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PARACYCLOPS FIERSI SP. NOV. (COPEPODA, CYCLOPOIDA, CYCLOPIDAE), A NEW FRESHWATER CYCLOPOID FROM NORTH-WESTERN MEXICO

BY

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ABSTRACT

Several individuals of free-living copepods were found in tap water of the Unidad Académica Mazatlán (Instituto de Ciencias del Mar y Limnología). These copepods turned out to belong to a new species of the freshwater genus *Paracyclops*. *Paracyclops poppei*, *P. hirsutus*, and *P. chiltoni* were the only species reported in Mexican freshwater ecosystems, and the record of *P. fiersi* sp. nov. is the fourth confirmed species of the genus from Mexico. The new species seems to be related to *P. hardingi* and *P. bromeliacola*. The new species differs in the ornamentation of the female antennary coxobasis, and in the posterior, subdistal, medial spinules on the coxa of the first–fourth leg in both sexes. The city of Mazatlan is supplied with groundwater from an aquifer of the Presidio River (south of Mazatlan), and the new species is most probably distributed in the southern state of Sinaloa (north-western Mexico).

Key words. — Systematics, taxonomy, new species, diversity

RESUMEN

Se encontraron algunos individuos de copépodos dulceacuícolas en el agua del grifo de la Unidad Académica Mazatlán (Instituto de Ciencias del Mar y Limnología). Estos copépodos resultaron pertenecer a una nueva especie del género dulceacuícola *Paracyclops*. Solo tres especies de *Paracyclops* (*P. poppei*, *P. hirsutus*, y *P. chiltoni*) se habían reportado en ecosistemas dulceacuícolas de México, y *P. fiersi* sp. nov. es la cuarta especie del género confirmada en el país. Esta nueva especie parece estar relacionada con *P. hardingi* y *P. bromeliacola*. Estas especies difieren en la ornamentación de la coxabase de la antena de la hembra, y en las espínulas subdistomediales ubicadas en la parte posterior de la coxa de la primera a la cuarta pata en ambos sexos. La ciudad de Mazatlán recibe agua subterranea del acuífero del Río Presidio (al sur de Mazatlán), y la nueva especie probablemente se distribuya en el sur del estado de Sinaloa (noroeste de México).

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Palabras clave. — Sistemática, taxonomía, nueva especie, diversidad

INTRODUCTION

Freshwater copepods can be found in unusual habitats such as tanks, discarded tires, and in a variety of other unlikely habitats (Reid, 2001). The occurrence of copepods in municipal water systems dates back to the 19th century, and they are probably more common in old municipal systems with poor sanitation procedures (Reid, 2001, and references cited therein). Some freshwater copepods were gathered during the processing and sieving of some deep-sea meiofauna samples and were found to be present in tap water in the Unidad Académica Mazatlán (UAMzt) (Instituto de Ciencias del Mar y Limnología (ICML), Universidad Nacional Autónoma de México (UNAM)). These copepods turned out to belong to the freshwater cyclopoid genus *Paracyclops* Claus, 1893 (cf. Claus, 1893a), and closer inspection revealed that they were, in fact, representatives of a new species. Currently, the city of Mazatlan is supplied with groundwater from the aquifer located on the right bank of the Presidio River, and the new species presented herein is most probably distributed in the southern state of Sinaloa (north-western Mexico).

The genus *Paracyclops* can be found in groundwater ecosystems (Itô, 1957, 1962; Pesce & Galassi, 1987; Tang & Knott, 2009), in the hyporheic zone of rivers (Strayer, 1989; Karaytuğ & Boxshall, 1998a), in rivers and lakes, ponds and mountain lakes (Karaytuğ & Boxshall, 1998a, c; Karaytuğ et al., 1998), in wet marshes (Reid, 1987b), in the pools in the leaf axils of terrestrial bromeliads and tree holes (Karaytuğ & Boxshall, 1998a), in moss (Dagget & Davis, 1974), in outdoor artificial freshwater cultures (Reid, 1987a), and in saline waters (Löffler, 1961). The genus can be found in plankton samples, but it is mostly benthic (Karaytuğ & Boxshall, 1998a; Karaytuğ, 1999), and is distributed worldwide. The occurrence of only three species of *Paracyclops* has been documented in Mexico so far. *Paracyclops poppei* (Rehberg, 1880) and *P. hirsutus* Mercado-Salas & Suárez-Morales, 2009 have been reported from the state of Aguascalientes (north-central Mexico), and *P. chiltoni* (Thomson, 1883) is known to be present in the state of Campeche (south-eastern Mexico) (Mercado-Salas & Suárez-Morales, 2009). Here, I present *P. fiersi* sp. nov. from the southern state of Sinaloa, the fourth confirmed species of *Paracyclops* from Mexico. Additionally, some comments on the relationships between the species of the genus *Paracyclops*, and a key to the species reported from Mexico, are given.

MATERIAL AND METHODS

The material presented here was collected accidentally during the processing and sieving of meiofauna samples from the deep-sea of the Gulf of California. The new species turned out to be present in tap water in the Mazatlan Academic Unit of the Instituto de Ciencias del Mar y Limnología (ICML). The material was sorted out in Petri dishes and the copepods were picked up and transferred into 1 ml vials with 70% ethanol. Some specimens were dissected for inspection and their dissected parts were mounted on separate slides with glycerine as a mounting medium and sealed with Neo-Mount®. Illustrations and figures were made from undissected individuals and their dissected parts using a Leica DMLB microscope equipped with L PLAN 10× eyepieces, N PLAN 100× oil immersion objective, and drawing tube.

Huys & Boxshall (1991), Karaytuğ & Boxshall (1998a, b, c), Karaytuğ (1999) and Karaytŭg & Boxshall (1999) were followed for general terminology. The actual segmentation of the female antennule is indicated in Arabic numerals, followed by the original segments in Roman numerals between squared brackets, and the number of setal elements between parentheses. The format of Sewell (1949) was adopted for the armature formulae of the swimming legs. Abbreviations used in the text and tables: A1, antennule; A2, antenna; ae, aesthetasc; ENP, endopod; EXP, exopod; EXP (ENP)1–3, first–third exopodal(endopodal) segments; P1–P6, first to sixth legs.

SYSTEMATICS

Order CYCLOPOIDA Burmeister, 1835
Family CYCLOPIDAE Rafinesque, 1815
Subfamily EUCYCLOPINAE Kiefer, 1927
Genus *Paracyclops* Claus, 1893 (cf. Claus, 1893a)

Type species.— *Paracyclops fimbriatus fimbriatus* (Fischer, 1853) (= *Cyclops fimbriatus* Fischer, 1853) by subsequent designation.

Other species.— *P. affinis* (Sars, 1863) (= *C. affinis* Sars, 1863), *P. aioiensis* Ito, 1957, *P. altissimus* Karaytuğ, Defaye & Boxshall, 1998, *P. andinus* Kiefer, 1957, *P. baicalensis* Mazepova, 1962, *P. bromeliacola* Karaytuğ & Boxshall, 1998, *P. canadensis* (Willey, 1934), *P. carectum* Reid, 1987, *P. chiltoni* (Thomson, 1883) (= *C. chiltoni* Thomson, 1883), *P. dilatatus* Lindberg, 1952, *P. fiersi* sp. nov., *P. fimbriatus paropamisi* Lindberg, 1960, *P. hardingi* Karaytuğ & Boxshall, 1998, *P. hirsutus* Mercado-Salas & Suárez-Morales, 2009, *P. imminutus* Kiefer, 1929 (cf. Kiefer, 1929b), *P. intermedius* Tang & Knott, 2009, *P. longispina* Karaytuğ, Defaye & Boxshall, 1998, *P. novenarius* Reid, 1987 (cf. Reid, 1987a), *P. oligarthrus* (Sars, 1909) (= *C. oligarthrus* Sars, 1909), *P. pilosus* Dussart, 1984, *P. poppei*

(Rehberg, 1880) (= *C. poppei* Rehberg, 1880), *P. punctatus* Karaytuğ & Boxshall, 1998, *P. reidae* Karaytuğ & Boxshall, 1998, *P. rochai* Karaytuğ & Boxshall, 1998, *P. smileyi* Strayer, 1989, *P. uenoi* Itô, 1962, and *P. yeatmani* Dagget & Davis, 1974.

Paracyclops fiersi sp. nov. (figs. 1–8)
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Material examined.— Female holotype (ICML-EMUCOP-040322-01) and male allotype (ICML-EMUCOP-040322-02) preserved in alcohol; eight dissected female paratypes (ICML-EMUCOP-040322-03–10), five dissected male paratypes (ICML-EMUCOP-040322-11–15), and 17 female and 22 male paratypes (ICML-EMUCOP-040322-16) preserved in alcohol.

Type locality.— Instituto de Ciencias del Mar y Limnología, Mazatlán, Sinaloa, north-western Mexico (23°10′59.99″N 106°25′32.99″W), in tap water.

Etymology.— The species is dedicated to the late Dr. Frank Fiers (Royal Belgian Institute of Natural Sciences, Brussels) for his contribution to the taxonomy and systematics of freshwater copepods. It is a noun in the genitive case, gender masculine.

Differential diagnosis.— Female: habitus fusiform compressed; P4-bearing somite with posterolateral row of setules; P5-bearing somite with posterolateral long setules. Antennules eight-segmented; third segment with suture line and with a spiniform element; ancestral segments VI–VII, VIII, IX–XI, XII–XIV, and XV–XX fused, ancestral segments XXI–XXIII and XXIV separated. Coxobasis of antenna with two outer distal and one inner distal seta, anteriorly with five groups of spinules on proximal half of segment, posteriorly without spinules on distal half and at the base of inner and outer setae; first endopodal segment with one, second segment with nine outer setae, third segment with seven setae. Mandibular palp one-segmented, with three setae. Maxillulary coxal endite and basis fused, with three setae; exopod incorporated into basis, represented by single seta; endopod small, one-segmented, with three setae. Maxillary praecoxal endite with two setae; proximal and distal coxal endites with one and two setae, respectively; first endopodal segment with two, second segment with three setae. Syncoxa of maxilliped with three, basis with two setae, first endopodal segment with claw-like spinulose, pinnate element, second segment with three setae. Coxa of P1 with posterior long spinules located in middle of segment. Coxa of P2 and P3 without posterior medial spinules. P5 one-segmented, with three elements of which inner spiniform, the other elements setiform. P6 with one seta.

Male: antennules geniculate, indistinctly 15-segmented; first segment with seta A (see Karaytŭg & Boxshall, 1999) modified into a seta with thick proximal part strongly spinulose and distal part whip-like and bipinnate, and with aesthetasc (setal element G in Karaytuğ, 1999, and Karaytŭg & Boxshall, 1999). Coxobasis of antenna with posterior additional spinular row close to insertion site of outer and inner setae. P1 ENP with distal most inner seta of ENP3 spiniform. Coxa of P3 with

medial transverse spinular row posteriorly. Both pairs of P6 functional, with three elements each, of which inner spiniform, medial and outer setiform; medial seta and inner spine subequal in length. Genital and third urosomite separated. Caudal rami shorter than in female.

