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First record of the genus *Kliopsyllus* Kunz, 1962 (Copepoda Harpacticoida, Paramesochridae) from Northeastern Brazil with description of the deep-sea species *Kliopsyllus minor* sp. nov.*

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Abstract

Sediment samples were collected from the deep sea adjacent to the State of Sergipe (Northeastern Brazil) within the framework of the Sergipe Continental Slope Environmental Characterization Project (coordinated by PETROBRAS, the Brazilian Petroleum Company S/A). These revealed a new species of the family Paramesochridae (Copepoda, Harpacticoida). *Kliopsyllus minor* sp. nov. is the smallest species discovered in this genus, with a body length of 0.19 mm in the adult male. Furthermore, it is one of the three *Kliopsyllus* species registered from the deep sea so far. In almost all *Kliopsyllus* species, the endopod of P4 is one-segmented. Only three species, i.e. *Kliopsyllus andeep* Veit-Köhler, 2004 from the abyssal Weddell Sea, a new species by Veit-Köhler and Thistle from the San Diego Trough (deep Pacific Ocean) and the new species presented here, show a two-segmented endopod in the P4. *Kliopsyllus andeep* is distinguished by the presence of strong, chitinous processes at the telson, and additional setae at the endopods of P3 and P4. The new Pacific species and the new species from Brazil can be distinguished by the shape of the segments of the swimming legs and detailed characteristics of their setae and spines.

Key words: Deep sea; Diversity; Harpacticoida; Paramesochridae; *Kliopsyllus*; Sergipe; Atlantic Ocean

Introduction

Compared to continental shelves, the diversity and species composition of Copepoda, Harpacticoida from the deep sea are poorly investigated. Although the number of harpacticoid copepod species is approximately 4,300 (Wells 2007), Seifried (2004) estimated that only about 460 species of Harpacticoida were described from the deep sea at that time.

As in most of the Paramesochridae, the species of the genus *Kliopsyllus* Kunz, 1962 are characterized by small cylindrical bodies and reduced segmentation and setation of the swimming legs. They frequently inhabit shallow waters and beaches (Nicholls 1939; Kunz 1962; Mielke 1984a, b, 1985, 1987; Mitwally & Montagna 2001). At present, *Kliopsyllus* includes 29 valid species and 7 subspecies described for these habitats.

Recently, two international deep-sea cruises, DIVA to the Angola Basin and ANDEEP to the northern Weddell Sea revealed the presence of two new *Kliopsyllus* species from the deep sea (Veit-Köhler 2004; 2005). *Kliopsyllus minor* sp. nov. is the third species described from the deep sea and raises the number of

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valid *Kliopsyllus* species to 32. According to Veit-Köhler (2005) the apparent lack of deep-sea *Kliopsyllus*-species is not due to the absence or rareness of these animals in this environment but to the lack of taxonomists working with them.

This work contributes to a better knowledge of the species composition of Copepoda, Harpacticoida on the Sergipe continental slope and adds a new member to the deep-sea Paramesochridae. Taxonomical studies of harpacticoid copepods from the deep-sea areas of the southwest Atlantic Ocean are of major importance to the evaluation of global biodiversity. In this special case they serve as background data to the environmental monitoring of petroleum production areas.

Material and Methods

The material described in this paper was collected from the continental slope of Sergipe (off North-eastern Brazil) during the Oceanographic Campaign NE2002-C1 of the "Astro Garoupa" at station 6 at a depth of 492 m, on 21 April 2002.

Sediment samples were obtained with a modified USNEL SPADE CORER MKI box-corer. This device collects 0.25 m^2 of sediment, subdivided into 25 subsamples. From each deployment, 3 subsamples (squares with sides of 10 cm and a depth of 5 cm, area 0.01 m^2) were used for meiofauna investigations. Each sample was fixed in 10% formalin buffered with borax.

In the laboratory, copepods were stored in 70% alcohol and subsequently transferred to glycerin. Specimens of *K. minor* sp. nov. were sorted with the aid of a Leica MZ 12.5 stereomicroscope.

The male holotype of *K. minor* sp. nov. was drawn from the dorsal and lateral side before dissection. Dissected parts of holotype and paratype were mounted in glycerine on slides. Drawings were made with the aid of a camera lucida on a Leica DMR microscope equipped with differential interference contrast (DIC) at 1000x magnification.

Due to the minute dimensions of the whole animal and of the antennule, antenna, and mouthparts, it has to be taken into account that we were only able to draw the clearly visible features. In order to cope with this, we show several mouthparts from two different angles.

Abbreviations used in the text: enp—endopod, exp—exopod, enp/exp1–3—first to third segment of enp/exp; P1–P5—swimming legs 1 to 5; aes–aesthetasc.

