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FORFICATOCARIS ODETEAE N. SP., A NEW PARASTENOCARIDIDAE
(COPEPODA, HARPACTICOIDA) FROM A HIGH-ALTITUDE POND IN
MINAS GERAIS STATE, BRAZIL

BY

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ABSTRACT

A new species of harpacticoid copepod, genus *Forficatocaris* (*F. odeteae* n. sp.) is described from a high-altitude pond at the Itacolomi National Park near Ouro Preto city, Minas Gerais state, Brazil. The main characters distinguishing the new species from *F. affinis* Dussart, 1983 and *F. lilianae* Noodt, 1972 are: (i) distal portion of exopod 1 of male leg 4 with stout spinules; (ii) male leg 5 lateral spine stout and with blunt apex; (iii) endopod of leg 4 curved outwards, but “c” shaped (not forming a straight angle); (iv) female with dorsal spinule row on anal somite larger than in congeners, ventral ornaments smaller and less numerous; and (v) the shape of the modified spine located at the leg 1 endopod 1 of the male; and (vi) the spine of leg 5 in males and females.

RESUMO

Uma nova espécie de copépode harpacticóide do gênero *Forficatocaris* (*F. odeteae* n. sp.) é descrita a partir de uma lagoa de altitude do Parque Nacional do Itacolomi, próximo à cidade de Ouro Preto, Minas Gerais, Brasil. Os principais caracteres que distinguem a nova espécie de *F. affinis* Dussart, 1983 e *F. lilianae* Noodt, 1972 são: (i) porção distal do exópodo 1 da pata 4 do macho com espinhos fortes; (ii) espinho lateral da quinta pata do macho curto e robusto, com ápice arredondado; (iii) endópodo da pata 4 curvado para fora, mas em forma de “c” (não formando um ângulo reto); (iv) somito anal da fêmea com fileira dorsal de espinhos maior que suas congêneres, ornamentos ventrais menores e menos numerosos; e (v) a forma do espinho modificado localizado no segmento 1 do endópodo da pata 1 do macho; e (vi) o espinho da pata 5 em machos e fêmeas.

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INTRODUCTION

Copepods belonging to the family Parastenocarididae are one of the most diverse groups of organisms among the meiofaunal community (Jakobi, 1962). Their extraordinarily high degree of ecological adaptation is particularly evident in the freshwater-rich, granulometrically differentiated sand-gap systems of tropical and subtropical South America (Jakobi, 1972). The current account of this diversity gives a total of 43 genera and 562 species and subspecies known in the world (Walter & Boxshall, 2018). However, the actual diversity of this family is yet to be discovered. An increasing rate in new species descriptions is indeed observed, which appears to be limited only by the intensity of research efforts (e.g., Karanovic et al., 2012; Schminke, 2013; Ranga Reddy et al., 2014, 2016; Totakura et al., 2014; Bruno & Cotarelli, 2015; Corgosinho et al., 2017a, b). Even at well-studied waterbodies new species are found, and despite the discovery of new species, studies are yet to cover the spatial diversity within the different freshwater basins, including altitudinal aquatic ecosystems, and poorly studied habitats in tropical countries (Gaviria et al., 2017).

In this paper we describe a new species of *Forficatocaris* Jakobi, 1969 that was discovered in samples taken at a high altitude pond in Brazil. This genus belongs to the subfamily Fontinalicaridinae Schminke, 2010 and its congeners occur in the psammic habitats within the limits of South America: *Forficatocaris tetracantha* Noodt, 1963 from Rio Huacamayo in the Peruvian Amazon basin; *F. amazonensis* Noodt, 1963 and *F. forficata* Noodt, 1963 from Santarem in the Brazilian Amazon basin; *F. shadeni* Reid, 1982 from the drainage system of the Rio Paraná (Prata basin) in the Distrito Federal, central Brazil; *F. guarani* Noodt, 1963 from Lago Ypacarai in Paraguay; *F. noodti* Jakobi, 1969, *F. fittkaui* Jakobi, 1972, *F. jakobii* Noodt, 1972, *F. evelinae* Noodt, 1972, *F. lilianae* Noodt, 1972, and *F. claudii* Noodt, 1972, from three small rivers east of the Serra da Mantiqueira and the Serra do Mar in southeastern Brazil; and *F. affinis* Dussart, 1983 from the Corrientes province, left margin of the Rio Paraná, Argentina.

