sousa and Elmoor-Loureiro (2012) also reviewed the checklist of cladocerans from Lake Paranoá and pointed to the occurrence of 18 species. Next, Elmoor-Loureiro (2013) reported *Bosmina huaronensis*; Sousa *et al.,* (2015a) indicated the occurrence of *Coronatella paulinae* Sousa, Elmoor-Loureiro & Santos, 2015 (as *C. poppei* (Richard, 1897)) and *Flavalona margipluma* (Sousa, Santos, Güntzel, Diniz, Melo-Júnior & Elmoor-Loureiro, 2015) (= *Alona margipluma* Sousa, Santos, Güntzel, Diniz, Melo-Júnior & Elmoor-Loureiro, 2015 in Sousa *et al.,* 2015b). Nevertheless, a higher number of species than are currently known in Lake Paranoá is presumed to exist, because its geographical position is within the distribution range of at least 37 species (Sousa and Elmoor-Loureiro, 2012). This information possibly underestimates the number of cladoceran species inhabiting Lake Paranoá.

In this study, we analyzed samples collected from Lake Paranoá, and we added 10 new records to cladoceran fauna. It was also our aim to describe the male morphology of *Leydigiopsis ornata* Daday, 1905 for the first time.

Material and Methods

Study Area

Lake Paranoá is a reservoir located in the urban area of Brasilia, in Brazil's Federal District (Fig. 1). It was formed in 1960 by damming the Paranoá River and its tributaries (Torto, Bananal, Acampamento, Gama and Riacho Fundo Streams). The lake presents a surface area of 39.48 km^2, a volume of 560 x 106 m^3, and maximum depth of 38 m (CEB – Companhia Energética de Brasília). The climate of the region is marked by strong seasonality, with two defined seasons, a dry and cool (May to September) and a rainy and warm (October to April).

Sampling, sorting and identification

Samples were taken at 12 sampling points in the littoral zone of Lake Paranoá during the dry and rainy seasons of 2014. In each site, samples were collected with the aid of buckets and by horizontal hauls with a plankton net, in different microhabitats such as macrophytes and sediments. The obtained samples were fixed in 70% alcohol. Individuals were transferred to slides containing glycerin and dissected under a stereomicroscope. The morphology of appendages and other structures was studied using an Olympus phase-contrast microscope BX41 attached to a camera lucida. All individuals were identified with the support of taxonomic specialized references (Smirnov, 1996; Elmoor-Loureiro, 1997; Kotov and Štifter, 2006; Sinev and Elmoor-Loureiro, 2010; Sinev, 2004; Van Damme *et al.,* 2011; Van Damme and Sinev, 2013). The voucher specimens were preserved in ethanol and deposited in the personal collection of FDRS (accession numbers FDRS486-495).

Abbreviations

The abbreviation in the illustrations and text are: cbs = copulatory brush seta; en = endite; IDL = inner distal lobe; ms = male seta; ODL = outer distal lobe. FDRS = Personal collection of Francisco Diogo Rocha Sousa.

Results and Discussion

Altogether, literature data and results from sampling indicate the occurrence of 31 species in Lake Paranoá. Ten species were recorded in the lake for the first time (Tab. 1). These species are widely distributed in Brazil, and are also reported in tributaries, ponds and shallow lakes near to Lake Paranoá (Sousa and Elmoor-Loureiro, 2012).

Table 1. Cladoceran species from Lake Paranoá based on Elmoor-Loureiro *et al.*, (2004), Sousa and Elmoor-Loureiro (2012), Elmoor-Loureiro (2013), Sousa *et al.,* (2015a, b), Sousa *et al.,* (2016). * First records. Higher classification follows Kotov (2013).

Superorder Cladocera
Order Anomopoda Sars, 1865
Suborder Aradopoda Kotov, 2013
Family Daphniidae Straus, 1820
Ceriodaphnia cornuta Sars, 1885 s.lat.
Ceriodaphnia silvestris Daday, 1902
Daphinia (*Daphnia*) *gessneri* Herbst 1967
Simocephalus (*Coronocephalus*) *serrulatus* (Koch, 1841)
Family Moinidae Goulden, 1968
Moina micrura Kurz, 1875
Suborder Radopoda Dumont & Silva-Briano, 1998
Family Ilyocryptidae Smirnov, 1976 *emend.* Smirnov, 1992
Ilyocryptus spinifer Herrick, 1882
Family Macrothricidae Norman & Brady, 1867 *emend.* Dumont & Silva-Briano, 1998
Macrothrix elegans Sars, 1901
Family Bosminidae Baird, 1845 *emend.* Sars, 1865
Bosmina (*Bosmina*) *freyi* De Melo & Hebert, 1994
Bosmina (*Liederobosmina*) *huaronensis* Delachaux, 1918
Bosmina (*Liederobosmina*) *tubicen* Brehm, 1953
Bosminopsis deitersi Richard, 1895
Family Chydoridae Dybowski & Grochowski, 1894 emend. Frey, 1967
Subfamily Chydorinae Dybowski & Grochowski, 1894 emend. Frey, 1967
Alonella dadayi Birge, 1910*
Chydorus eurynotus Sars, 1901*
Chydorus pubescens Sars, 1901
Ephemeroporus tridentatus (Bergamin, 1939)*
Subfamily Aloninae Dybowski & Grochowski, 1894 emend. Frey, 1967
Acroperus tupinamba Sinev & Elmoor-Loureiro, 2010*
Alona guttata Sars, 1862
Alona ossiani Sinev, 1998*
Anthalona verrucosa verrucosa (Sars, 1901)*
Coronatella paulinae Sousa, Elmoor-Loureiro & Santos, 2015
Euryalona orientalis (Daday, 1898)
Flavalona margipluma (Sousa, Elmoor-Loureiro & Santos, 2015)
Kurzia polyspinia Hudec, 2000
Leydigia (*Neoleydigia*) *striata* Baribén, 1939
Leydigiopsis ornata Daday, 1905*
Nicsmirnovius sp.*
Notoalona sculpta (Sars, 1901)*
Ovalona glabra (Sars, 1901)
Parvalona parva (Daday, 1905)*
Order Ctenopoda Sars, 1865
Family Sididae Baird, 1850
Diaphanosoma brevirreme Sars, 1901
Diaphanosoma spinulosum Herbst, 1975