Taxonomy

Paramesochridae Lang, 1944
Kliopsyllus Kunz, 1962
***Kliopsyllus minor* sp. nov.**

Material: The specimens examined are deposited in the Museum of the University of São Paulo (MZUSP), Brazil. Male holotype No. 18833 (5 slides) and paratype No. 18834 (8 slides) were collected at a depth of 492 m along the continental slope of Sergipe state, Brazilian coast (11°29'42"S/37°09'41"W), in a muddy (>85% silt-clay) sediment.

Etymology: The species name *minor* refers to the species size, the smallest species registered for this genus so far.

Description of male: Habitus (Figs. 1A and B). Total body length measured from anterior tip of rostrum to posterior margin of telson: 0.19 mm. Including the furcal rami total length: 0.22 mm. Spermatophore is situated on the right side of body.

Body slender and cylindrical (Figs. 1A and B), slightly depressed dorsoventrally, with prosome only slightly wider than urosome. Whole body covered with small, round depressions resembling the surface of a

golf ball. Pores are distributed dorsally and laterally on cephalothorax. Posterior margin of third and fourth urosomites (ventrally and ventrolaterally) and fifth urosomite (ventrolaterally) ornamented with row of minute spinules (Fig. 1B, 2A). Fifth urosomite carrying a thin, well developed pseudoperculum (Fig. 1 B). Telson short with minute spinules ventrally and ventrolaterally along the posterior margin (Fig. 1 B, 2 A). Posterior margin of furcal rami ventrally with row of spinules.

Furcal rami long and cylindrical (Figs. 1 A–C), 6 times longer than wide, with several distal spinules ventrally and 6 discernible setal elements: seta I not detected; seta II slender, situated proximally and dorsally displaced; seta III slender, shorter than II, situated laterally and subterminally; seta IV and V long and slender, situated terminally; seta VI minute, situated at inner margin of caudal rami; seta VII slender, near middle of dorsal surface.

Rostrum very small, hyaline (Fig. 1D), fused with cephalothorax.

Antennule (Figs. 3A and B) 7-segmented, chirocer. Segment I with several small spinules at inner margin. Segment V very small (not visible in Fig. 1B). Segment VI rounded and bulbous at proximal margin. Following segments not completely separated and forming segment VII. Armature formula: I (1): only visible in Fig. 3B; II (1): only visible in Fig. 3B; III (7): at least 7 slender naked setae of different sizes; IV (2): 2 setae (second only visible in Fig. 3 B); V (1): at least 1 seta; VI (5+aes): at least 5 naked setae, one of which strong, and 1 aesthetasc, broken; VII (5+(1+aes)): at least 6 slender naked setae, one of which is fused at base with aesthetasc, two of which strong.

Antenna (Fig. 3C). Basis asetose. Enp 2-segmented. Enp1 with 1 pinnate seta. Enp2 bearing 6 apical setae, two of which fused at base, one of which pinnate, and 3 small subapical setae. Exp 1-segmented with 4 apical elements and at 3 lateral setae, one of which spinulose at tip.

Labrum (Fig. 3D) with minute spinules apically.

Mandible (Figs. 4A and B). Coxa with elongated gnathobasis. Cutting edge with 1 large and 7 smaller teeth, and 1 short, subdistal spinule. Basis asetose. Palp biramous. Exp 1-segmented with 4 bare slender setae apically. Enp 2-segmented, first segment bearing 3 naked setae, second segment with 5 bare setae apically.

Maxillula (Figs. 4C and D). Praecoxal arthrite with 2 juxtaposed slender setae on anterior surface. Inner margin of arthrite with altogether 8 strong spines and 1 additional seta. Coxal endite bearing 4 slender setae. Basal endite armed with 5 slender, naked setae. Enp and exp broken off in holotype. Enp in paratype with 4 slender naked setae (Fig. 4D, behind basis), exp hidden behind basis.

Maxilla (Figs. 4E and F). Praecoxa and coxa fused to form a syncoxa bearing 3 endites. No separation towards basis visible. Proximal endite slightly bilobed, 2 setal elements on proximal lobe, 3 on distal lobe. Middle endite with 3 naked setae. Distal endite with 3 setal elements, one of which spinulose. Basis with 3 strong, naked setae. Enp 2-segmented with 1 naked seta on first segment and 4 naked setae on second.

Maxilliped (Fig. 3E) prehensile. Praecoxa and coxa fused to form syncoxa with 1 slender naked seta near middle of inner margin. Basis asetose. Enp 1-segmented with 2 apical setae of different sizes and 1 small element.

Swimming legs (Figs. 5A–D, Table 1) with intercoxal sclerites as in Fig. 5B.

TABLE 1. Setal formula of swimming legs of *Kliopsyllus minor* sp. nov.