Armature formulae of P1–P4:

	P1	P2	P3	P4
EXP	I-1;I-1;III,2,3♀♂	I-1;I-1;III,I1,4♀♂	I-1;I-1;III,I1,4♀♂	I-1;I-1;II,I1,4♀♂
ENP	0-1;0-1;1,I1,3♀ 0-1;0-1;1,I1,I2♂	0-1;0-2;1,I1,3♀♂	0-1;0-2;1,I1,3♀♂	0-1;0-2;1,II,2♀♂

Description of female.— Total body length measured from the anterior margin of cephalothorax to posterior margin of caudal rami, ranging from 515–735 μm (holotype = 560 μm; mean = 618 μm; n = 10). Habitus (fig. 1A) fusiform compressed.

Prosome (fig. 1A) composed of cephalothorax (P1-bearing somite fused to the latter), and three (P2–P4-bearing somites) free prosomites. Cephalothorax about 35% of total body length and visibly longer than three free prosomites combined. Cephalothorax and P2-bearing somite with surface sensilla as figured, with smooth posterior margin. P3-bearing somite with sensilla as shown, with posterior margin finely serrated. P4-bearing somite with surface sensilla as depicted, with smooth posterior margin, with posterolateral row of setules (arrowed in fig. 1A).

Urosome (figs. 1A, 2A, B) composed of P5-bearing somite, genital double-somite, two free urosomites, and anal somite, the latter bearing caudal rami. P5-bearing somite dorsally with few sensilla, and with smooth posterior margin and with posterolateral long setules (figs. 1A, 2A). Genital and third urosomite fused forming genital double-somite about as long as wide and slightly tapering posteriad from dorsal view, and with anterior part slightly expanded laterally (fig. 1A), with dorsolateral P6 proximally (figs. 1A, 2A, C); with few dorsal, lateral, and ventral sensilla, and pores as depicted; ornamented with transverse rows of minute spinules (figs. 1A, 2A, B); with posterior margin moderately serrated laterodorsally (figs. 1A, 2A) and coarsely serrated lateroventrally (fig. 2A, B); seminal receptacle as figured (fig. 2B). Fourth and fifth urosomites with pores as shown, the former with, the latter without sensilla; with transverse rows of minute spinules (figs. 1A, 2A, B); posterior margin coarsely serrated. Anal somite wider than long from dorsal view and with naked anal operculum accompanied by one sensillum on each side; somite cleft medially, with medial longitudinal row of small spinules; with row of spinules running from each sensillum posteriad, and along the insertion site of caudal rami laterally and ventrally (lateral and ventral spinules visibly stronger). Caudal rami (figs. 1A, 2A, B) elongate, about 3 times

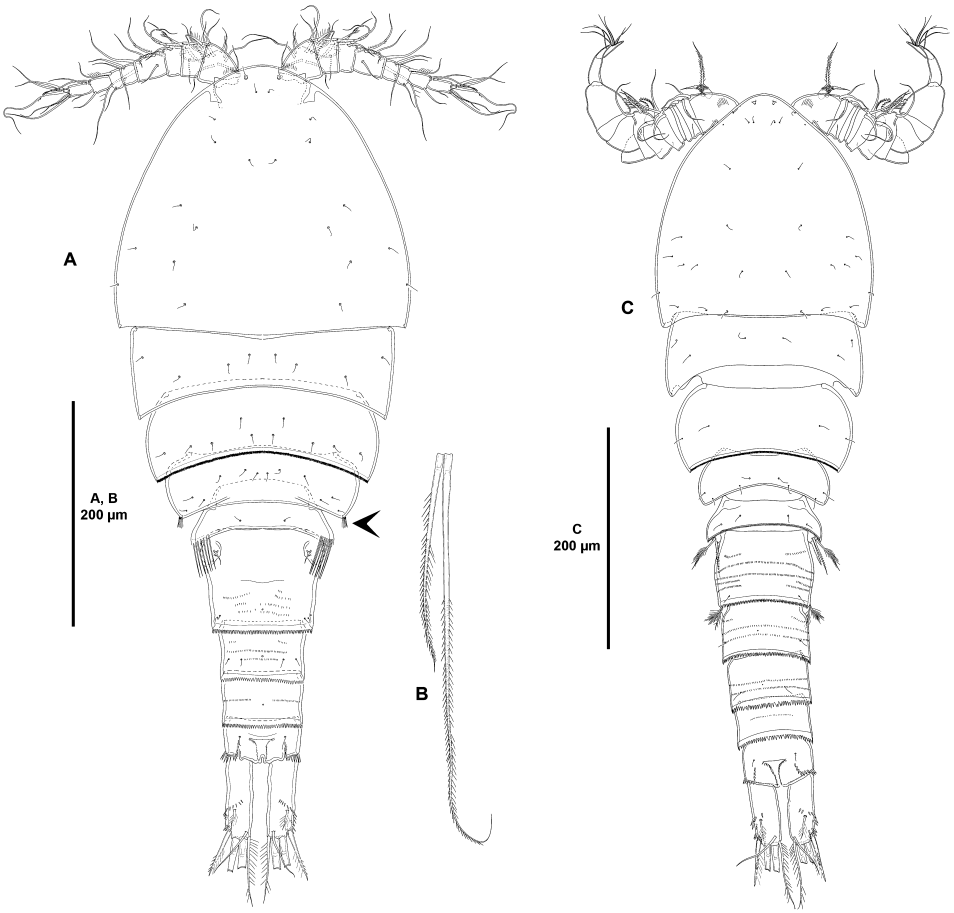

Fig. 1. *Paracyclops fiersi* sp. nov. A, Female, habitus, dorsal (row of posterolateral setules on P4-bearing somite arrowed); B, caudal setae IV and V of the left caudal ramus of the female; C, male, habitus, dorsal.

as long as wide, slightly convergent; inner margin unornamented; with oblique spinular row running dorsoventrally on posterior half, with additional short row of stronger spinules at base of seta III dorsally and ventrally (fig. 2A, B), with few proximal cuticular pits ventrally (fig. 2B); with six setae as follows: seta II short, seemingly naked, displaced dorsally; seta III spiniform, bipinnate, half as long as ramus; seta IV with fracture plane, posterior half rat-tail like, bipinnate — with outer slender spinules proximally and along inner margin, and with comparatively stronger outer spinules medially and distally; seta V with fracture plane, distal half rat-tail like, bipinnate — proximal outer spinules shorter and thicker than outer medial and distal, and inner spinules; seta VI visibly longer than seta III, issuing

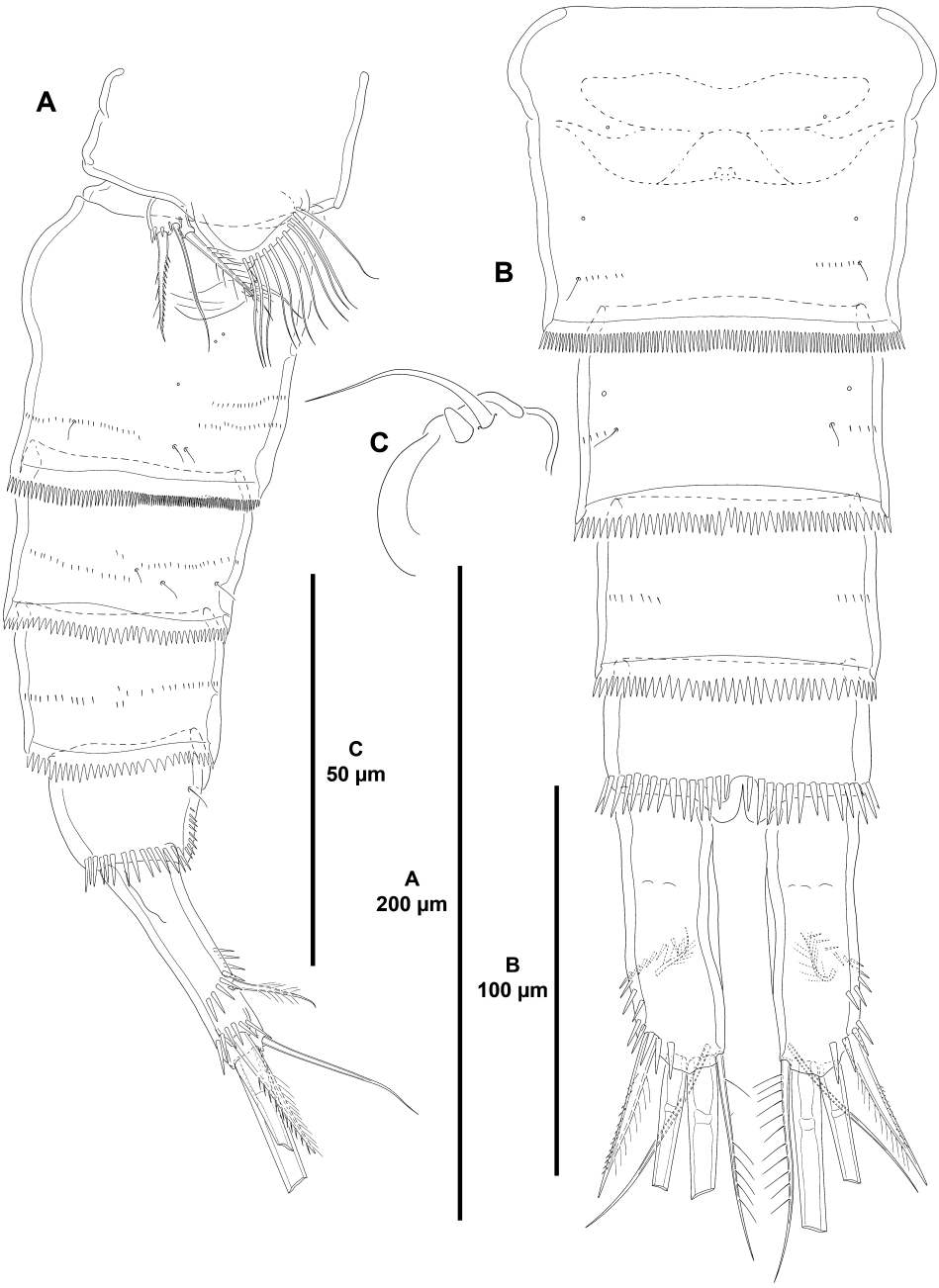

Fig. 2. *Paracyclops fiersi* sp. nov., female. A, Urosome, lateral; B, urosome, ventral (P5-bearing somite omitted); C, P6.