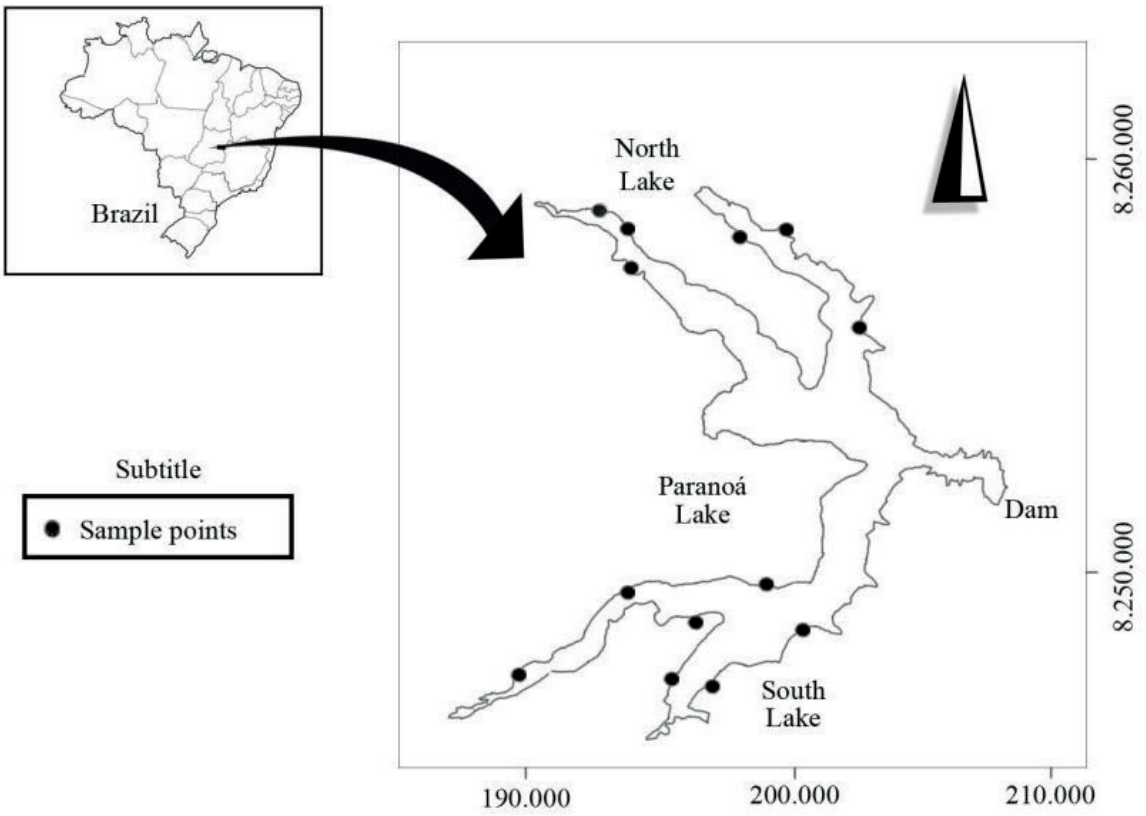

Figure 1. Lake Paranoá, Federal District, Brazil. Black circles correspond to the sampling points.

Systematics

Order Anomopoda Sars, 1865

Family Chydoridae Dybowski and Grochowski, 1894 *emend.* Frey, 1967

Subfamily Aloninae Dybowski and Grochowski, 1894 *emend.* Frey, 1967

Genus *Acroperus* Baird, 1843

***Acroperus tupinamba* Sinev and Elmoor-Loureiro, 2010**
(Fig. 2A–C)

Material examined: One adult parthenogenetic female (FDRS486).