	Basis	Exopod	Endopod
P1	1-1	0.022	0.020
P2	0-1	0.0.022	010
P3	0-1	0.0.022	010
P4	0-1	0.0.011	0.010

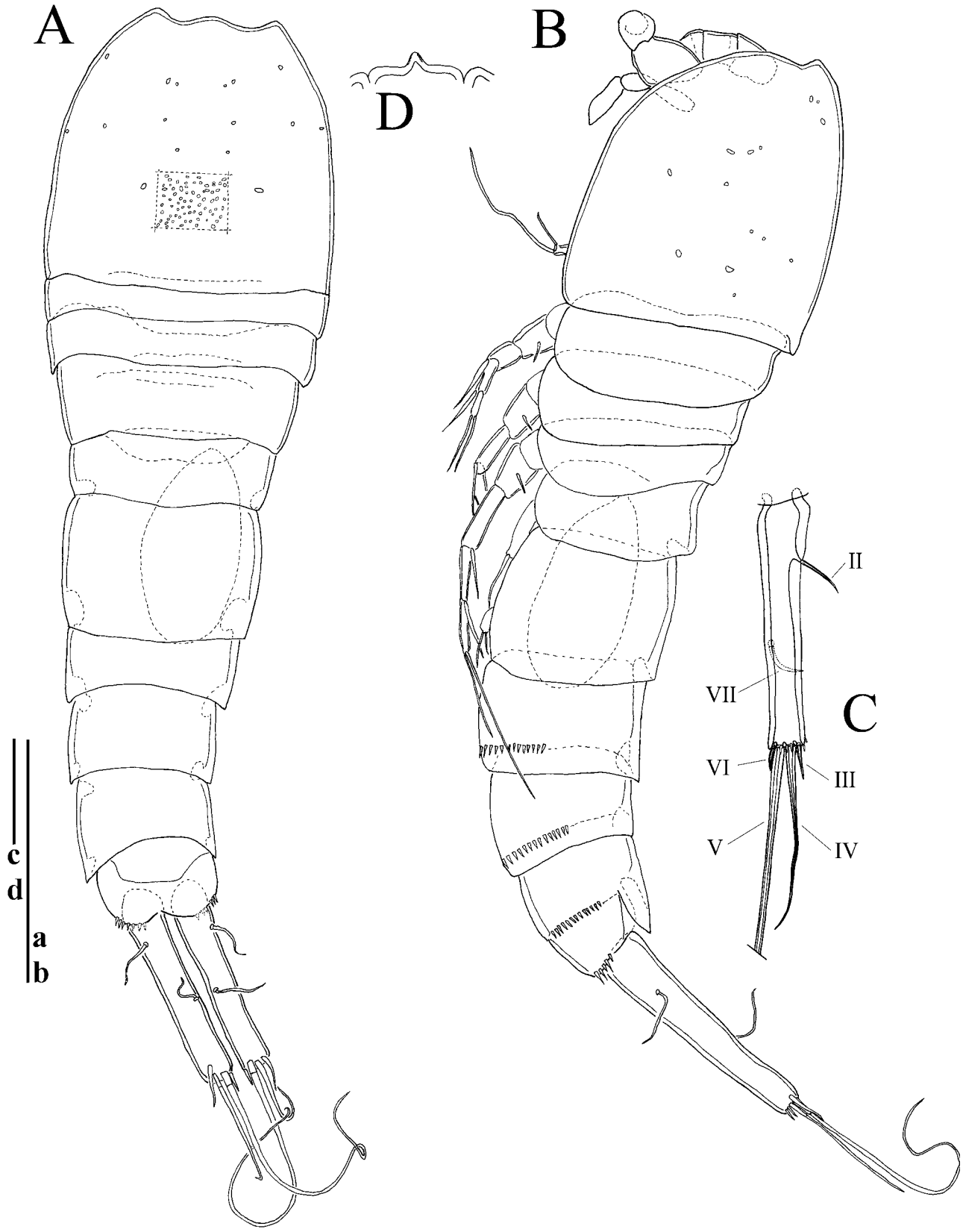

FIGURE 1. *Kliopsyllus minor* sp. nov., male holotype. (A) habitus, dorsal view; (B) habitus, lateral view; (C) left furcal ramus, ventral view; (D) rostrum, ventral view. Scale bars a, b = 0.05 mm, c, d = 0.02 mm