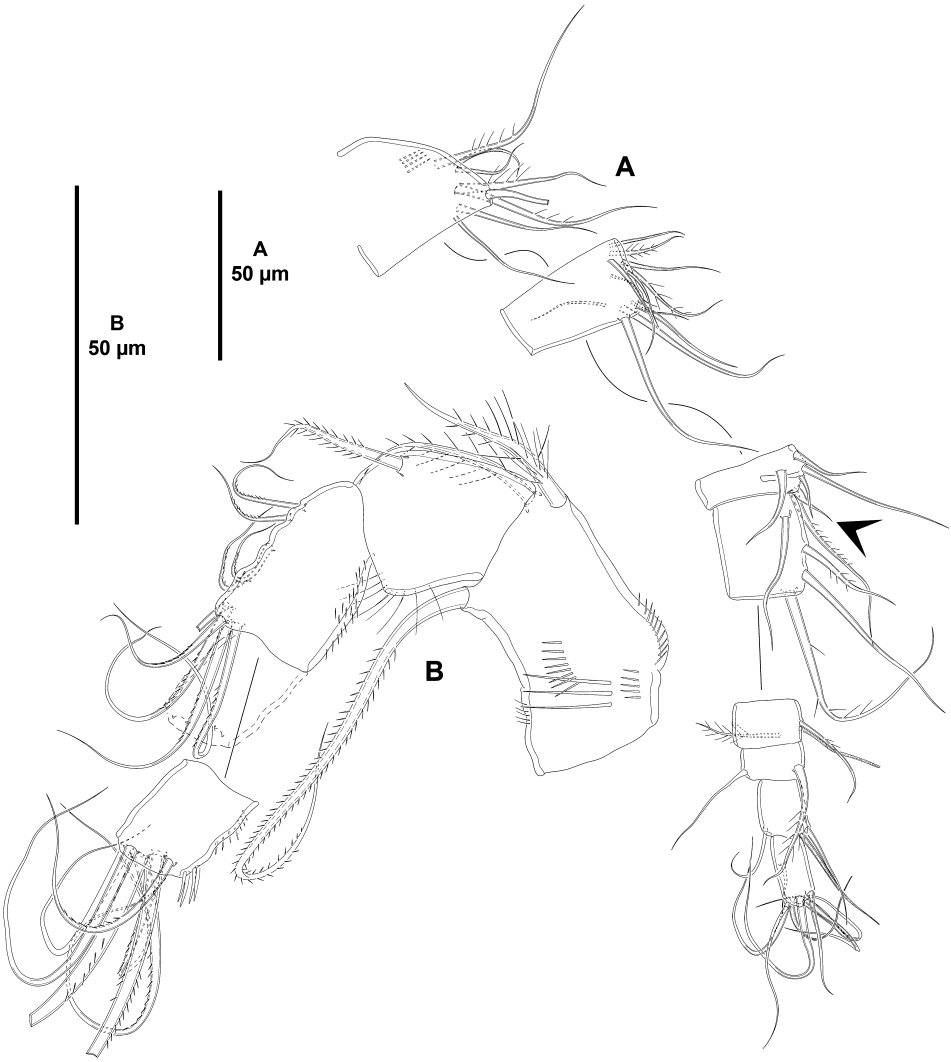

Fig. 3. *Paracyclops fiersi* sp. nov., female. A, Antennule (spiniform element on third segment arrowed); B, antenna, anterior.

from inner distal corner, bipinnate; dorsal seta VII seemingly naked, situated close to inner distal corner, as long as seta III.

Antennule (fig. 3A) eight-segmented; first segment with ventral row of few short spinules; third segment with a spiniform element (arrowed in figure) and with suture line; ancestral segments VI–VII, VIII, IX–XI, XII–XIV, and XV–XX fused, ancestral segments XXI–XXIII and XXIV separated. Armature formula: 1[I–V](8), 2[VI–XI](12), 3[XII–XIV](6), 4[XV–XX](4), 5[XXI–XXIII](2 + ae), 6[XXIV](2), 7[XXV](2 + ae), 8[XXVI–XXVIII](6 + (1 + ae)). The aesthetasc

on seventh segment seemingly not, of eighth segment seemingly fused basally to a seta.

Antenna (fig. 3B) composed of coxobasis and three-segmented endopod. Coxobasis 2 times as long as first and second endopodal segments combined; with two outer distal bipinnate setae and one inner distal bipinnate element (exopod), the latter very long; anteriorly with five groups of spinules on proximal half of segment, of which the medial group composed of few long spinules, posteriorly without spinular ornamentation on distal half and at the base of inner and outer setae. First endopodal segment subquadrate, as long as second endopodal segment, with one outer distal bipinnate seta, outer margin of segment unornamented, inner margin with long slender spinules as shown; second endopodal segment with four outer lateral and five outer distal setae, with minute inner spinules as depicted; third endopodal segment smallest, with seven long setae, and ornamented with small outer spinules proximally and with visibly larger outer spinules subdistally.

Mandible (fig. 4A) with elongate coxa ornamented with medial transverse row of small spinules between palp and gnathobase, and with posterior spinular row close to palp. Gnathobase with five distal teeth as shown, and a long unipinnate subdistal seta. Palp small, one-segmented; with three setae of which one shorter and slenderer, other two elements much longer and plumose.

Maxillule (fig. 4B) praecoxa robust, with small spiniform process; arthrite with four strong spines fused basally to arthrite, and five spiniform elements ornamented as figured. Coxal endite and basis fused, with three distal setae one of which bipinnate, the others smooth. Exopod represented by one bipinnate seta. Endopod small, with three pinnate setae.

Maxilla (fig. 4C) with praecoxa, coxa, basis and two-segmented endopod. Praecoxa with row of outer spinules; praecoxal endite with two setae. Coxa unornamented, with two endites; proximal endite largely incorporated into coxa, with one spinulose seta; distal endite cylindrical with one spinulose thick element and one slightly spinulose seta. Allobasis drawn out into strong spinulose claw accompanied by strong spinulose spine and a slender seta. Endopod two-segmented; first segment with two, second segment with three setae.

Maxilliped (fig. 4D) with syncoxa, basis, and two-segmented endopod. Syncoxa with transverse spinular row; with three bipinnate setae. Basis with few outer distal spinules; with two bipinnate setae. Endopod two-segmented; first segment with strong claw-like element ornamented with small pinnae along distal half and with two long spinules proximally; second segment with three setae as shown.

P1 (fig. 5A). Intercoxal sclerite subquadrate; with anterior, oblique, subdistal row of spinules at the base of chitinized outer, distal, rounded projections. Coxa rectangular; with inner bipinnate seta reaching middle of ENP2; anterior surface with transverse inner row of minute spinules; posterior surface with long slender

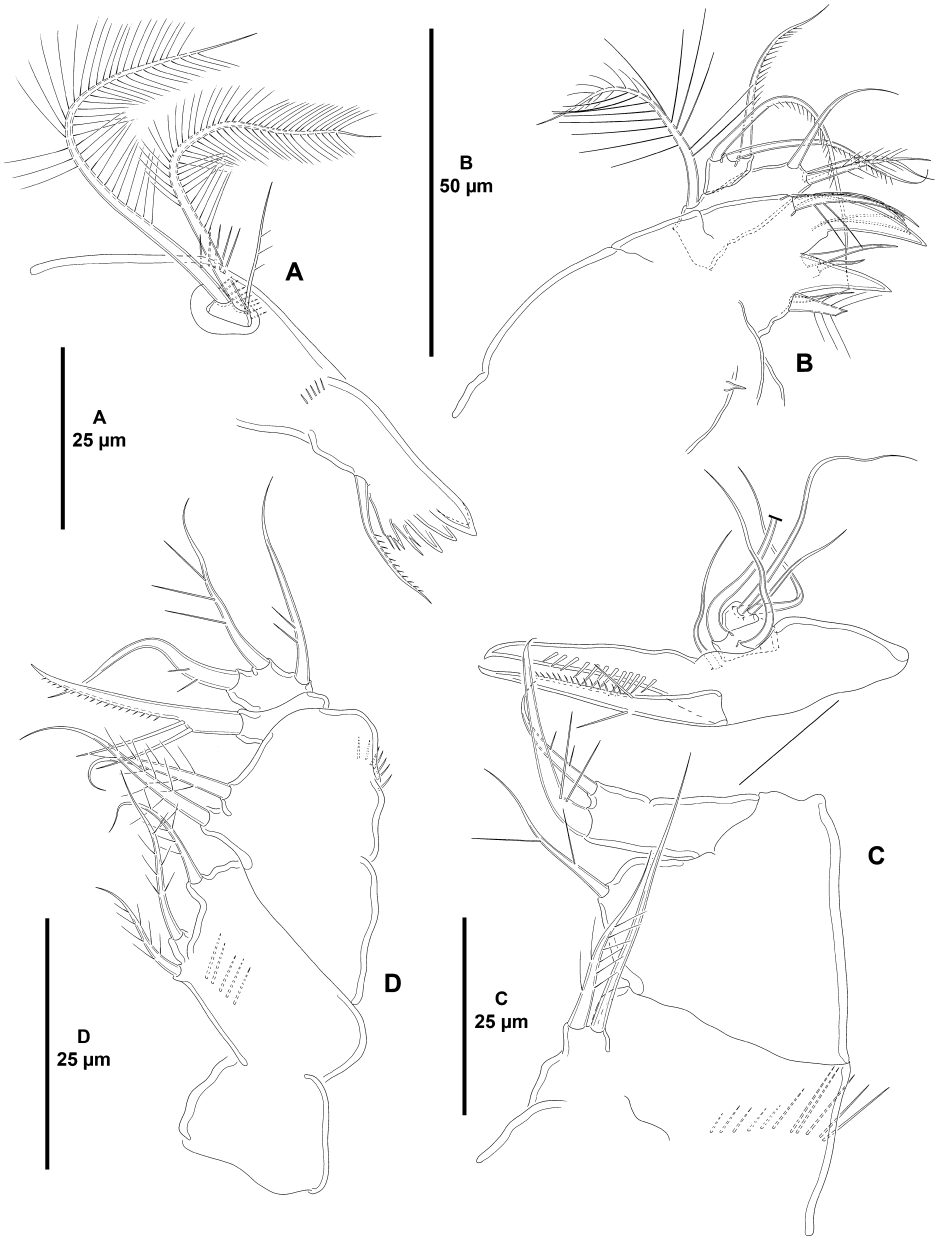

Fig. 4. *Paracyclops fiersi* sp. nov., female. A, Mandible; B, maxillule; C, maxilla; D, maxilliped.

spinules medially and close to outer distal margin. Basis with rounded inner margin, and with distal extension medially; with inner bipinnate thick spiniform element reaching slightly beyond ENP2, and with slender outer seta; anterior surface with spinules at bases of rami. Exopod three-segmented, inserted at a lower