Remarks: Species previously identified as the Palearctic *Acroperus harpae* (Baird, 1834), but Sinev and Elmoor-Loureiro (2010) confirmed species status for Neotropical populations. The only species of the genus with Neotropical distribution, *Acroperus tupinamba* is easily recognized because it has dorsal keel well-expressed, posteroventral corner of valves with 1–3 denticles with setulae between them. Besides, *A. tupinamba* differs from the other two species of the genus by longer posterior setae on the valves, shorter and wider postabdomen (length/height ratio 3.2), shorter setulae near to base of postabdominal claw and spoon-like setae 1–2 on the exopodite of the fourth limb.

Distribution: Neotropics (Rey and Vasquez, 1986; Sinev and Elmoor-Loureiro, 2010; Debastiani-Júnior *et al.,* 2015). In Brazil, *A. tupinamba* occurs in the Amazônica, Paraguai, Paraná, São Francisco, Parnaíba and Atlântico Sudeste hydrographic regions (Elmoor-Loureiro, 2017).

Genus *Alona* Baird, 1843

***Alona ossiani* Sinev, 1998**
(Fig. 2D–G)

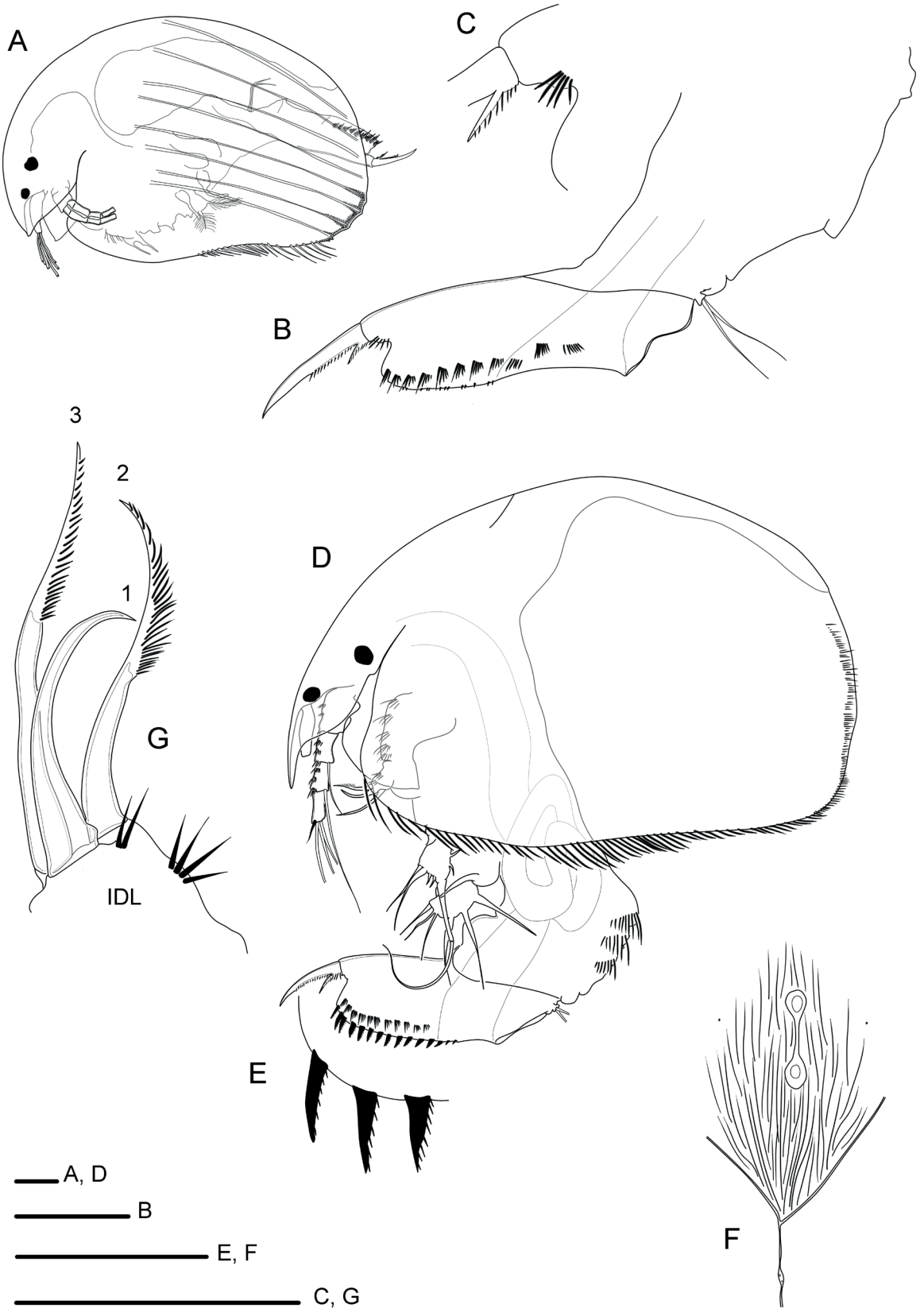

Figure 2. Parthenogenetic females from Lake Paranoá: A, *Acroperus tubinamba*; B, *idem*, postabdomen; C, *idem*, base of postabdominal claw; D, *Alona ossiani*; E, *idem*, marginal denticles on the postabdomen; F, *idem*, main head pores; G, *idem*, Inner Distal Lobe (IDL) of the first limb. Scale bars = 50 μm.