MATERIAL AND METHODS

Lagoa Seca is a small pond located in the Itacolomi Park, a Conservation Unit within the districts of Ouro Preto and Mariana (Minas Gerais State, Brazil), of the Velhas River hydrographic basin waters. This is a seasonal, temporary natural freshwater body, formed in a small depression at 1609 m above sea level, with as coordinates 20°22'30"-20°30'00''S 43°32'30"-43°22'30''W (fig. 1). Lagoa Seca is filled with water during the rainy season by surface runoff, reaching a maximum depth of 1.5 m and covering an area of 300 m², and remaining completely dry from

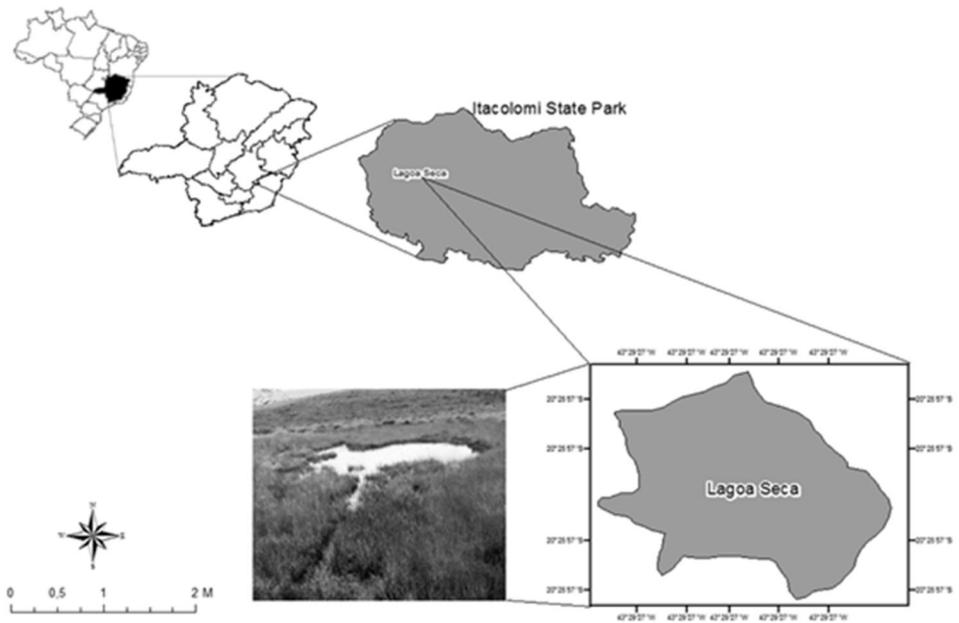


Fig. 1. Maps showing the location of the Lagoa Seca pond in Minas Gerais state and Itacolomi State Park, Brazil. Also a general view of the pond, showing its shape, and its geographical coordinates.

April to September. The climate is altitudinal, warm temperate, characterized by a mean annual air temperature of 18.9°C, with a maximum mean air temperature of 21.4°C in January and a minimum of 15.7°C in July. Historically, the mean annual rainfall is 1475 mm, with a monthly mean of 308 mm in December, the wettest month, and 15 mm in July, the driest month of the year (INMET, 2015).

The pond is oligotrophic as indicated by several factors, such as: low total dissolved solids (26.7 mg/l), total phosphorus (5.75 $\mu\text{g/l}$) and total nitrogen concentrations (276.2 $\mu\text{g/l}$), besides low algal biomass (4.85 μg chlorophyll-*a/l*) (mean values from Brito, 2015). It has a rounded shape, with arms in the form of narrow canals radiating in several directions, and it is surrounded by natural alpine vegetation, predominantly grasses and small herbaceous plants. The sediment surface is almost entirely covered by macrophytes, notably *Eleocharis minima* Kunth, *Juncus densiflorus* Kunth and *Egeria minima* Kunth; there are no records of fish, and potential vertebrate predators are tadpoles of the anurans *Scinax curicica* Pugliesse, Pombal & Sazima, 2004, *S. squalirostris* Lutz, 1925 and *Physalaemus erythros* Caramaschi, Feio & Guimarães-Neto, 2003 (cf. Moreira et al., 2016).