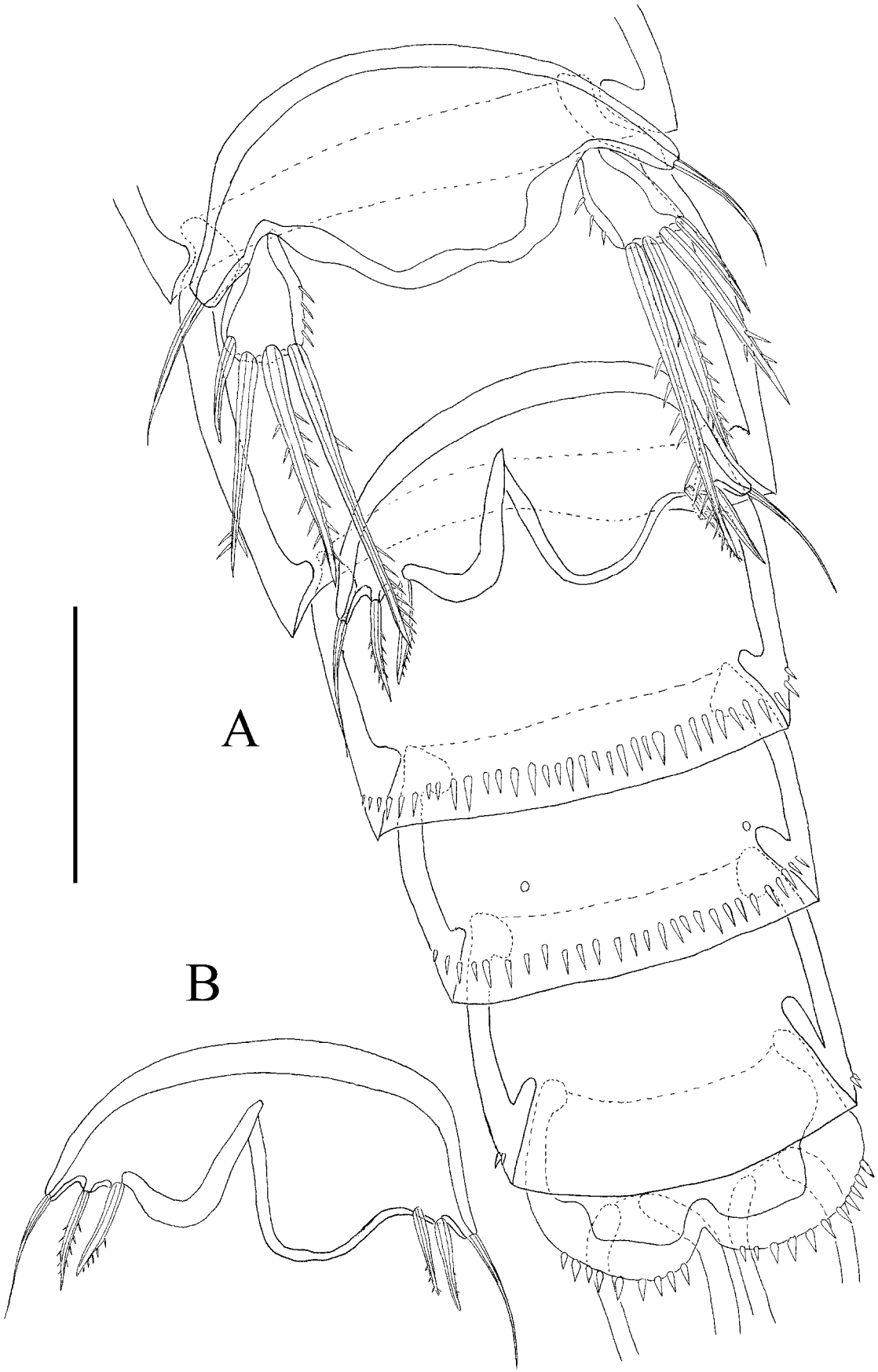

FIGURE 2. *Kliopsyllus minor* sp. nov., male paratype. (A) abdomen (ventral view), with P5 and P6; (B) P6. Scale bar = 0.02 mm.