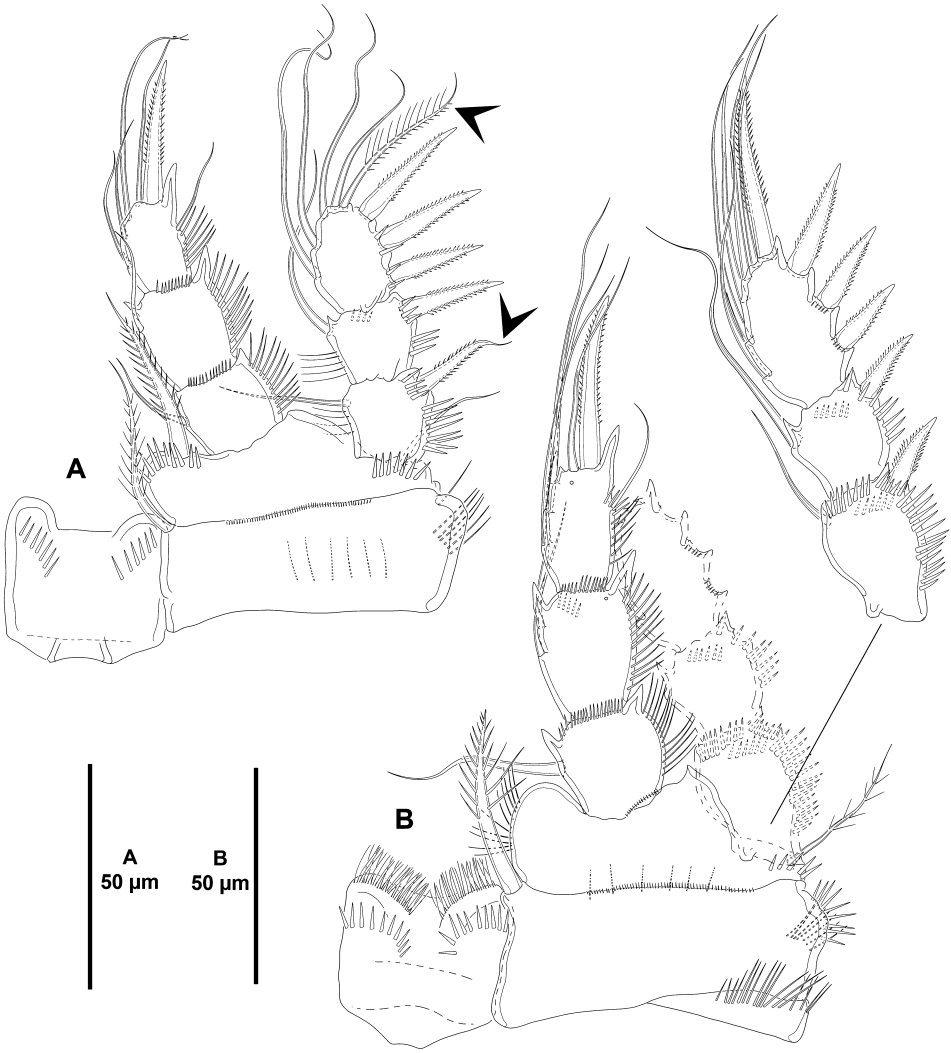

Fig. 5. *Paracyclops fiersi* sp. nov., female. A, P1, anterior (whip-like distal part of outer spine of EXP1, and outer distal seta of EXP3 with inner setulose margin and pinnate outer border, arrowed) B, P2, anterior. Setulose ornamentation of setae omitted for clarity.

level than ENP and reaching middle of ENP3; all setae setulose except for outer distal seta of EXP3 with setulose inner margin and pinnate outer border (arrowed in fig. 5A). EXP1 with outer spine whip-like distally (arrowed in fig. 5A), and inner seta; anterior surface with outer spinules and inner setules as shown. EXP2 with outer spine and inner seta; ornamented as EXP1 but with additional posterior spinules subdistally. EXP3 with three outer spines, and two apical and three inner setae; with few anterior outer spinules at the base of proximal and medial

outer spines. Endopod three-segmented; all setae setulose. ENP1 subquadrate; with inner seta; anterior surface with small spinules distally, and with long inner spinules; inner distal corner without, outer distal corner with moderate projection. ENP2 slightly longer than ENP1; armed and ornamented as in ENP1; inner distal projection moderate, outer distal projection well-developed. ENP3 shortest, 1.5 times as long as wide; with three inner setae, one inner distal seta, one outer distal spine, and one outer medial seta; with anterior outer long spinules as depicted; outer distal projection well-developed.

P2 (fig. 5B). Intercoxal sclerite subquadrate; ornamented as in P1, but with additional distal tuft of setules on chitinized outer, distal, rounded projections. Praecoxa small, triangular; with transverse subdistal row of long spinules. Coxa rectangular; with inner spinulose seta reaching slightly beyond ENP1; anterior surface with transverse distal row of minute spinules and with comparatively thicker outer spinules; posterior surface with few long slender spinules distally, and close to outer margin. Basis with rounded inner margin and with distal pointed extension medially; with inner slender long spinules, with row of minute spinules at base of endopod, and with spinules at base of outer seta. Exopod three-segmented, inserted at a lower level than ENP and reaching middle of ENP3; all setae setulose. EXP1 with outer spine and inner seta; anterior surface with outer and distal spinules as shown; posterior surface with subdistal row of spinules. EXP2 with outer spine and inner seta; anterior surface with outer spinules; posterior surface with subdistal row of spinules. EXP3 with three outer spines, one outer distal spine, one inner distal seta, and four inner setae; with minute spinules at the base of proximal and medial outer spines. Endopod three-segmented; all setae setulose. ENP1 subquadrate; with inner seta; anterior surface with small spinules distally, and with long inner spinules; inner and outer distal corners with moderate projections. ENP2 slightly longer than ENP1; with two inner setae; anterior surface with distal and inner spinules, and one subdistal pore; inner and outer distal projections well-developed. ENP3 about as long as ENP2; with one outer medial seta, one outer distal spine, one inner distal and three inner setae; with anterior outer long spinules and subdistal pore.

P3 (fig. 6A). Intercoxal sclerite largely as in P2, but posterior surface with additional row slender spinules at the base of outer, distal, rounded projections. Praecoxa as in P2. Coxa rectangular; with inner spinulose seta reaching middle of ENP1; anterior surface with transverse distal row of minute spinules and with outer spinules; posterior surface without distal spinules, with proximal transverse row of small spinules, and with medial transverse row of longer slender spinules close to outer margin. Basis largely as in P2. Exopod three-segmented, inserted at a lower level than ENP and reaching distal fourth of ENP3; all setae setulose. EXP1–3 as in P2, but with comparatively longer setae, and EXP2 and EXP3 with

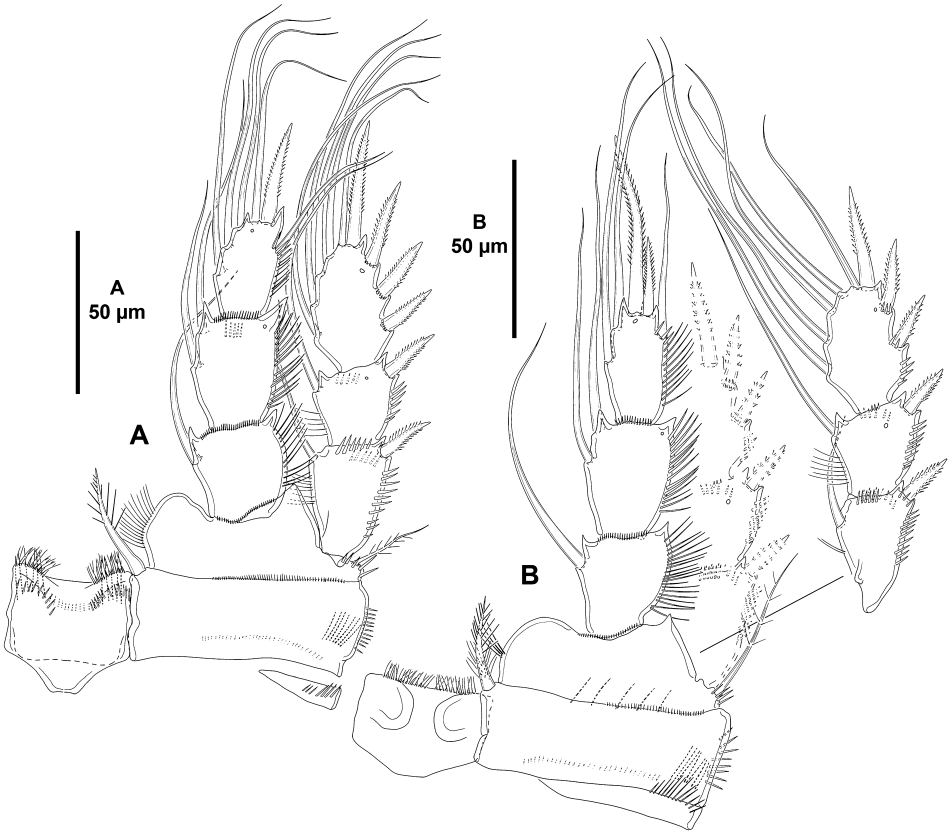

Fig. 6. *Paracyclops fiersi* sp. nov., female. A, P3, anterior; B, P4, anterior. Setulose ornamentation of setae omitted for clarity.

subdistal pore. Endopod three-segmented; all setae setulose. ENP1–3 as in P2, but with comparatively longer setae.

P4 (fig. 6B). Intercoxal sclerite without distal rounded projections; anterior and posterior surface unornamented; with row of distal setules as shown. Praecoxa as in P2. Coxa as in P2, but inner seta comparatively shorter, i.e., reaching slightly beyond distal margin of basis, and with posterior transverse row of minute spinules proximally. Basis largely as in P2. Exopod three-segmented, inserted at a lower level than ENP and reaching middle of ENP3; all setae setulose. EXP1–3 as in P3, but EXP3 with outer proximal spinules, and with comparatively stronger spinules at the base of proximal and medial outer spines. Endopod three-segmented; all setae setulose. ENP1 as in P3. ENP2 as in P3 but without posterior spinules, and inner and outer distal projections less developed. ENP3 ornamented as in P3, as long as other segments, with one outer subdistal seta, one distal outer and one distal inner spine of which the latter 2.3 times as long as the former, and two inner setae.

Armature formulae of P1–P4 as follows:

	P1	P2	P3	P4
EXP	I-1;I-1;III,2,3	I-1;I-1;III,I1,4	I-1;I-1;III,I1,4	I-1;I-1;II,I1,4
ENP	0-1;0-1;1,I1,3	0-1;0-2;1,I1,3	0-1;0-2;1,I1,3	0-1;0-2;1,II,2

P5 (fig. 2A) one-segmented, subquadrate; with one inner bipinnate spine, one medial slender smooth seta, and one outer setulose element, the latter slightly longer than the former.