Material examined: One adult parthenogenetic female (FDRS487)

Remarks: The single known species of *affinis*-group from the Neotropics. Recently, a new subspecies from North America was described based on male morphology, *Alona ossiani herricki* Sinev, 2013 (Sinev, 2013). Regarding Brazilian fauna, *A. ossiani* has a singular morphology and can be recognized by elongate body with length reaching over 1mm, posterior border of head shield triangular and two connected main head pores; postanal margin elongated with about 50% of length of postabdomen itself, distal angle rounded, 15–17 merged marginal denticles.

Distribution: Neotropics (Sinev, 1998; Sinev and Silva-Briano, 2012). In Brazil, *A. ossiani* occurs in the Amazônica, Tocantins/Araguaia, Paraná, Paraguai, São Francisco, Atlântico Nordeste Ocidental, Nordeste Oriental, Leste, Sudeste, and Sul hydrographic regions (Elmoor-Loureiro, 2017; Sousa *et al.*, 2014).

Genus *Anthalona* Van Damme, Sinev and Dumont, 2011

Anthalona verrucosa verrucosa (Sars, 1901)
(Fig. 3A–E)

Material examined: One adult parthenogenetic female (FDRS488)

Remarks: The *verrucosa*-group has a complicated taxonomic history. It was considered a member of the artificial genus *Biapertura* Smirnov, 1971. More recently, Van Damme *et al.* (2011) raised the *verrucosa*-group to genus status and, at the same time, they showed the existence of a high diversity of species. *Anthalona verrucosa verrucosa* is easily recognized by the presence of two connected main head pores, lateral head pores with cosmaria-like sacs underneath them; lateral fascicles of postabdomen not exceeding the level of marginal denticles; single denticles on the labral keel; large proximal denticle on the IDL setae. The specimen observed at Lake Paranoá had a single main head pore.

Distribution: Neotropics (Van Damme *et al.*, 2011). Recently, Sousa *et al.* (2015c) revised many populations of *A. verrucosa verrucosa,* indicating wide distribution of this species in Brazil.

Genus *Leydigiopsis* Sars, 1901

Leydigiopsis ornata Daday, 1905
(Figs. 3F–G, 4A–I)

Material examined: Two adult parthenogenetic females and one adult male (FDRS489).

Description of adult male: *Habitus* (Fig. 4A). Smaller and more elongated than female, length 0.60 mm, about 1.4 times as long as high; greater height close to half length of body; laterally compressed, without dorsal keel; marginal line not straight, with a depression behind middle of body.

Head (Fig. 4A). Rostrum markedly shorter than in female, about 1.2 times longer than length of antennular body; ocellus and eye of subequal size. *Head shield* (Fig. 4B) about two times as long as wide; posterior region triangular-shaped, apex rounded; single slot-shaped main head pore about 3 times longer than wide, tiny lateral head pores inserted at middle level of length of main pore; PP about same length of the main head pore. *Labral keel* (Fig. 4D) triangular, margin slightly convex and armed with three rows of short setulae, apex not acute.

Carapace (Fig. 4A) relatively elongated, ornamentation as fine striae, ventral margin armed with 76 setae slightly plumose, strongly differentiated in groups; posteroventral corner of carapace, rounded, without denticles.

Antennules (Fig. 4G). Antennular body not exceeding the tip of rostrum, about two times as long as wide; one pair of aesthetascs laterally inserted, eight apical aesthetascs of which seven of them longer than antennular body itself. Sensory seta about same length as antennular body. Male seta short and robust, about 3.6 times shorter than antennular body length, apex sharp.

Thorax and abdomen (Fig. 4A). Thorax longer than abdomen. Abdomen armed with four rows of setulae.

Postabdomen (Fig. 4E, F). Straighter and more elongated than in females, about 2.5 times longer than wide; dorsal and ventral margins slightly convex. Anal margin as in females. Postanal margin slightly convex, armed with 16 long and slender marginal denticles