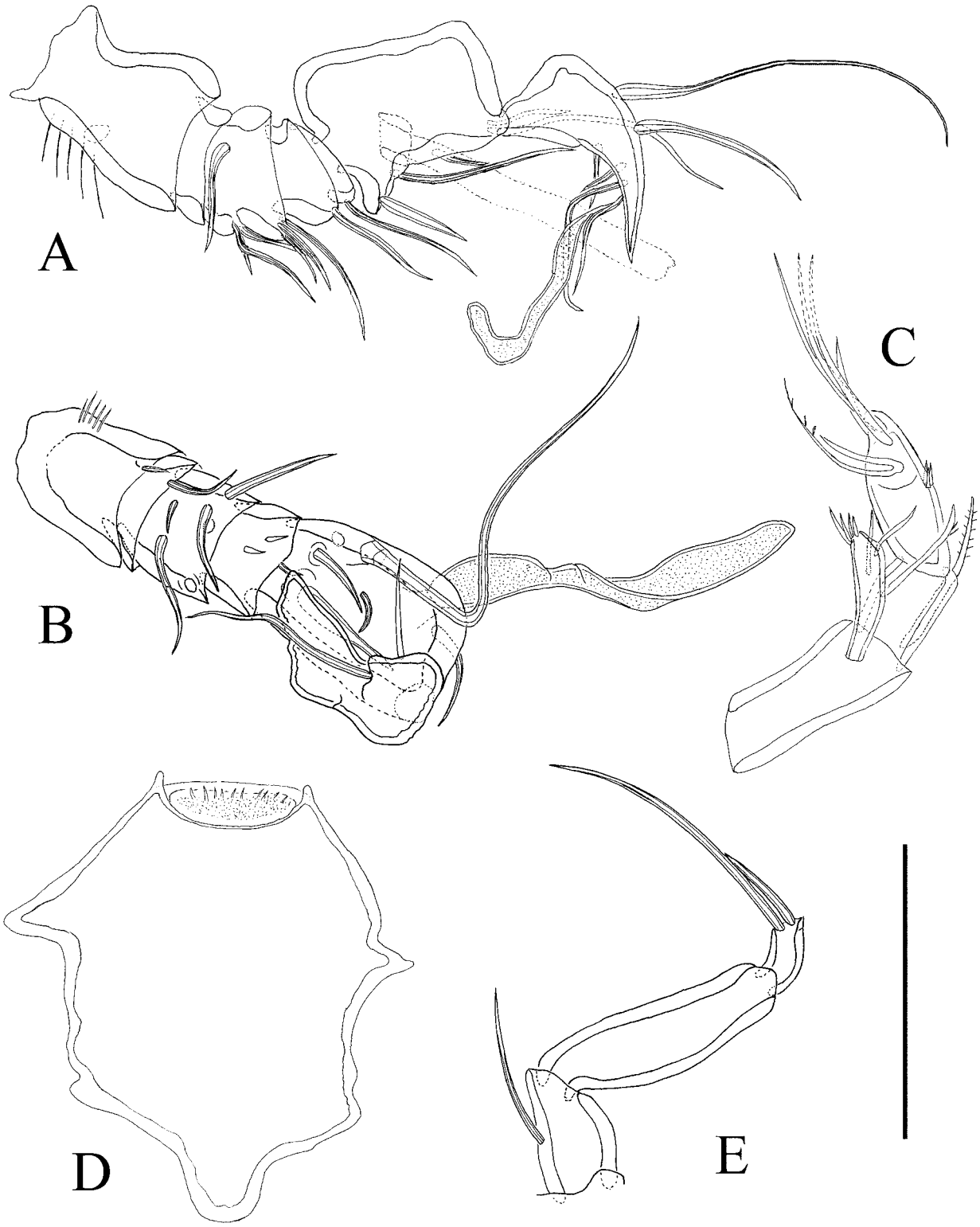

FIGURE 3. *Kliopsyllus minor* sp. nov. Male. (A) Antennula (paratype), dotted aesthetasc damaged; (B) Antennula (holotype); (C) Antenna (paratype); (D) Labrum (paratype); (E) Maxilliped (holotype). Scale bar = 0.02 mm.