P6 (figs. 1A, 2A, C) displaced dorsolaterally; with one seta and a small, pointed projection.

Description of male.— Total body length measured from anterior margin of cephalothorax to posterior margin of caudal rami, ranging from 545–685 μm (allotype = 685 μm; mean = 631.5 μm; n = 10). Habitus (fig. 1C) as in female but somewhat slenderer. Sexual dimorphism expressed in antennule, spinular ornamentation of the antennary coxobasis, coxa of P3, P6, segmentation of urosome, and caudal rami.

Antennule (fig. 7A, B) geniculate, indistinctly 15-segmented; all segments smooth except for first segment with two rows of ventral spinules as shown; first segment with seta A (see Karaytŭg & Boxshall, 1999) modified into a seta with thick proximal part strongly spinulose and distal part whip-like and bipinnate (arrowed in fig. 7B), and with aesthetasc (setal element G in Karaytuğ, 1999 and Karaytŭg & Boxshall, 1999). Armature formula as follows: 1(8 + ae), 2(4), 3(2), 4(2 + ae), 5(2), 6(2), 7(2), 8(2), 9(2 + ae), 10(2), 11(2), 12(2), 13(7), 14(2 + ae), 15(11 + ae).

Antenna largely as in female. Coxobasis with anterior spinular ornamentation as in female, but posteriorly with additional spinular rows close to the insertion site of outer and inner setae (arrowed in fig. 7C).

Mandible, maxillule, maxilla and maxilliped (not shown) as in female.

P1 largely as in female, but with distalmost inner seta of ENP3 spiniform (arrowed in fig. 8B).

P2 and P4 (not shown) as in female.

P3 as in female except for coxa with additional transverse row of long spinules on posterior surface (arrowed in fig. 8C).

Armature formulae of P1–P4 as follows:

	P1	P2	P3	P4
EXP	I-1;I-1;III,2,3	I-1;I-1;III,I1,4	I-1;I-1;III,I1,4	I-1;I-1;II,I1,4
ENP	0-1;0-1;1,I1,I2	0-1;0-2;1,I1,3	0-1;0-2;1,I1,3	0-1;0-2;1,II,2

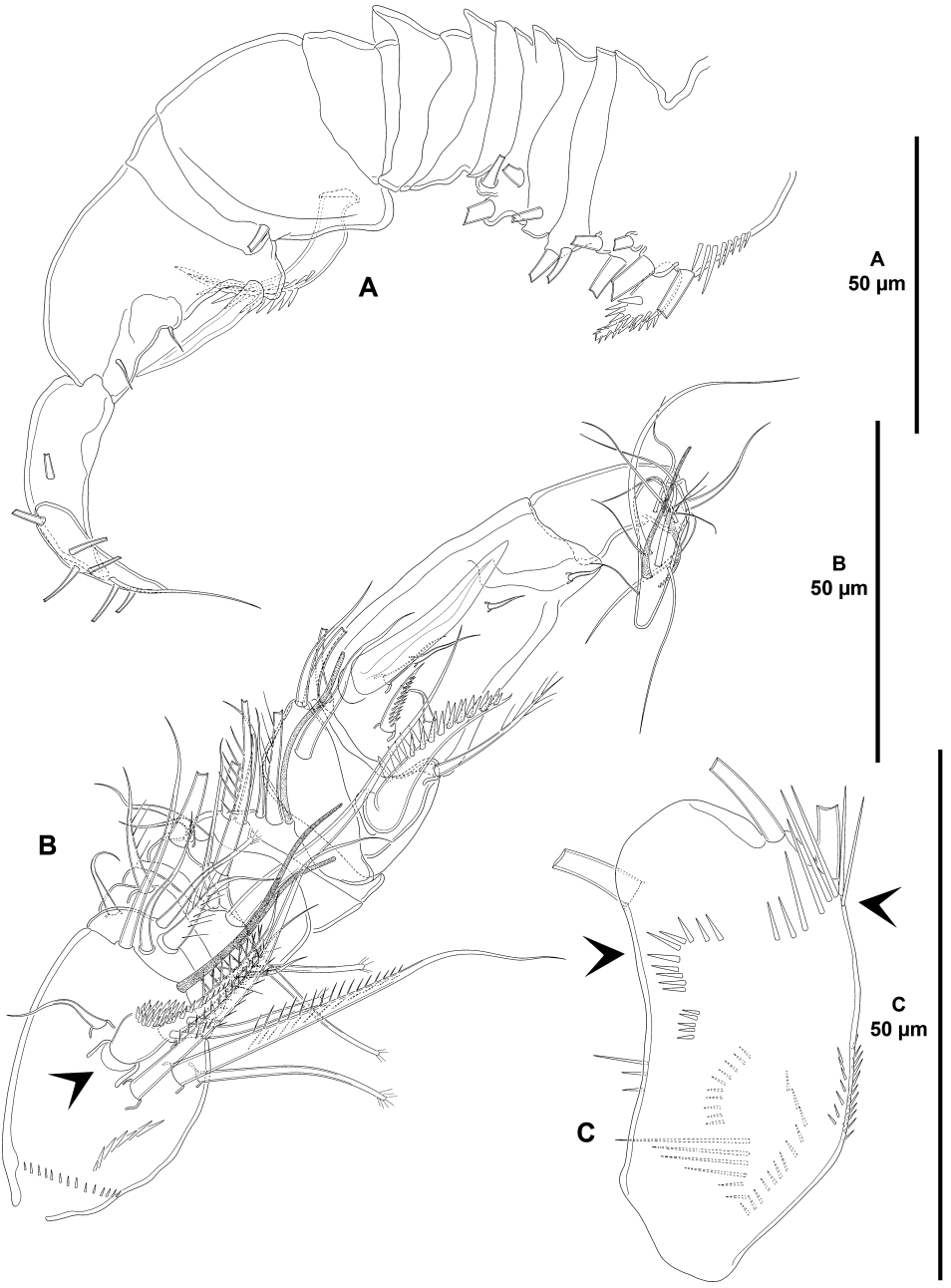

Fig. 7. *Paracyclops fiersi* sp. nov., male. A, Antennule, ventral, showing segmentation, some setae omitted for clarity; B, antennule, anteroventral, showing setation, modified seta A arrowed; C, antennary coxobasis, posterior (spinular ornamentation arrowed).

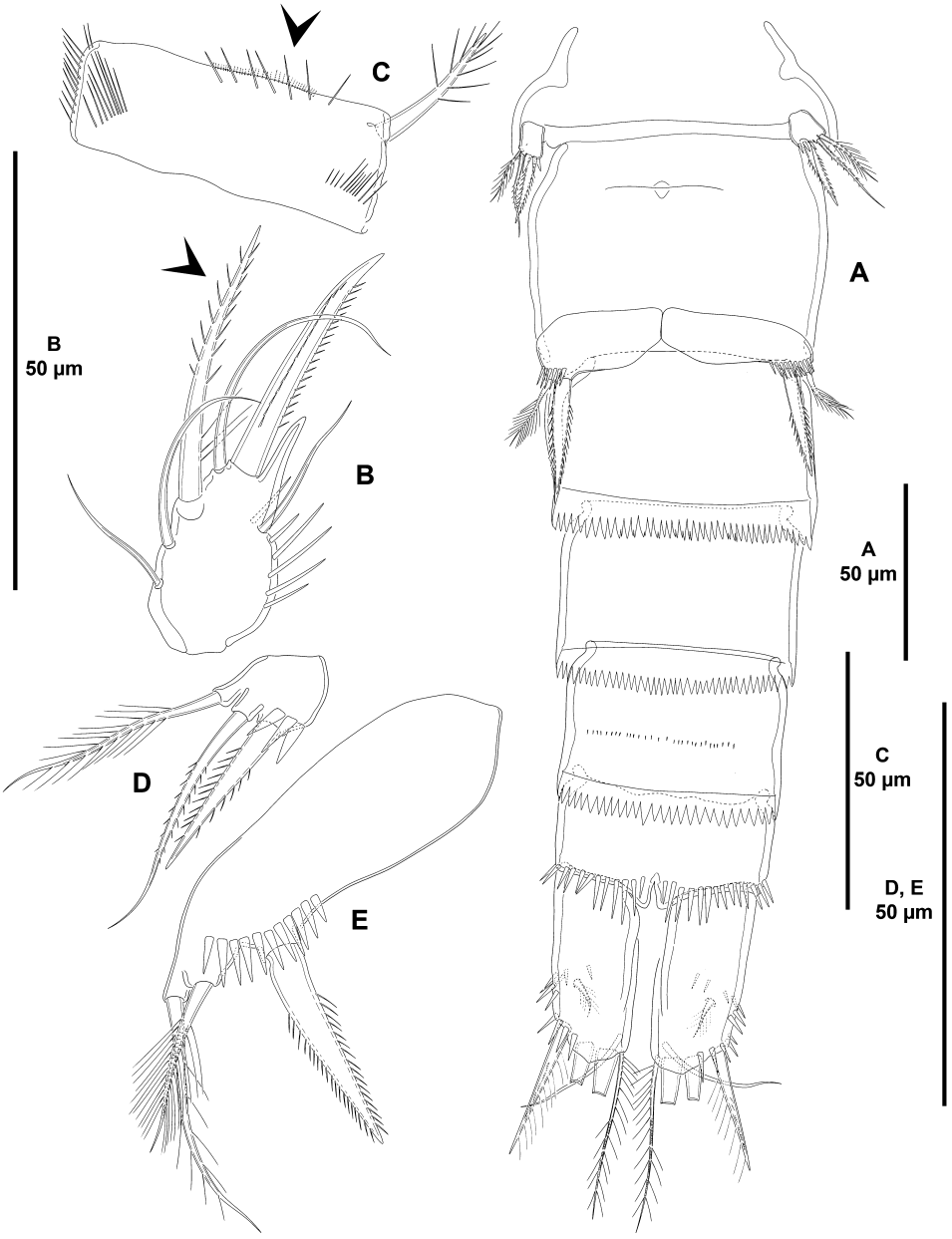

Fig. 8. *Paracyclops fiersi* sp. nov., male. A, Urosome, ventral; B, P1 ENP3 (distalmost inner spiniform seta arrowed); C, coxa of P3, posterior (distal posterior spinules arrowed); D, P5, anterior; E, P6, anterior.

P5 (fig. 8D) as in female.

P6 (fig. 8A, E) a functional plate on distal outer corner of genital somite; with one outer plumose and one medial bipinnate seta, and one inner bipinnate spine, the two former subequal in length and longer than the latter; with three strong spinules at the base of inner spine.

Urosome (fig. 8A) largely as in female but with genital somite and third urosomite separated.