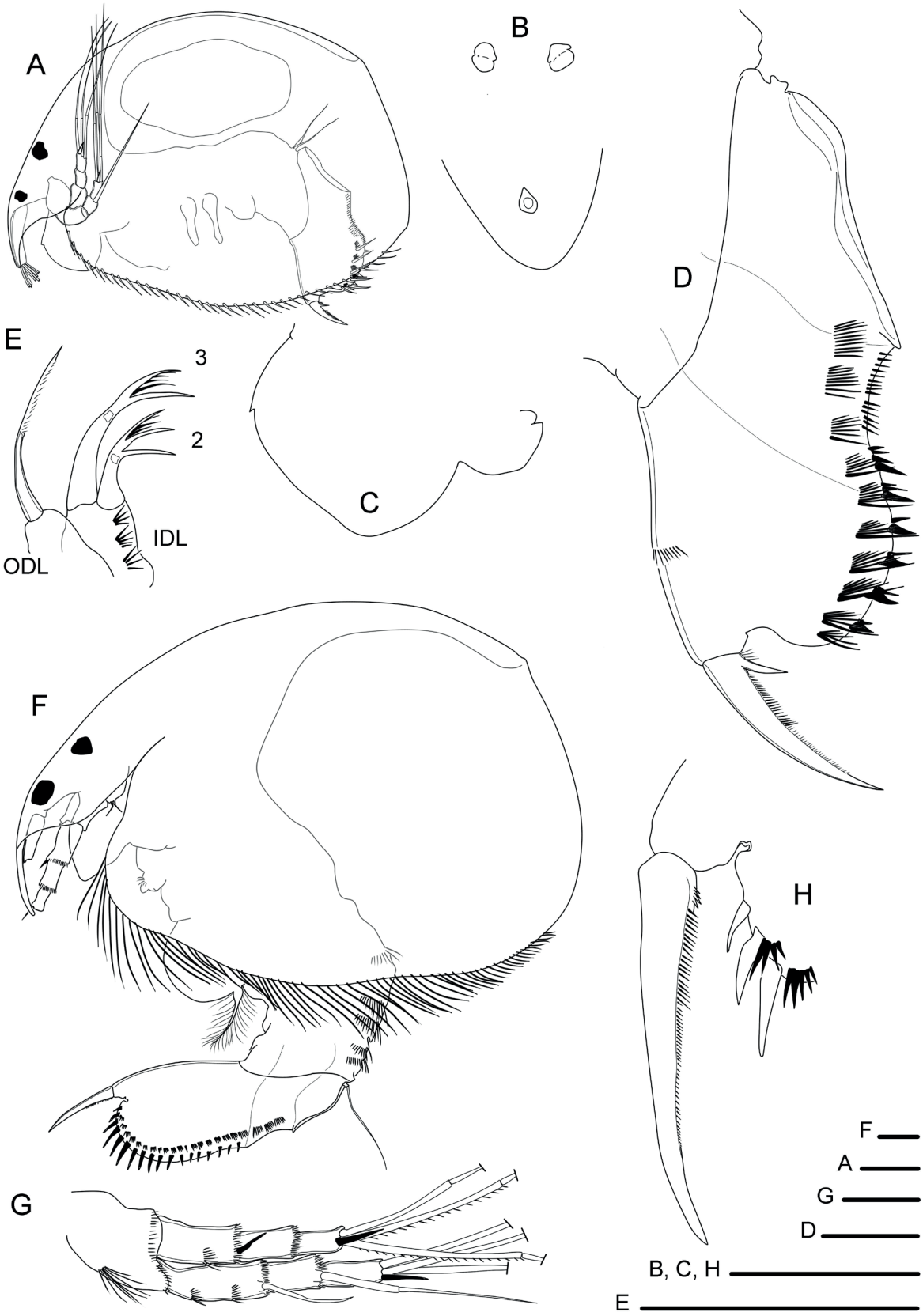

Figure 3. Parthenogenetic females from Lake Paranoá: A, *Anthalona verrucosa verrucosa*; B, *idem*, main head pores; C, *idem*, labral keel; D, *idem*, postabdomen; E, *idem*, Inner Distal Lobe (IDL) of the first limb. F, *Leydigiopsis ornata*, G, *idem*, antenna; H, *idem*, postabdominal claw. Scale bars = 50 µm.