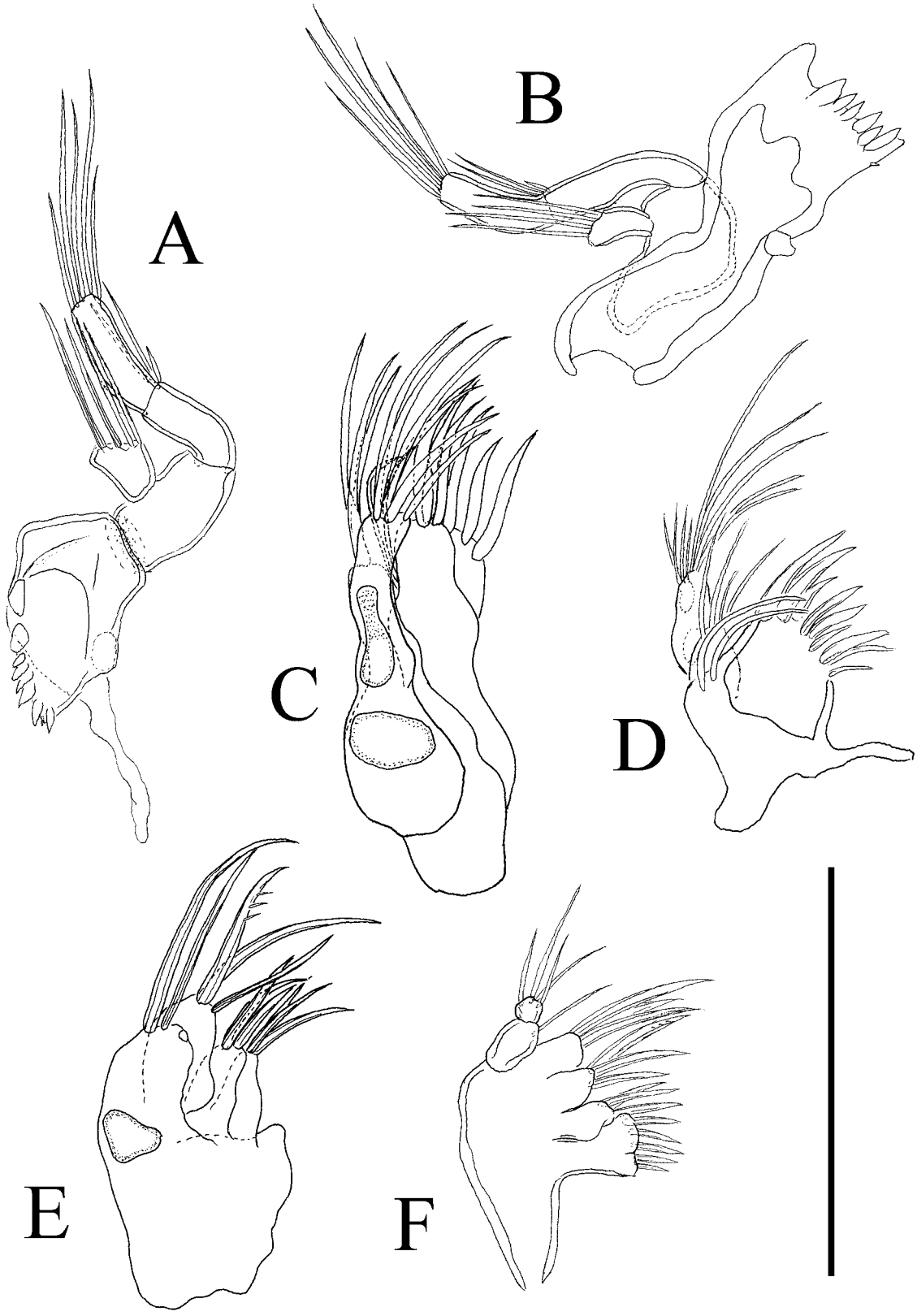

FIGURE 4. *Kliopsyllus minor* sp. nov. Male. (A, B) Mandible, different views (holotype); (C) Maxillula (paratype), enp and exp broken off (dotted regions); (D) Maxillula (holotype), enp and exp hidden behind basis (see description); (E) Maxilla, enp broken off (dotted region), basis damaged (paratype); (F) Maxilla (holotype). Scale bar = 0.02 mm.