Zooplankton samples were collected once per month during the rainy season in October, November and December 2010 and January 2011, at distinct mesohabitats, including the shallowest areas of the littoral region that is covered by emergent macrophytes and the open water area, which is covered mainly by submerged

macrophytes. Water samples of around 90 L were collected with a plastic bucket and filtered through a plankton net with 68 μm mesh. Samplings were performed at three evenly spaced points in the littoral zone of the pond and then integrated in one sample. In the open water area, zooplankton samples were also obtained on 3 spots, equally distributed from the beginning to the end of the open water line and these were also integrated into one sample. Samples were preserved with 4% (v/v) formaldehyde. Limnological features of the pond including water temperature ($^{\circ}\text{C}$), pH and conductivity (mS/cm) were measured using a multi-parameter water quality meter (model U-50, Horiba Trade, Japan). The mean pH was 6.5 ± 0.07 , temperature $19.2 \pm 0.18^{\circ}\text{C}$ and electrical conductivity 0.008 ± 0.006 mS/cm.

Specimens were selected from the preserved samples using a stereomicroscope, and were next stained with Bengal Rose dye. The specimens were then mounted on slides in lactic acid and dissected to observe some of the morphological characters. Drawings were made with an Olympus BX51 microscope equipped with a drawing tube, at magnifications of $400\times$ and $1000\times$. Anatomical nomenclature as in Corgosinho et al. (2017a, b). The term 'furca' is here used in accordance with Schminke (1976). Abbreviations used are: A1, antennule; A2, antenna; Ae, aesthetasc; GS, genital somite; MD, mandible; Mxl, maxillula; Mx, maxilla; Mxp, maxilliped; enp, endopod; exp, exopod; P1-P5, legs 1 to 5; Th, thoracic somite; Fu, furca; and, Ur, urosomal somite. The type material is deposited in the invertebrate collection of the Museum of Zoology of the University of São Paulo — MZUSP, São Paulo, Brazil.

RESULTS

Subphylum CRUSTACEA Brünnich, 1772

Class HEXANAUPLIA Oakley, Wolfe, Lindgren & Zaharof, 2013

Subclass COPEPODA H. Milne Edwards, 1840

Order HARPACTICOIDA Sars, 1903

Family PARASTENOCARIDIDAE Chappuis, 1940

Subfamily FONTINALICARIDINAE Schminke, 2010

Genus *Forficatocaris* Jakobi, 1969

***Forficatocaris odeteae* n. sp. (figs. 2-5)**

Material examined.— Holotype: female, MZUSP 36771 (Museu de Zoologia da Universidade de São Paulo), dissected on five slides. Paratypes: one male (MZUSP 36772) and one female (MZUSP 36828). Dates of sampling: October, November and December 2010 and January 2011.

Location: Minas Gerais, from a small altitudinal pond at Itacolomi State Park, Brazil.

Type locality: small pond (Lagoa Seca) in Itacolomi State Park, Minas Gerais, Brazil, position $20^{\circ}22'30''-20^{\circ}30'00''\text{S}$ $43^{\circ}32'30''-43^{\circ}22'30''\text{W}$, altitude 1609 m a.s.l.

Accompanying species encountered in the plankton samples: *Bosminopsis* sp. (Cladocera); *Epactophanes richardi* Mrazek, 1893 (Harpacticoida, Canthocamptidae).

Description of male.— Length 460 μm , measured from rostrum to end of anal somite, excluding Fu. Rostrum not fused to cephalothorax, with wide base and pair of sensilla; cephalothorax and Ur2 to 5 with dorsal integumental window (fig. 2). Ur5 ornamented with very fine spinules in rows next to integumental window (fig. 2B). Anal somite with transverse row of small spinules dorsally, anterior to sensilla, located at medial portion of somite; two long dorsal spines on each side of anal operculum, innermost spines longer (about twice as long) than outer ones; ventral pair of stout spines with size similar to smaller dorsal spines (fig. 2E); anal operculum convex, with rows of fine hairs covering most of preopercular lateral