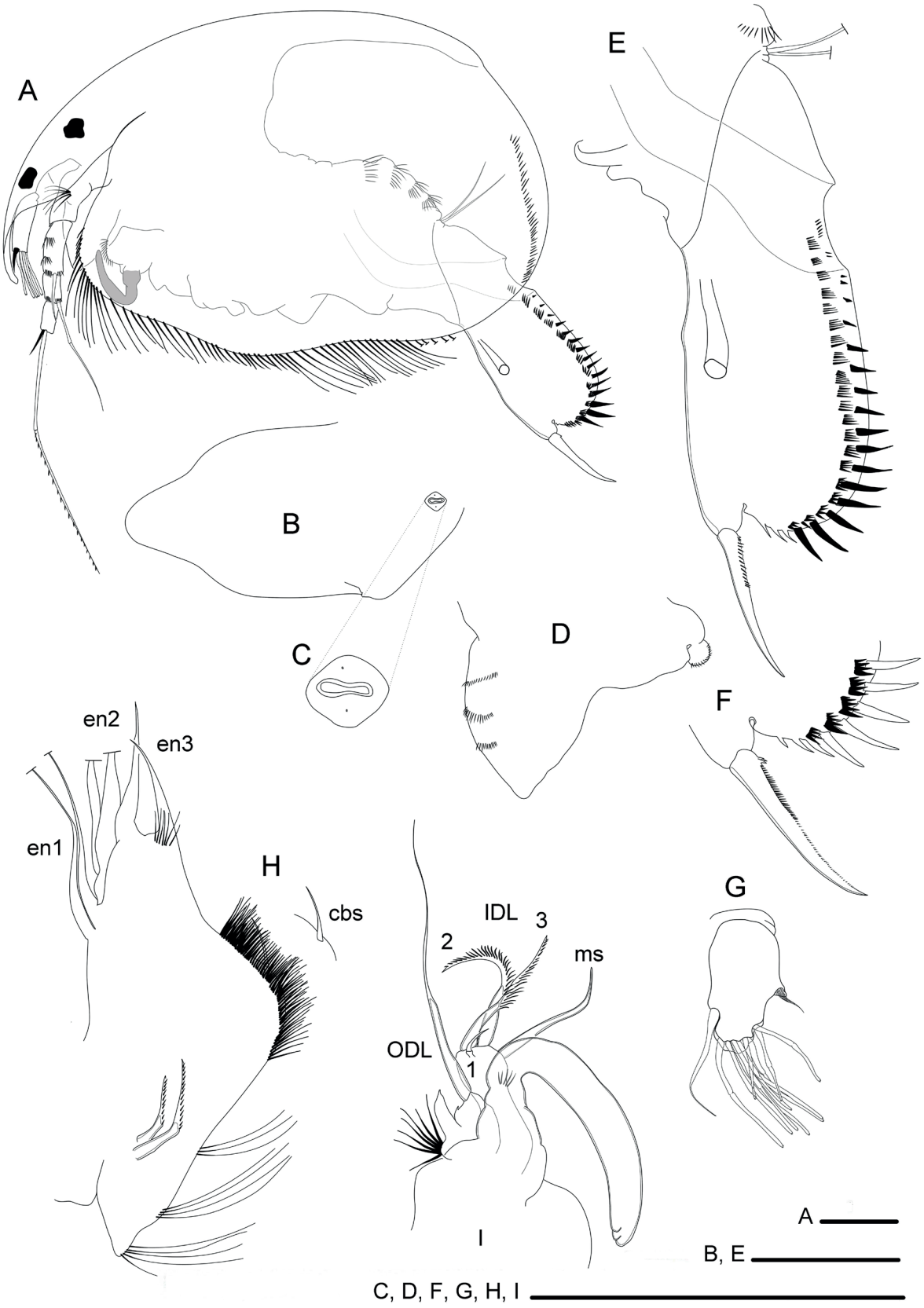

Figure 4. Adult male of *Leydigiopsis ornata*: A, *Habitus*; B, Head Shield; C, main head pores; D, Labral keel; E, Postabdomen; F, *idem*, postabdominal claw; G, Antennule; H, First limb, endites (en) and copulatory brush seta (cbs); I, *idem*, copulatory hook, Inner Distal Lobe (IDL) and Outer Distal Lobe (ODL). Scale bars = 50 µm.

unmerged, decreasing in length towards anal margin; twenty lateral fascicles, distalmost bears smaller number of setulae (3–4), setulae of the distalmost fascicles thicker than others; distal portion rounded. Gonopores inserted laterally near to ventral margin, at same level as postabdominal claw. *Postabdominal claw* (Fig. 4E, F). Shorter than in female, with length about two times longer than anal margin; length of proximal pecten spinulae not exceeding the level of basal spines; a group of four short basal spines, inserted at some distance from the base of postabdominal claw.

Limb I (Fig. 4I). Ventral face with 13 long setulae; copulatory brush armed with many setulae, the distalmost being longer. Copulatory hook U-shaped, arms of different length. ODL bears a projection (accessory seta?) at base and a row of long and thick setulae; ODL seta slender, bi-segmented, about two times longer the IDL setae. IDL with three setae, first one markedly shorter than setae 2–3, which have similar length; setae 2-3 armed with setulae; male setae long, subequal in length to IDL setae, apex curved.

Remarks: For full redescription and differential diagnosis based on parthenogenetic females see Van Damme and Sinev (2013), which also provides good illustrations and an identification key to *Leydigiopsis* Sars, 1901 species. The male of *L. ornata* is quite similar to males already described for the genus (Sinev, 2004). The presence of three rows of setulae on labral keel is unique to *L. ornata* male. As in females, the male of *L. ornata* is mainly differentiated from *Leydigiopsis megalops* Sars, 1901 and *Leydigiopsis curvirostris* Sars, 1901 by the morphology of the postabdomen.

Distribution: Neotropics (Van Damme and Sinev, 2013). In Brazil, the species occurs in the Amazônica, Paraná, Paraguai, São Francisco, Atlântico Nordeste Oriental, Sudeste, and Sul hydrographic regions (Elmoor-Loureiro, 2017).

Genus *Nicsmirnovius* Chiambeng and Dumont, 1999

Nicsmirnovius sp.
(Fig. 5A)

Material examined: One adult parthenogenetic female (FDRS490).

Remarks: From the Neotropics, the genus has two members: *Nicsmirnovius incredibilis* Smirnov, 1984 endemic from Amazonia (Kotov, 2003) and *Nicsmirnovius fitzpatricki* (Chien, 1970) which is distributed from Florida (USA) to Argentina. Comparison between specimens of *N. fitzpatricki* from South America and those from the type-region (USA) revealed morphological differences, leading Van Damme *et al.* (2003) to suggest a possible species-complex. The morphology of the specimen from Lake Paranoá did not fit any of the species already described, showing that they constitute a new species (Sousa and Elmoor-Loureiro, 2017). *Nicsmirnovius* sp. is recognized by three connected median head pores, cosmaria sacs underneath the lateral pores, IDL of the first pair of limbs with a chitinized hook seta, postanal portion of postabdomen wide and quadrangular.