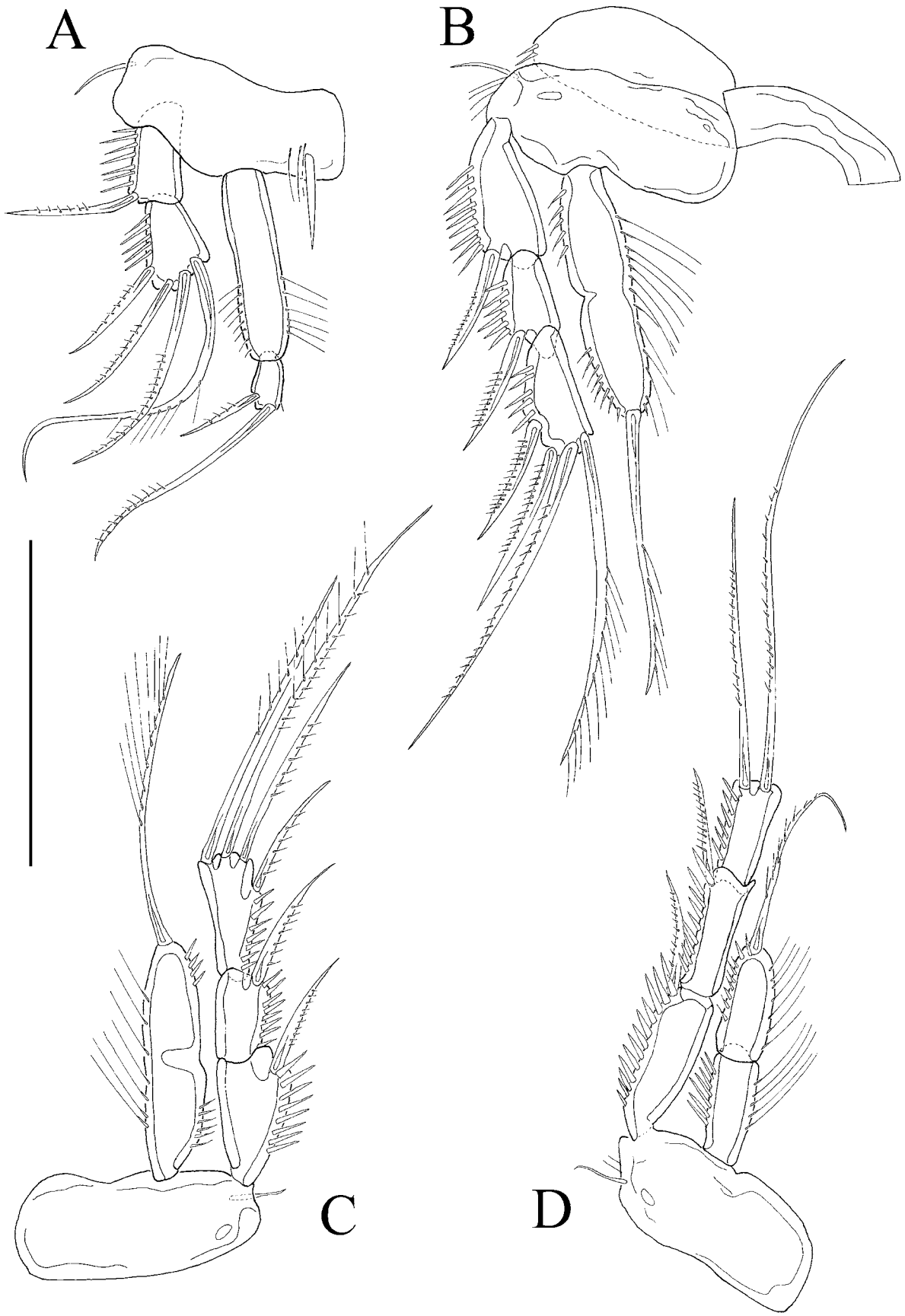

FIGURE 5. *Kliopsyllus minor* sp. nov. Male holotype, swimming legs. (A) P1; (B) P2 with intercoxal sclerite; (C) P3; (D) P4. Scale bar = 0.02 mm

P1 (Fig. 5A) basis with 1 outer and 1 inner naked seta accompanied by several spinules. Enp and exp 2-segmented and armed with spinule rows along outer margin of exp and inner and outer margin of enp1, those in enp1 very fine and long. Enp1 asetose and of same size as complete exp. Enp2 bearing terminally 1 long seta and 1 spine, both unipinnate. Exp1 with 1 outer pinnate spine. Exp2 with 2 outer unipinnate spines, and 1 spine with outer spinules and 1 seta with inner setules, terminally.

P2–P4 (Figs. 5B–D). Basis bearing 1 outer seta, in P2 and P4 accompanied by some spinules, and 1 pore. Three-segmented exopods longer than respective endopods, with strong stout spinules along outer margin. Exopodal segments with elongate shape, especially pronounced in P4. Exps1 and 2 of P2–P4 with outer spine. Exp3 of P2 and P3 with 2 outer spines with spinules along outer margin, 1 outer terminal spine and 1 inner terminal seta with setules along inner margin. Enp of P2 and P3 1-segmented with long, fine spinules along inner margin, short spinules along outer margin, and 1 long unipinnate seta apically. Both enps slightly constricted near middle of outer margin. Exp3 of P4 with 1 outer spine and 1 outer terminal spine, both with spinules along outer margin. Enp P4 2-segmented with long spinules along inner side and short along outer side of both segments. Enp1 of P4 asetose and enp2 of P4 with 1 terminal pinnate seta.

P5 (Fig. 2A). Legs fused medially. Exopod separated from baseoendopod. Exp with 3 terminal bipinnate setae and 1 small and naked outer seta. Benp bearing only 1 outer basal, naked seta.

P6 (Figs. 2A and B) represented by small, medially fused plates, each bearing 2 small bipinnate inner setae and 1 naked outer seta.

Discussion

Systematics

Phylogenetic relationships among the genera of Paramesochridae have been analyzed by Huys (1987). This author recognized two new subfamilies: the more primitive Diarthrodellinae Huys, represented by *Diarthrodella* Klie, *Tisbisoma* Bozic and *Rossopsyllus* Soyer; and the more derived Paramesochrinae Huys, formed by the *Scottopsyllus*-group, the *Paramesochra*-group and the genus *Remanea* Klie. The *Paramesochra*-group included *Paramesochra*, *Kliopsyllus* and *Kunzia*. The lineage *Kliopsyllus-Kunzia* could be defined by three apomorphies: (1) endopodite P2–P4 uniarticulated; (2) exopodite P1 with 4 setae on distal segment (parallel evolution in the *Scottopsyllus*-group); and (3) distal segment exopodite P4 with 3 setae.