Caudal rami (fig. 8A) largely as in female but somewhat shorter.

DISCUSSION

In his PhD thesis, Karaytuğ (1998) recognized five lineages within *Paracyclops*: *eucyclopoides-timmsi-waiariki*, *affinis-canadensis-uenoi*, *P. smileyi*, *P. yeatmani*, and the *P. fimbriatus*-group: *P. fimbriatus*, *P. imminutus* and *P. chiltoni* (cf. Karaytuğ & Boxshall, 1998c). Additionally, Karaytuğ (1998) suggested — phylogenetic — relationships between *Paracyclops*, *Ochridacyclops* Kiefer, 1937 and *Eucyclops* Claus, 1893 (cf. Claus, 1893b), questioned the validity of *Ochridacyclops*, and commented on the need of giving his five lineages full generic or subgeneric status. Later on, Karaytuğ (1999) diagnosed the genus *Paracyclops*, recognized 28 valid species, and gave a key to the females and males of the species of the genus. Some years later, Karanovic (2006) created and diagnosed the genus *Australoeucyclops* Karanovic, 2006 for *A. karaytugi* Karanovic, 2006 (the type species), and removed *P. eucyclopoides* Kiefer, 1929 (cf. Kiefer, 1929a), *P. timmsi* Kiefer, 1969 and *P. waiariki* Lewis, 1974 (these species constitute one of Karaytuğ's (1998) lineages) and *P. linderi* (Lindberg, 1948), from *Paracyclops* to his newly created genus. Additionally, Karanovic (2006) questioned the generic position of *P. yeatmani* Dagget & Davis, 1974 (it could well belong to *Eucyclops* or to a new genus (Karanovic, 2006)) and *P. smileyi* Strayer, 1989 (that differs from *Paracyclops* in the armature formulae of swimming legs, in the shorter antennule and shorter caudal rami, and some reductions in mouthparts (Karanovic, 2006)), both species considered as different lineages within *Paracyclops* in Karaytuğ (1998). Karanovic (2006) suggested a close relationship between *Australoeucyclops*, *Eucyclops* and *Paracyclops*, and defined the former by the combination of (i) a slender habitus, (ii) shape of the caudal rami, (iii) the 12-segmented female antennule, (iv) armature formulae of the swimming legs, (v) lack of inner armature on P4EXP1, and (vi) shape of P5. Karanovic (2006) also noted that *Australoeucyclops* is restricted to Australia, New Zealand and Indonesia (Karanovic, 2006). Mercado-Salas & Suárez-Morales (2009) described *P. hirsutus* from La Chica Dam in the state of Aguascalientes, north-central Mexico, at 2021 m asl, and reported

on the presence of *P. chiltoni* and *P. poppei* in the state of Campeche (south-eastern Mexico) and in the state of Aguascalientes, respectively. That same year, Tang & Knott (2009) described *P. intermedius* Tang & Knott, 2009, presented new records of *P. chiltoni* from Western Australia, and gave a key to the Australian species of the genus. At present, the genus *Paracyclops* is composed of *P. f. fimbriatus* (the type species) and 27 valid species, including the new species presented herein.

Karanovic's (2006) view about the concept of *Australoeucyclops*, as well as the doubtful belonging of *P. yeatmani* and *P. smileyi* to *Paracyclops*, are followed here. However, some other species depart from *Paracyclops* in some important ways. For example, some species ascribed to *Paracyclops* (*P. affinis*, *P. aioiensis*, *P. canadensis*, *P. intermedius*, *P. oligarthrus*, *P. pilosus* and *P. uenoi*) depart from the most common armature formula of the swimming legs of the genus, viz., P1 EXP/ENP (I-1;I-1;III,2,3/0-1;0-1;1,I1,3), P2 EXP/ENP (I-1;I-1;III,I1,4/0-1;0-2;1,I1,3), P3 EXP/ENP (I-1;I-1;III,I1,4/0-1;0-2;1,I1,3), P4 EXP/ENP (I-1;I-1;II,I1,4/0-1;0-2;1,II,2) (see table I); *P. canadensis*, *P. affinis*, and *P. uenoi* (one of Karaytuğ's (1998) lineages) possess 11-segmented female antennules, and the segmentation pattern of the female antennules is different also in *P. affinis*, *P. canadensis*, *P. intermedius*, *P. uenoi*, *P. oligarthrus*, *P. pilosus*, *P. smileyi* and *P. yeatmani* (the description of the female antennule of *P. aioiensis* lacks necessary detail making homologization of ancestral segments difficult) (table II); seta A in the first antennulary segment of the males of *P. canadensis*, *P. affinis* and *P. intermedius* is not modified into the usual thick and strongly spinulose seta commonly found in *Paracyclops* (tables III–V), among other inconsistencies. Amongst the species above, *P. pilosus* is the only species distributed in the Neotropics. The original description of *Paracyclops andinus* is rather sketchy and incomplete, making detailed comparison with other species difficult. This species was added to tables I–III but it had to be excluded from the analyses and discussion.

Eighteen species of *Paracyclops* (*P. andinus* excluded) display the most common armature formulae of P1–P4 above (table I). *Paracyclops chiltoni* and *P. poppei* have been reported from Nearctic and Neotropical localities (Rehberg, 1880; Thomson, 1883; Karaytuğ & Boxshall, 1998b; Karaytuğ, 1999; Dussart & Defaye, 2006; Mercado-Salas & Suárez-Morales, 2009), and the former is known also from Australia (Karaytuğ & Boxshall, 1998c; Karaytuğ, 1999; Dussart & Defaye, 2006; Tang & Knott, 2009). *Paracyclops bromeliacola*, *P. carectum*, *P. fiersi* sp. nov., *P. hardingi* (not *P. hardingui* [sic!] as in Mercado-Salas & Suárez-Morales, 2009), *P. hirsutus*, *P. novenarius*, *P. punctatus*, *P. reidae* and *P. rochai* are known from their type localities in the Neotropics only (Reid, 1987a, b; Karaytuğ & Boxshall, 1998a; Karaytuğ, 1999; Dussart & Defaye, 2006; Mercado-Salas & Suárez-Morales, 2009). *Paracyclops baicalensis*, *P. dilatatus*, *P. imminutus*, *P. f. fimbriatus*, *P. fimbriatus paropamisi* are known from the Palaearctic (Fischer, 1853;

TABLE I

Armature formula of swimming legs (exopods and endopods) of the species ascribed to the genus *Paracyclops* Claus, 1893 (cf. Claus, 1893a)

	P1		P2		P3		P4	
	EXP	ENP	EXP	ENP	EXP	ENP	EXP	ENP
Species with usual armature formulae								
P. altissimus	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. baicalensis	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. andinus	?	?	?	?	?	?	?	0-1;0-2;1,II,2
P. bromeliacola	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. carectum	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. chiltoni	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. dilatatus	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. fiersi sp. nov.	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. f. fimbriatus	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. f. paropamisi	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. hardingi	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. hirsutus	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. imminutus	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. longispina	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. novenarius	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. poppei	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1:0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. punctatus	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. reidae	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. rochai	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2

TABLE I
(Continued)

	P1		P2		P3		P4	
	EXP	ENP	EXP	ENP	EXP	ENP	EXP	ENP
Species with unusual armature formulae								
P. affinis	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-**1**;1,I1,3	I-1;I-1;III,**2**,**3**	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-**1**;1,II,2
P. aioiensis	I-1;I-1;III,2,3	0-1;0-**2**;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. canadensis	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-**1**;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-**1**;1,II,2
P. intermedius	I-1;I-1;III,2,3	0-1;0-1;1,I1,3	I-1;I-1;III,I1,4	0-1;0-**1**;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-**1**;1,II,2
P. uenoi	I-1;I-1;III,2,3	0-1;0-**2**;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,**2**,**3**	0-1;0-2;1,I1,3	I-**0**;I-1;II,I1,4	0-1;0-**1**;1,II,2
P. oligarthrus	I-1;I-1;III,2,3	0-1;0-1;1,I1,**2**	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. pilosus	I-1;I-1;III,2,3	0-1;0-**2**;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,**2**	I-1;I-1;II,I1,**3**	0-1;0-2;1,II,2
P. smileyi	I-1;I-1;III,2,3	0-1;0-**2**;1,I1,3	I-1;I-1;III,I1,4	0-1;0-**1**?;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2
P. yeatmani	I-1;I-1;III,2,3	0-1;0-**2**;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;III,I1,4	0-1;0-2;1,I1,3	I-1;I-1;II,I1,4	0-1;0-2;1,II,2

Species with unusual armature formulae in bold, and their unusual armature complements in bold and underlined. The armature formulae of coxa (0-1) and basis (P1 [1-I], P2–P4 [1-0]) is constant in all species and have not been included. The armature formulae of *P. andinus* Kiefer, 1957 remain unknown but was provisionally and arbitrarily added to the group of species with usual armature formulae.

TABLE II

Segmentation pattern of the female antennule of the species ascribed to the genus *Paracyclops* Claus, 1893 (cf. Claus, 1893a)

	Ancestral segments VI–VII, VIII, IX–XI (actual segment 2)	Ancestral segments XII–XIII and XIV (actual segment 3)	Ancestral segments XV and XVI–XX (actual segment 4)	Ancestral segments XXI–XXIII (actual segment 5) and XXIV (actual segment 6)
		Species with usual segmentation		
P. altissimus	Fused	Fused with suture	Fused	Separated
P. andinus	?	?	?	?
P. baicalensis	Fused	Fused with suture	Fused	Separated
P. bromeliacola	Fused	Fused with suture	Fused	Separated
P. carectum	Fused	Fused with suture	Fused	Separated
P. chiltoni	Fused	Fused with two sutures	Fused	Separated
P. dilatatus	Fused	Fused with suture	Fused	Separated
P. fiersi sp. nov.	Fused	Fused with suture	Fused	Separated
P. f. fimbriatus	Fused	Fused with suture	Fused	Separated
P. f. paropamisi	?	?	?	?
P. hardingi	Fused	Fused with suture	Fused	Separated
P. hirsutus	Fused	Fused with suture	Fused	Separated
P. imminutus	Fused	Fused with suture	Fused	Separated
P. longispina	Fused	Fused with suture	Fused	Separated
P. novenarius	Fused with suture	Fused with suture	Fused	Separated
P. poppei	Fused	Fused with suture	Fused	Separated
P. punctatus	Fused	Fused with two sutures	Fused with suture	Separated
P. reidae	Fused	Fused with suture	Fused	Separated
P. rochai	Fused	Fused with suture	Fused	Separated
		Species with unusual segmentation		
P. aioiensis	?	?	?	?
P. affinis	Separated	Separated	Separated	Fused
P. canadensis	Separated	Separated	Separated	Fused
P. intermedius	Separated	Separated	Separated	Fused
P. uenoi	Separated	Separated	Separated	Fused
P. oligarthrus	Fused	Fused with suture	Fused	Fused with suture
P. pilosus	I–V and VI–XI fused with suture	Fused with suture	Fused	Separated
P. smileyi	separated	Separated	Separated	Separated
P. yeatmani	VI–VII separated; VIII and IX–XI fused	Separated	Separated	Separated