Distribution: Preliminary data indicated that *Nicsmirnovius* sp. does not occur in median and lower portions of the Amazon Basin. *Nicsmirnovius* sp. has no geographic distribution overlap with *N. incredibilis*. A wide distribution in the Neotropics is expected.

Genus *Notoalona* Rajapaksa and Fernando, 1987

Notoalona sculpta (Sars, 1901)
(Fig. 5B)

Material examined: Two adult parthenogenetic females (FDRS491).

Remarks: Notoalona sculpta is part of a small group from the Chydoridae, with two other valid species (Rajapaksa and Fernando, 1987; Van Damme *et al.*, 2013). Although an addition to its description is necessary, *N. sculpta* is recognized by: globular body, head pores bean-like, lateral margin of head shield without a notch; postabdomen elongated, postanal portion nearly distally armed with about 14 very short marginal denticles, distalmost lateral fascicles exceeding the margin of postabdomen.

Distribution: Neotropics (Van Damme *et al.*, 2013). In Brazil, the species occurs in the Amazônica, Tocantins/Araguaia, Paraná, Paraguai, São Francisco, Atlântico Nordeste Ocidental, Nordeste Oriental, Leste, Sudeste, and Sul hydrographic regions (Elmoor-Loureiro, 2017).

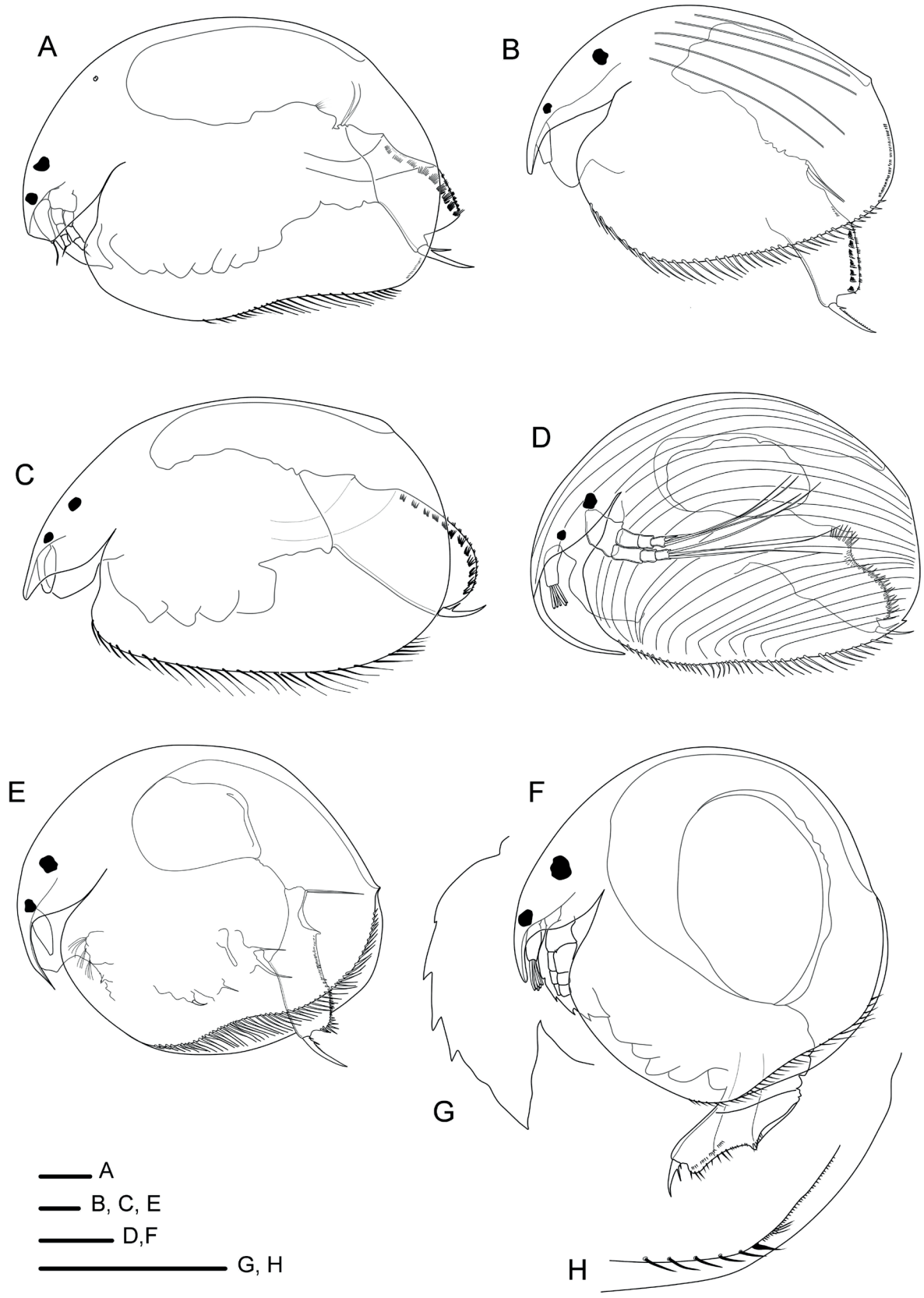

Figure 5. Parthenogenetic females from Lake Paranoá: A, *Nicsmirnovius* sp.; B, *Notoalona sculpta*; C, *Parvalona parva*; D, *Alonella dadayi*; E, *Chydorus eurynotus*; F, *Ephemeroporus tridentatus*; G, *idem*, labral keel; H, *idem*, posteroventral corner of carapace. Scale bars = 50 µm.

Genus *Parvalona* Van Damme, Kotov and Dumont, 2005

Parvalona parva (Daday, 1905)
(Fig. 5C)

Material examined: One adult parthenogenetic female (FDRS492).

Remarks: The only species of the genus (Van Damme *et al.*, 2005; Elmoor-Loureiro *et al.*, 2009), it has a very particular morphology: body sub-ovoid, rostrum short and protruding, three main head pores connected, postabdomen wide with large and broad postanal portion, marginal denticles in groups.

Distribution: Possibly in the Neotropics (Van Damme *et al.*, 2005; Elmoor-Loureiro *et al.*, 2009; Fuentes-Reines, 2015). In Brazil, *P. parva* occurs in the Tocantins/Araguaia, Paraná, Atlântico Nordeste Ocidental and Nordeste Oriental hydrographic regions (Elmoor-Loureiro, 2017).

Subfamily Chydorinae Dybowski and Grochowski, 1894 *emend.* Frey, 1967

Genus *Alonella* Sars, 1862

Alonella dadayi Birge, 1910
(Fig. 5D)

Material examined: Four adult parthenogenetic females (FDRS493).