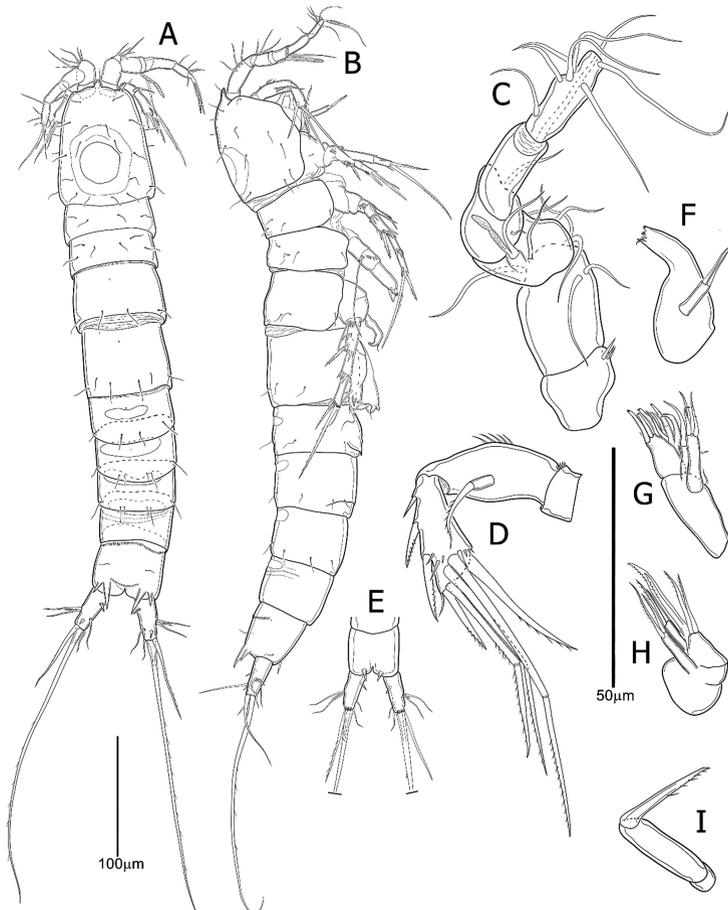


Fig. 2. *Forficatocaris odeteae* n. sp., male: A, habitus, dorsal; B, habitus, lateral; C, right A1; D, A2; E, Ur, ventral; F, left Md; G, Mx; H, Mx1; I, Mxp.

margins (fig. 2A). Furcal rami rectangular, with small distal outer pore; about two times as long as wide; ornamented with two stout dorsal spines, one at proximo-inner portion and one next to dorsal seta; with seven setae as follows: setae I, II and III and dorsal seta VII aligned; setae I, II and III slender, grouped at mid portion of the outer margin of segment; one of these smaller than remaining ones; seta IV inserted distally on outer margin, slightly longer than anal somite; seta V inserted distally, almost four times as long as seta IV; seta VI inserted distally, next to seta V, much shorter than seta IV; dorsal seta VII inserted in innermost portion of furcal ramus.

A1 (fig. 2A-C) eight-segmented, haplocer (segments 3 to 5 with separations not represented in fig. 2C), with small patch of spinules on segment 1; segments 5, 6, and 7 forming functional unit for clasping female; in grasping position, setal armature per segment as follows: (1(0)/2(5)/3(4)/4(1)/5(3 + (1 + ae))/6(1)/7(0)/8(7 + modified seta + (2 + ae)); segment 8 with seven slender setae, two setae fused basally to aesthetasc, and one modified seta.

A2 (fig. 2D) allobasis without abexopodal armature, with small outer spinule row distally; one-segmented exp with one seta; free endopodal segment with spinules on distal margin and bearing seven setae/spines, of which outermost strongly developed.

Md as in fig. 2F. Coxal gnathobasis with distal teeth and one seta; palp one-segmented, with two distal setae.

Mx1 as in fig. 2G. Praecoxal arthritis with five elements (one surface seta, three claw-like pinnate spines, and one slender seta); coxal endite with one seta and basis with three setae.

Mx as in fig. 2H. Allobasis with two endites; proximal endite with one and distal endite with two elements, one of these transformed into serrated spine; proximal endopodal segment drawn out into claw; distal endopodal segment with two setae.

Mxp (fig. 2I) subchelate; syncoxa about 1/5 of length of basis; enp drawn into spinulose claw.