TABLE III

Salient features of A1 of the species of the genus *Paracyclops* Claus, 1893 (cf. Claus, 1893a), with armature formulae of: P1 EXP/ENP: I-1;I-1;III,2,3/0-1;0-1;1,I1,3; P2 EXP/ENP: I-1;I-1;III,I1,4/0-1;0-2;1,I1,3; P3 EXP/ENP: I-1;I-1;III,I1,4/0-1;0-2;1,I1,3; P4 EXP/ENP: I-1;I-1;II,I1,4/0-1;0-2;1,II,2

	♂ A1, segment 1, setal element G (aesthetasc)	♂ A1, segment 1, setal element C (aesthetasc)	Fringe of elongated setules on the fifth pedigerous somite	Surface spinular ornamentation on the anal cleft	Shape of the spinular row close to dorsal seta VII of caudal rami	Inner spinular ornamentation on caudal rami	♀ A1 (No. of segments)	♀ A1 ancestral segments VI-VII, VIII, IX-XI (actual segment 2)	♀ A1 ancestral segments XII-XIII y XIV (actual segment 3)
P. andinus	?	?	With	Without	Oblique	Without	8	?	?
A									
P. f. fimbriatus	Without	Without	With	Without	Oblique	Without	8	Fused	Fused with one suture
P. f. paropamisi	♂ Unknown	♂ Unknown	With	Without	Oblique	Without	8	?	?
P. hirsutus	Without	Without	With	Without	Oblique	With	8	Fused	Fused with one suture
P. longispina	Without	Without	With	Without	Oblique	Without	8	Fused	Fused with one suture
P. poppei	Without	With	With	Without	Longitudinal	Without	8	Fused	Fused with one suture
B									
P. altissimus	With	Without	With	Without	Oblique	Without	8	Fused	Fused with one suture
P. baicalensis	?	?	Without	Without	Oblique	Without	8	Fused	Fused with one suture
P. bromeliacola	With	Without	With	Without	Oblique	Without	8	Fused	Fused with one suture

TABLE III
(Continued)

	♂ A1, segment 1, setal element G (aesthetasc)	♂ A1, segment 1, setal element C (aesthetasc)	Fringe of elongated setules on the fifth pedigerous somite	Surface spinular ornamentation on the anal cleft	Shape of the spinular row close to dorsal seta VII of caudal rami	Inner spinular ornamentation on caudal rami	♀ A1 (No. of segments)	♀ A1 ancestral segments VI-VII, VIII, IX-XI (actual segment 2)	♀ A1 ancestral segments XII-XIII y XIV (actual segment 3)
P. carectum	With	Without	With	Without	Oblique	With	8	Fused	Fused with one suture
P. chiltoni	With	Without	With	Without	Oblique	Without	8	Fused	Fused with two sutures
P. dilatatus	♂ Unknown	♂ Unknown	With	Without	Without	Without	8	Fused	Fused with one suture
P. fiersi sp. nov.	With	Without	With	Without	Oblique	Without	8	Fused	Fused with one suture
P. hardingi	With	Without	With	Without	Oblique	Without	8	Fused	Fused with one suture
P. imminutus	With	Without	With	Without	Oblique	Without	8	Fused	Fused with one suture
P. novenarius	With	Without	With	Without	Oblique	Without	8	Fused with one suture	Fused with one suture
P. punctatus	With	Without	With	Without	Oblique	Without	8	Fused	Fused with two sutures
P. reidae	With	Without	With	Without	Oblique	Without	8	Fused	Fused with one suture
P. rochai	With	Without	With	Without	Oblique	Without	8	Fused	Fused with one suture

TABLE IV

Salient features of A2 and P1 of the species of the genus *Paracyclops* Claus, 1893 (cf. Claus, 1893a), with armature formulae of: P1 EXP/ENP: I-1;I-1;III,2,3/0-1;0-1;1,I1,3; P2 EXP/ENP: I-1;I-1;III,I1,4/0-1;0-2;1,I1,3; P3 EXP/ENP: I-1;I-1;III,I1,4/0-1;0-2;1,I1,3; P4 EXP/ENP: I-1;I-1;II,I1,4/0-1;0-2;1,II,2

	♀ A2 seta VIII	♀ A2 coxobasis, surface spinular ornamentation	♀ A2 coxobasis, spinules at the base of inner setae	♂ A2 coxobasis, spinules at the base of inner setae	♀ P1 coxa, medial spinular row	♂ P1 coxa, medial spinular row	♂ P1 ENP3 subdistal (third) inner seta
P. andinus	?	?	?	?	?	?	?
A							
P. f. fimbriatus	Normal	With	Without	With	Subdistal	Subdistal	Spiniform
P. f. paropamisi	?	?	?	♂ Unknown	?	?	♂ Unknown
P. hirsutus	Normal	With	Without	Without	?	?	Setiform
P. longispina	Normal	With	With	With	Subdistal	As in female?	Spiniform
P. poppei	Normal	With	Without	With	Subdistal	As in female?	Spiniform
P. altissimus	Normal	With	With	With	Without	As in female?	Setiform
P. baicalensis	Normal	With	With	?	Subdistal	?	?
P. bromeliacola	Normal	With	Without	?	?	?	Spiniform
P. carectum	Normal	With	Without	Without	Subdistal	Subdistal	Setiform
P. chiltoni	Normal	With	Without	With	Subdistal	As in female?	Spiniform
P. dilatatus	Transformed into massive claw	Without	With	♂ Unknown	?	?	♂ Unknown
B							
P. fiersi sp. nov.	Normal	With	Without	With	Medial (sparse)	Medial (sparse)	Spiniform
P. hardingi	Normal	With	With	With	Subdistal	As in female?	Spiniform
P. imminutus	Normal	With	With	With	Medial (dense)	Medial (dense)	Setiform
P. novenarius	Normal	With	Without	Without	Subdistal	Subdistal	Spiniform
P. punctatus	Normal	With	Without	Without	Without	As in female?	Setiform
P. reidae	Normal	With	With	With	Without	Without	Setiform
P. rochai	Normal	With	Without	?	Without	As in female?	Setiform

TABLE V

Salient features of P3 and P4 of the species of the genus *Paracyclops* Claus, 1893 (cf. Claus, 1893a), with armature formulae of: P1 EXP/ENP: I-1;I-1;III,2,3/0-1;0-1;1,I1,3; P2 EXP/ENP: I-1;I-1;III,I1,4/0-1;0-2;1,I1,3; P3 EXP/ENP: I-1;I-1;III,I1,4/0-1;0-2;1,I1,3; P4 EXP/ENP: I-1;I-1;II,I1,4/0-1;0-2;1,II,2

	♀ P2 coxa, medial spinular row	♂ P2 coxa, medial spinular row	♀P3 coxa, medial spinular row	♂ P3 coxa, medial spinular row	♀ P4 coxa, medial spinular row	♂ P4 coxa, medial spinular row
P. andinus	?	?	?	?	?	?
A						
P. f. fimbriatus	Subdistal	Subdistal	Subdistal	subdistal	subdistal (small, conical)	subdistal (small, conical)
P. f. paropamisi	?	?	?	?	?	?
P. hirsutus	?	?	?	?	?	?
P. longispina	Subdistal	As in female?	Subdistal	Subdistal?	Subdistal (small, conical)	Subdistal (small, conical)
P. poppei	Subdistal	As in female?	Subdistal (Few)	As in female?	Subdistal (small, conical)	Subdistal (small, conical)
B						
P. altissimus	Without	As in female?	Without	As in female?	Subdistal (small, conical)	Subdistal (small, conical)
P. baicalensis	Subdistal	?	Subdistal	?	Subdistal	?
P. bromeliacola	Without	As in female?	Without	As in female?	Subdistal (small, conical)	Subdistal (small, conical)
P. carectum	Subdistal	Subdistal	Subdistal (Few)	Subdistal (few)	Subdistal (small, conical)	Subdistal (small, conical)
P. chiltoni	Subdistal	As in female?	Subdistal	As in female?	Subdistal (small, conical)	Subdistal (small, conical)
P. dilatatus	?	?	?	?	?	?
P. fiersi sp. nov.	Subdistal	Subdistal	Without	Subdistal	Subdistal (long, slender)	Subdistal (long, slender)
P. hardingi	Subdistal	As in female?	Subdistal	As in female?	Subdistal (small, conical)	Subdistal (small, conical)
P. imminutus	Subdistal	Subdistal	Subdistal	Subdistal	Subdistal (small, conical)	Subdistal (small, conical)
P. novenarius	Subdistal	Subdistal	Subdistal	Subdistal	without	without
P. punctatus	Without	As in female?	Without	As in female?	Subdistal (small, conical)	Subdistal (small, conical)
P. reidae	Without	Without	Without	Without	Without	Without
P. rochai	Without?	As in female?	Without?	As in female?	Subdistal (small, conical)	Subdistal (small, conical)

Kiefer, 1929b; Lindberg, 1952, 1960; Mazepova, 1978; Karaytuğ & Boxshall, 1998a, c; Karaytuğ, 1999; Dussart & Defaye, 2006). *Paracyclops altissimus* and *P. longispina* are known from the Palaeotropics (Karaytuğ et al., 1998; Karaytuğ, 1999; Dussart & Defaye, 2006). Only three species have been confirmed to be

present in Mexico. These are the cosmopolitan *P. chiltoni* and *P. poppei*, and *P. hirsutus* (cf. Mercado-Salas & Suárez-Morales, 2009). *Paracyclops fiersi* sp. nov. from north-western Mexico (present study) is the fourth confirmed species of *Paracyclops* from Mexico. Karaytuğ & Boxshall (1998b) considered the records of *P. f. fimbriatus* from Mexico (see Súarez-Morales & Reid, 1998) as doubtful and in need to be confirmed.

The genus *Paracyclops* has been diagnosed upon the combination of several character states (see Karaytuğ, 1999: 20–21), and the modified seta A on the first segment of the male antennules is the only synapomorphy detected so far for the genus (Karaytuğ & Boxshall, 1999), but the unmodified nature of seta A in *P. affinis*, *P. canadensis*, and *P. intermedius* is not clear (see above). The new species presented herein was attributed to *Paracyclops* by the combination of the short (eight-segmented) female antennules, presence of an exopodal seta on the antenna, armature formulae of P1–P4, presence of a fringe of long setules on the P5-bearing somite, the one-segmented P5 with three elements (one outer and one medial seta, and one inner spine), the spinular ornamentation of the caudal rami, and above all, by the synapomorphic modified seta A on the first antennulary segment modified into a thick densely spinulose element in males (see Karaytuğ, 1999; Karaytŭg & Boxshall, 1999; and Karaytŭg & Boxshall, 1999).