Remarks: Species named in many studies as *Disparalona dadayi* or *Phryxura dadayi*, but Smirnov (1996) considered *Alonella dadayi* as the valid name for this species. Additionally, Fryer (1997) wrote that the description of *Phryxura* Müller, 1867 was based on a single abnormal specimen, making the name invalid according to the rules of the International Code of Zoological Nomenclature. *Alonella dadayi* has a remarkable rostrum, which is long and curved, posteroventral corner of valves with 1–7 denticles with short setulae between them, postabdomen with preanal angle prominent. The high variability of some morphological traits recommends a wide revision of *A. dadayi*.

Distribution: Neotropics (Kotov *et al.*, 2013). In Brazil it occurs in the Amazônica, Tocantins/Araguaia, São Francisco, Paraná, Paraguai, Atlântico Nordeste Oriental, Leste, Sudeste and Sul hydrographic regions (Elmoor-Loureiro, 2017).

Genus *Chydorus* Leach, 1816

Chydorus eurynotus Sars, 1901
(Fig. 5E)

Material examined: Six adult parthenogenetic females (FDRS494).

Remarks: Originally described for the Neotropics, *C. eurynotus* has been recorded worldwide, suggesting it is a complex of species. It is recognized by rostrum acute and elongated; labral keel convex with apex not projected; postabdomen narrow with distinct postanal angle, 7–11 marginal denticles of which two-three most distal longer than others, postabdominal claw with 5–7 strong spinulae on the proximal pecten. According to Kotov *et al.* (2013), it is a species with one valid subspecies: *C. eurynotus strictomarginatus* Paggi, 1972.

Distribution: presumed Cosmopolitan (Kotov *et al.*, 2013). In Brazil, it occurs in Amazônica, Tocantins/Araguaia, Paraná, Paraguai, São Francisco, Atlântico Nordeste Ocidental, Nordeste Oriental, Leste, Sudeste and Sul (Elmoor-Loureiro, 2017).

Genus *Ephemeroporus* Frey, 1982

Ephemeroporus tridentatus (Bergamin, 1939)
(Figs. 5F–H)

Material examined: One adult parthenogenetic female (FDRS495).

Remarks: Initially identified by Sars (1901) from São Paulo as *Chydorus poppei* Richard, 1897. Later, Bergamin (1939) noted differences in the valves and labral keel from *C. poppei*, which led to a description of a new species, *Chydorus tridentatus* Bergamin, 1939. Finally, Frey (1982) assigned the *Ephemeroporus* Frey, 1982 genus to a species with similar morphology of

the *Chydorus barroisi*-group. *Ephemeroporus tridentatus* is recognized by the following combination of morphological traits: labral keel armed with three teeth and posteroventral corner of valves without denticles.

Distribution: According to Kotov *et al.* (2013) the species occurs in Neotropics and Oriental zone. In Brazil, the distribution of *E. tridentatus* extends through the Amazônica, Tocantins/Araguaia, Paraná, Paraguai, Parnaíba, Atlântico Nordeste Oriental, Leste and Sudeste hydrographic regions (Elmoor-Loureiro, 2017).

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