P1 (fig. 3A) with unarmed coxa, ornamented by one row of tapering, stout spinules of different sizes; inner seta of basis not reaching medial portion of enp1, with small row of spinules near insertion of exp; enp two-segmented, enp1 longer than enp2, with distal row of spinules, and two groups of spinules, each of which comprising two spinules, on outer margin; chitinous hook projecting ventrally from midpoint of inner margin of segment 1; end 2, outer margin with spinules, distal margin with one large outer spine and geniculate seta, inner margin with 2 spines inserted distally; exp three-segmented, exp1 with one small outer distal spine and row of spinules proximal to distal spine, exp2 outer margin without spine, with row of spinules close to distal corner, exp3 outer margin with row of spinules and one

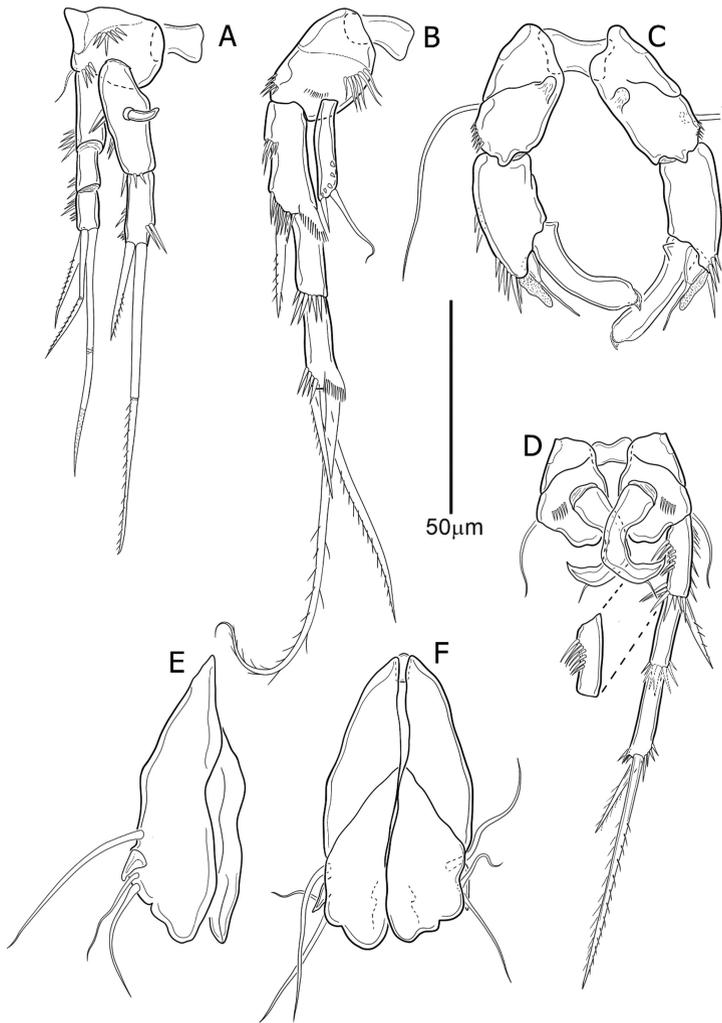


Fig. 3. *Forficatocaris odeteae* n. sp., male: A, right P1; B, right P2; C, P3; D, P4; E, right P5; F, P6. All appendages in anterior view.

spine inserted subapically. Distal portion with two geniculate setae and two spines (fig. 3A, second spine broken and not represented).

P2 (fig. 3B) coxa without ornaments; basis without outer seta, with row of spinules on outer margin, row of fine spinules near insertion of endopod and row of long spinules near inner margin; enp one-segmented, reaching over middle of exp1, armed with one distal seta and one distal spine, ornamented with denticles along anterior surface; exp three-segmented, exp-1 with long outer spine, ornamented with medial row of outer spinules, with one row of long spinules close to outer spine, and on opposite side inner hyaline frill; exp2 outer margin without spine,

with distal row of spinules; exp3 outer margin with one unipinnate spine inserted subapically and row of spinules, one distal unipinnate spine twice as long as outer element, and one bipinnate apical seta nearly twice as long as previous element, additionally with longitudinal row of spinules on distal third, proximal to outer spine and adjacent to inner hyaline frill.