According to Veit-Köhler (2004) a comparison of segmentation and armature of the swimming legs of different Paramesochridae illustrates the unsatisfactory situation of the existing system, which is in many parts based only on different combinations of the same characters. Within the Paramesochrinae, a similar segmentation of the P1 as in *Kliopsyllus* can be found in *Paramesochra*, *Scottopsyllus*, *Apodopsyllus*, *Biuncus* Huys, 1996, and *Leptopsyllus* Lang. The number of segments and endopodal setae of P2 and P3 of *Kliopsyllus* are comparable to *Kunzia* and to some *Scottopsyllus* (*Scottopsyllus*) Kunz species. The number of segments and exopodal and endopodal setae of P4 are comparable to *Kunzia*, *Scottopsyllus* (*Wellsopsyllus*) and *Leptopsyllus* but in no case to *Paramesochra*, the nearest relatives of the *Kliopsyllus-Kunzia* lineage according to Huys (1987). Veit-Köhler (2004) suggests that these observations clearly show that apomorphies based on single characters have to be found for the different genera.

Most of the older descriptions of Paramesochridae show poor illustrative and descriptive information, especially with respect to the mouthparts. The scarce or incorrect taxonomic information results in the necessity to increase the effort on redescriptions of the known species and revisions of the uncertain ones.

Given the current taxonomic situation we have provisionally placed the new species in *Kliopsyllus*. The species' characters agree with the short working diagnosis of the genus given by Veit-Köhler (2004) in the combination of the following characters: P1 exp two-segmented, enp two-segmented; P2–P3 exp three-segmented, enp one-segmented with one seta; P4 exp three-segmented, exp3 with two setae. It differs from this diagnosis in the enp of P4, which is not one- but two-segmented, with one seta apically on enp2.

At present, all *Kliopsyllus* species have a one-segmented Enp P4, with exception of *Kliopsyllus andeep*

Veit-Köhler, 2004, a new Pacific species (currently under description by Veit-Köhler and Thistle, pers. comment) and the new species *K. minor* sp. nov. *Kliopsyllus andeep* carries strong, chitinous appendages at the telson, and additional 1 and 2 setae at the endopods of P3 and P4. These characters easily separate *K. andeep* from the new Brazilian species. The new Pacific species and the new species from Brazil can be distinguished by several characters of the swimming legs. *K. minor* sp. nov. has more slender and elongate exopodal segments of the swimming legs and distinct patterns of spinulation in the exps and enps as compared to the Pacific species. Setae and spines of P1–P4 of both species differ in size, shape and pinnation with the Pacific species showing distinctly serrated spines.

The setal formula of *K. minor* sp. nov. is consistent with Seifried (2003). The inner terminal seta on exp3 of the swimming legs P2–P4 is a long, flexible and pinnate seta, whereas the outer terminal seta is a rigid spiniform seta ornamented with spinules along the outer margin and setules along the inner margin. Most likely due to the small dimensions of *K. minor* sp. nov. these inner setules were only detected in the outer terminal seta of exp3 P3. We interpret this seta with outer spinules and inner setules, as well as the terminal setae with outer spinules on P2 and P3 clearly as "outer terminal setae". The setal formula (Tab. 1) is erected accordingly. This interpretation is supported by the revised setal formulae of *K. andeep* and *K. diva* (Tab. 2 and 3). Both species clearly show the ornamentation in question on their outer terminal setae in P2–P4 and their setal formulae are similar to *K. minor* sp. nov. in many aspects.

TABLE 2. Revised setal formula of swimming legs of *Kliopsyllus andeep* Veit-Köhler, 2004.

	Basis	Exopod	Endopod
P1	0-1	0.022	0.020
P2	0-0	0.0.022	010
P3	0-1	0.0.022	110
P4	0-1	0.0.011	1.011

TABLE 3. Revised setal formula of swimming legs of *Kliopsyllus diva* Veit-Köhler, 2005.

	Basis	Exopod	Endopod
P1	1-1	0.022	0.020
P2	0-1	0.0.022	010
P3	0-1	0.0.022	010
P4	0-1	0.0.011	011

The two-segmented enp of P4 and the smallest body size ever reported for a *Kliopsyllus* species are the most striking characters of *K. minor* sp. nov. This new species is the first record of *Kliopsyllus* from the deep sea off Northeastern Brazil.

Ecological remarks

Most of the Paramesochridae have been described from sandy beaches, the intertidal zone and shallow waters. Their interstitial lifestyle limits their average body length to about 0.4 mm. However, even the very large *Kliopsyllus major* Nicholls, 1939 (female: 0.8 mm; male: 0.7 mm), collected from a depth of 8 m in the St. Lawrence River (Baie de Mille Vaches, Canada), seems to live interstitially in very coarse sand (Nicholls 1939). Although the males of *Kliopsyllus diva* Veit-Köhler, 2005 have an average body size of 0.29 mm their lifestyle cannot be interstitial as they have been described from muddy deep-sea sediments (Veit-Köhler 2005). Specimens of *K. minor* sp. nov. have been collected from a similar habitat. This smallest *Kliopsyllus*-

species described (body length 0.19 mm) is therefore assumed to have a burrowing lifestyle in very fluid muds or it may live in the organic fluff layer at the sediment surface.

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