P3 (fig. 3C) coxa partially fused to basis, with row of outer spinules close to exp and chitinized digitiform process next to inner margin; enp absent; exp1 rectangular, about four times as long as wide, inner margin irregular, outer margin convex, with two spinules at medial portion, and row of stout spinules distally inserted; distal margin with hyaline element inserted on outer corner; exp2 transformed into apophysis, strongly chitinized laterally, thumb longer than apophysis, blade-shaped, with broad base, curved inwards proximally, and ending in spinule as in *F. evelinae* and *F. affinis*.

P4 (fig. 3D) coxa without ornamentation; basis with outer seta, and row of spinules between insertions of exp and enp; enp strongly chitinized, curved inwards ("L-shaped"), ending with acute tip and lateral/outer setule; exp 3-segmented, exp-1 with long outer spine, ornamented with row of spinules proximally and sub-distally, with inner row of long spinules, and distal row of stout spinules; exp-2 without spine on outer margin, distal margin with row of spinules; exp-3 outer margin with row of outer spinules subdistally, distal margin with one bipinnate outer spine, and one bipinnate distal seta nearly twice as long as outer element, followed by one inner hyaline frill.

P5 (fig. 3E-F), distinct from somite and with complex structure, typical for this genus; without inner ornamentation; armature consisting of very long outer basal seta, one well-developed outer spine and two outer distal setae of similar length.

P6 (fig. 2B) reduced to lobe at distal portion of somite.

Description of female.— Length of holotype 515 μm . Body vermiform, sub-cylindrical. Rostrum not fused to cephalothorax and bearing one pair of sensilla; right antennule (fig. 4B) with seven segments. Cephalothorax and Ur 2 to 4 with one dorsal integumental window; GS window with wider area than in remaining Ur (fig. 4A, C). Genital field of female divided medioventrally by sulcus and surrounded by one protuberance on each side (fig. 4D).

Dorsal pores on Th1, 3 and 4 and on GS and Ur2. Anal somite bearing two dorsal spines on each side of anal operculum, with inner spine large and extending nearly until half Fu length, with outer spine about one-fourth of length of inner one. Anal somite also bearing pair of dorsal sensilla and row of small spinules dorsally, ending with small pore at both sides and one small ventral tube pore near insertion of furcal rami (fig. 4E, F); ventrally also four semi-circular rows of spinules, larger than dorsal ones. Anal operculum with three rows of fine spinules at margin directed towards anal opening.

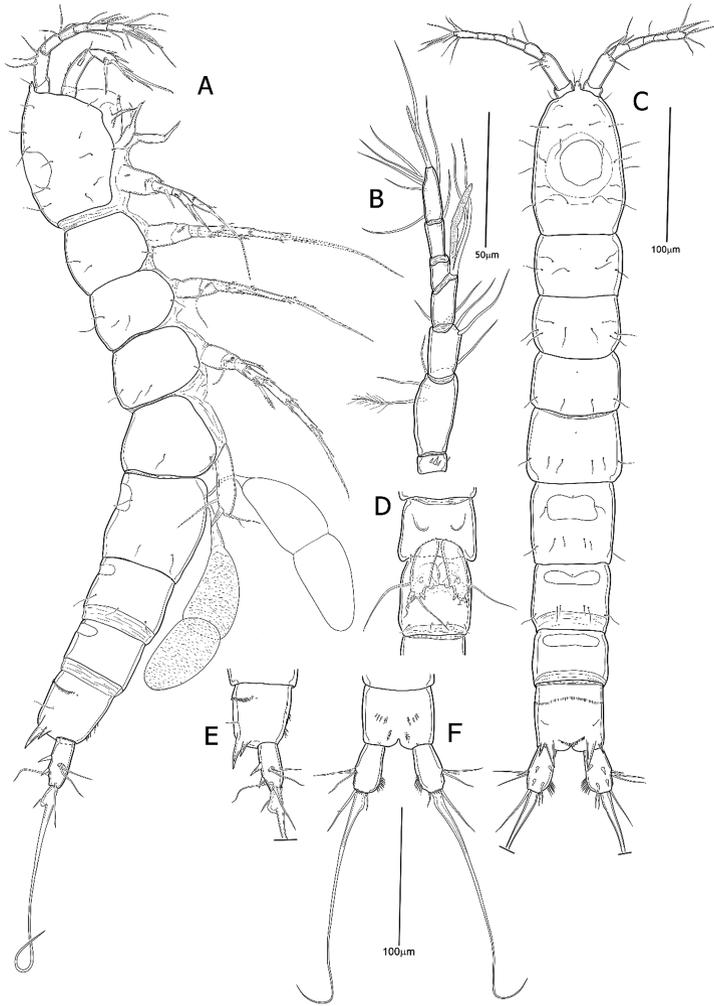


Fig. 4. *Forficatocaris odeteae* n. sp., female: A, habitus, lateral; B, right antennule; C, habitus, dorsal; D, GS, ventral; E, Ur and Fu, lateral; and, F, Ur and Fu, ventral.

Furcal rami barrel-like, about two times as long as wide, with seven setae as follows: setae I, II and III inserted medially, one of these shorter than others; dorsal seta VII subdistally inserted, dislocated towards inner portion of segment; setae IV, V and VI inserted distally, length and ornamentation as in male. Distal portion with large ventral pore (fig. 4E). Ornamentation composed of one row of setules at inner margin, three stout spinules dorsally (fig. 4C) and one row of small spinules at distal margin (fig. 4C). Female bearing 1-3 banana-shaped egg sacs, each sac containing one or two eggs (fig. 4A).

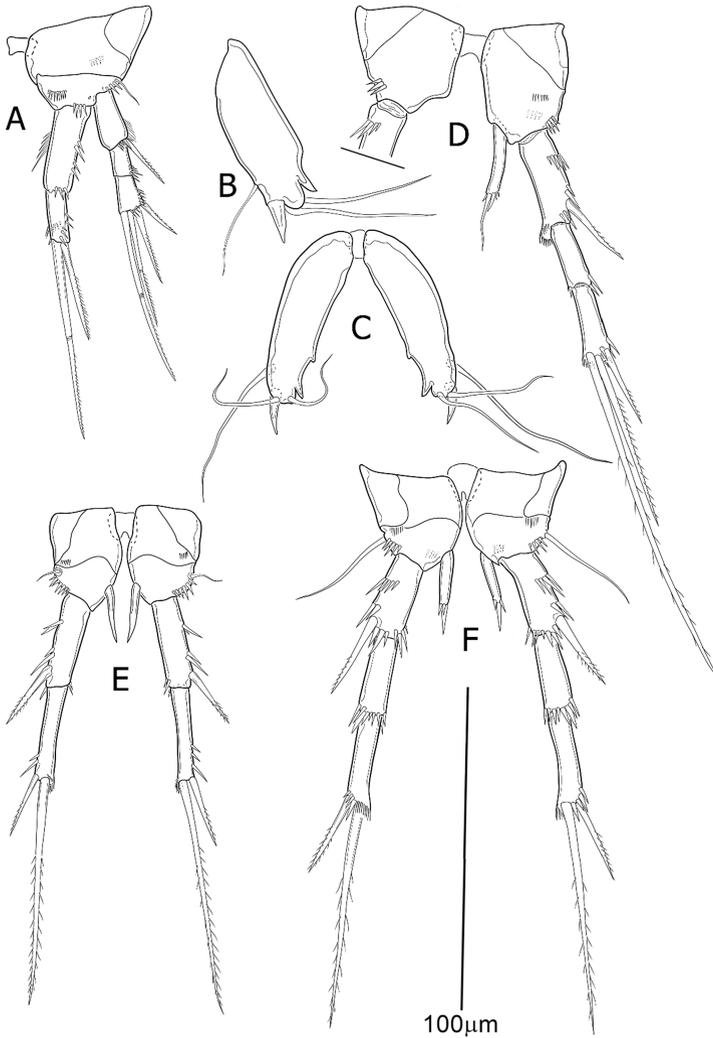


Fig. 5. *Forficatocaris odeteae* n. sp., female: A, left P1; B, left P5; C, P5; D, left P2; E, P3 and F, P4. All appendages in anterior view.

A1 seven-segmented (fig. 4A, B); armature as follows: (1(0)/2(4)/3(4)/4(1 + 1 + ae))/5(1)/6(1)/7(6 + (1 + ae)). First segment with three to five stout spinules. P1 (fig. 5A) as in male, with comparatively shorter outer basal seta.

P2 (fig. 5D and table I) coxa, basis and exp as in male, but with more slender outer spine on exp1 and exp3. Enp one-segmented, with two distal spines, one thinner and longer than other, and ornamented with spinules on each side.

P3 (fig. 5E) coxa unarmed, with row of small spinules near distal margin; basis with short outer seta and row of stout spinules along distal margin; endopod one-

TABLE I
Formula for the major setal and spine armature in
Forficatocaris odeteae n. sp., male and female

P1	coxa 0-0	basis 1-0	exp 1-0; 0-0; 2.2.0 enp 0-0; 0.2.0
P2	coxa 0-0	basis 0-0	exp 1-0; 0-0; 1.2.0 enp 0.2.0
P3	coxa 0-0	basis 1-0	exp 1-0; 0.2.0 enp 0,0,0
P4	coxa 0-0	basis 1-0	exp 1-0; 0-0; 0.2.0 enp 0.1.0

segmented, naked, with spine-like distal margin; exp 2-segmented, exp1 with outer distal bipinnate spine and outer spinule patches; exp2 with one outer bipinnate spine subapically inserted, distal bipinnate seta and inner hyaline frill on distal corner.

P4 (fig. 5F) coxa unarmed, with distal spinule row; basis with outer seta and adjacent spinule row on anterior surface plus similar ornamentation on posterior surface near base of endopod; endopod one-segmented, with one stout spine and two small spinules distally; exopod 3-segmented, exp1 with outer distal bipinnate spine, two outer spinule patches and distal row of spinules; exp2 unarmed, with distal row of spinules; exp3 with one outer bipinnate spine and distal bipinnate seta, outer spinules and inner hyaline frill distally.

P5 (fig. 5B-C) composed of one single plate, bearing four setal elements; outer margin with one long seta, followed by stout, short spine and two long distal setae; inner margin with one medial protuberance and one more distal spinous process.

Etymology.— This species is dedicated to Prof. Dr. Odete Rocha (Federal University of São Carlos), who gave strong support to several Brazilian students in developing plankton studies. The specific name thus is a noun in the genitive singular.

TABLE II
Some morphological differences between *Forficatocaris odeteae* n. sp. and presumably closely related species of *Forficatocaris*

	<i>F. odeteae</i> n. sp.	<i>F. affinis</i> Dussart, 1983	<i>F. liliana</i> e Noodt, 1972
A1 F first segment	3 spinules	3 sensilla	2 sensilla
A2 exopod seta	pinnate	blunt	blunt
P5 exopod spine	acute	acute	blunt
P5 inner margin	medial	distal	subdistal
protuberance, female			
P5 spine, male	rhomboid	bifid	bifid

DISCUSSION

Noodt (1972) states that only few characters can be regarded as unquestionable plesiomorphies within the family Parastenocarididae, namely (i) exp of the A2 sometimes with two setae; (ii) palpus of Md with 2 setae and 1 sensillum; (iii) Mx still with 3 endites (even a fourth endite is sometimes still present); (iv) exp of the P2 sometimes still 2-segmented; and (v) exp of the P3 of the male usually still clearly two-segmented. *Forficatocaris odeteae* n. sp. possesses all those characters, and also shares with *F. affinis* and *F. lilianae* the general aspect of the endopods and exopods in males and females, suggesting that they are closely related. However, the new species differs from its congeners by the shape of the modified spine located at leg 1 endopod 1 of the male, as well as by the spine of leg 5 in males and females (table II).

F. odeteae is the first species of Harpacticoida described from Itacolomi State Park waters, which are part of the Velhas River hydrographic basin. The closest known occurrence of *Forficatocaris* is from Serra da Mantiqueira (*F. noodti*), located at least 200 km from Itacolomi, and belonging to a different hydrographic basin. Since most of the central region of Brazil has not been surveyed for copepods, new records are expected. Additionally, the limited number of different habitats that have been sampled so far could explain the presumed discrepancy between the real number of species and that of the known records (Ahnert, 1998). The diversity of unstudied ponds and lakes in the region together with the inclusion of DNA analysis of the representants of *Forficatocaris*, could thus reveal more new species in future studies.

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