Paracyclops fiersi sp. nov. belongs to the group of species displaying the most common armature formulae of P1–P4, viz., P1 EXP/ENP (I-1;I-1;III,2,3/0-1;0-1;1,I1,3), P2 EXP/ENP (I-1;I-1;III,I1,4/0-1;0-2;1,I1,3), P3 EXP/ENP (I-1;I-1;III,I1,4/0-1;0-2;1,I1,3), P4 EXP/ENP (I-1;I-1;II,I1,4/0-1;0-2;1,II,2). These species are *P. altissimus*, *P. baicalensis*, *P. bromeliacola*, *P. carectum*, *P. chiltoni*, *P. dilatatus*, *P. f. fimbriatus*, *P. f. paropamisi*, *P. hardingi*, *P. hirsutus*, *P. imminutus*, *P. longispina*, *P. novenarius*, *P. poppei*, *P. punctatus*, *P. reidae* and *P. rochai* (table I). Also, these species share the fusion of the female ancestral antennulary segments VI–VII, VIII, IX–XI, ancestral segments XII–XIII and XIV (with one or two sutures), and ancestral segments XV and XVI–XX (with or without suture), but they also share the separation of ancestral segments XXI–XXIII and XXIV (table II). The nature of the elements on the male antennule of the species of *Paracyclops* may be useful to understand their phylogenetic relationships (Karaytuğ & Boxshall, 1999). For example, some species, *P. f. fimbriatus*, *P. hirsutus*, *P. longispina* and *P. poppei* (group A in tables III–V) share the synapomorphic loss of setal element G (aesthetasc) (see Karaytuğ, 1999; and Karaytŭg & Boxshall, 1999). Unfortunately, the male of *P. fimbriatus paropamisi* remains unknown, and the condition of the setal element G of the first antennulary segment of the male antennule is uncertain (the species was included provisionally into group A in tables III–V). Amongst the above four species, *P. poppei* stands out by the autapomorphic seta C of the first antennulary segment of the males, modified

into a thick densely spinulose seta, similar but not homologous to seta A (Karaytuğ, 1999; Karaytuğ & Boxshall, 1999), and by the autapomorphic longitudinal row of spinules on the dorsal surface of the caudal rami in both sexes (tables III–V). *Paracyclops poppei*, *P. longispina*, and *P. f. fimbriatus* share the derived, sexually dimorphic, spiniform, subdistal inner element of the male P1 ENP3 (arrowed in fig. 8B for *P. fiersi* sp. nov.) (tables III–V). As noted above, the male of *P. f. paropamisi* remains unknown and the condition of this element is uncertain. The dimorphic transformation of this element on the male P1 ENP3 is also present in other species, e.g., *P. bromeliacola*, *P. chiltoni*, *P. fiersi* sp. nov., *P. hardingi* and *P. novenarius*, and seems to have evolved independently more than once (tables III–V). Amongst *P. f. fimbriatus*, *P. longispina*, and *P. poppei* (and probably *P. f. paropamisi*), *P. hirsutus* stands out by the plesiomorphic setiform, subdistal, inner element of the male P1 ENP3. This setiform element is also present in *P. altissimus*, *P. carectum*, *P. imminutus*, *P. punctatus*, *P. reidae* and *P. rochai* (tables III–V). *Paracyclops hirsutus* is unique amongst *P. f. fimbriatus*, *P. longispina*, and *P. poppei* (and probably *P. f. paropamisi*) by the lack of spinules at the base of the inner setae of the male antennary coxobasis, and by the setulose inner margin of the caudal rami (tables III–V). The setulose nature of the inner margin of the female caudal rami of *P. hirsutus* is different from that of the females of *P. carectum* (cf. Mercado-Salas & Suárez-Morales, 2009: 2799–2800). The setular inner ornamentation of the female caudal rami (sparse long setules) and the sexually dimorphic setular ornamentation on the ventral surface of the male caudal rami of *P. hirsutus* (see Mercado-Salas & Suárez-Morales, 2009) are regarded here as autapomorphic for the species. Amongst *P. hirsutus*, *P. f. fimbriatus*, *P. longispina* and *P. poppei* (and probably *P. f. paropamisi*), *P. longispina* stands out by the presence of spinules at the base of the inner setae of the antennary coxobasis in the females, which are also present in the females of *P. altissimus*, *P. baicalensis*, *P. dilatatus*, *P. hardingi*, *P. imminutus* and *P. reidae* (tables III–V). On the other hand, *P. longispina*, *P. f. fimbriatus*, *P. poppei*, and probably *P. f. paropamisi* (the male of the latter remains unknown) share the presence of spinules at the base of the inner setae of the male antennary coxobasis (as noted above, such spinules are missing in the male antennary coxobasis of *P. hirsutus*) (tables III–V). Such spinules are also present in the male antennary coxobasis of *P. altissimus*, *P. chiltoni*, *P. fiersi* sp. nov., *P. hardingi*, *P. imminutus* and *P. reidae*. The presence of a subdistal, medial spinular row on the posterior surface of the coxa of P1–P4 has been used to establish the phylogenetic relationships between the species of *Paracyclops*. On this regard, the females and males of *P. f. fimbriatus*, *P. longispina* and *P. poppei* (the presence of such spinules in both sexes of *P. f. paropamisi* and *P. hirsutus* needs to be confirmed) share the presence of a subdistal, medial, transverse row of slender spinules on the posterior

surface of the coxa of P1–P3 (the spinules on the coxa of P3 of *P. poppei* are comparatively fewer), and a subdistal, medial, transverse row of smaller but thicker, conical spinules on the posterior surface of the coxa of P4. Such spinules are also present in some other species (tables III–V).

A larger group of species (*P. altissimus*, *P. baicalensis*, *P. bromeliacola*, *P. carectum*, *P. chiltoni*, *P. dilatatus*, *P. fiersi* sp. nov., *P. hardingi*, *P. imminutus*, *P. novenarius*, *P. punctatus*, *P. reidae* and *P. rochai*) retained the plesiomorphic setal element G (aesthetasc) on the first antennulary segment in the males (see Karaytuğ, 1999; and Karaytŭg & Boxshall, 1999) (group B in tables III–V). All these species also share the fusion of the female antennulary ancestral segments VI–VII, VIII, and IX–XI, segments XII–XIII and XIV, and XV and XVI–XX (table II). A subgroup of species (*P. altissimus*, *P. imminutus*, *P. punctatus*, *P. reidae*, *P. rochai* and *P. carectum*, and probably *P. dilatatus*; the male of the latter remains unknown) share the (sym)plesiomorphic setiform, subdistal inner element on the male P1 ENP3 (tables III–V). The male of *Paracyclops dilatatus* remains unknown, but the female seems to be unique in the lack of an oblique spinular row in the caudal rami close to dorsal seta VII; the condition of a subdistal, medial, transverse row of spinules on the posterior surface of the coxa of P1–P4 in this species still needs confirmation. Amongst the species of this subgroup, *P. carectum* is unique in (i) the presence of setules on the inner margin of the caudal rami (considered here as autapomorphic for the species; for a comparison between the inner ornamentation of the caudal rami of *P. hirsutus* and *P. carectum* see Mercado-Salas & Suárez-Morales, 2009), and (ii) the presence of a subdistal, medial, transverse row of slender spinules on the posterior surface of the coxa of P1 in both females and males (the posterior spinular row on the coxa of P1 in *P. imminutus* is comparatively denser and is displaced to a medial position; tables III–V). *Paracyclops imminutus* and *P. carectum* share the presence of a subdistal, medial, transverse row of slender spinules on the posterior surface of the coxa of P2 and P3 in both sexes, but the posterior row of spinules on the coxa of P2 and P3 in *P. carectum* is composed of comparatively fewer and smaller spinules. *Paracyclops punctatus*, *P. rochai*, *P. altissimus* and *P. reidae* share the lack of a subdistal, medial, transverse row of slender spinules on the posterior surface of the coxa of P1–P3 in both sexes. *Paracyclops punctatus* and *P. reidae* share the lack of spinules at the base of the inner setae on the antennary coxobasis in the female (the male of *P. punctatus* also lacks such spinules, but the condition of *P. rochai* is inconclusive); the lack of such spinules is also shared with *P. carectum* and seems to be widespread throughout the genus. *Paracyclops punctatus* is unique amongst the species of this subgroup, viz., *P. altissimus*, *P. imminutus*, *P. punctatus*, *P. reidae*, *P. rochai*, *P. carectum* and *P. dilatatus*, in the presence of two sutures in the fused ancestral segments XII–XIII and XIV of the female antennules (the latter condition is also present in *P. chiltoni*),

and seems to be unique in the presence of one suture in the fused ancestral segments XV and XVI–XX of the female antennules (table II). *Paracyclops reidae* is unique in this subgroup in the lack of a subdistal, medial, transverse row of spinules on the posterior surface of the coxa of P4 in both sexes (this condition is also present in *P. novenarius*).

Paracyclops fiersi sp. nov. belongs to a group of species (*P. baicalensis*, *P. bromeliacola*, *P. chiltoni*, *P. hardingi* and *P. novenarius*) in which the subdistal inner element of the male P1 ENP3 is transformed into a spine. This transformation is regarded here as derived in contrast to the primitive setiform element of *P. imminutus*, *P. carectum*, *P. punctatus*, *P. rochai*, *P. altissimus*, *P. reidae* and *P. dilatatus*. *Paracyclops hirsutus* also displays a spiniform, subdistal inner element on the male P1 ENP3 but belongs to a group of species without setal element G (aesthetasc) on the first antennulary segment in the males. The sexually dimorphic spiniform inner element on the male P1 ENP3 seems to have evolved independently more than once in the different lineages of *Paracyclops*. *Paracyclops baicalensis* is unique amongst the species of the genus in the lack of the typical fringe of elongated setules on the P5-bearing segment. Unfortunately, the male of *P. baicalensis* is no longer available and Karaytuğ & Boxshall (1998a) could not include it in the redescription of the species, and the setation pattern of the male antennule as well as the spinular pattern on the posterior surface of the coxa of P1–P4 remain inconclusive.

Paracyclops fiersi sp. nov. seems to be related to the Peruvian *P. hardingi*, the Brazilian *P. bromeliacola* and the Colombian *P. novenarius*, but also with the cosmopolitan *P. chiltoni*. All these species share the — synapomorphic — spiniform subdistal (third) inner seta of the male P1 ENP3 (see tables III–V). *Paracyclops novenarius* is the only species of the genus with a partial suture in the fused ancestral segments VI–VII, VIII, and IX–XI of the female antennules (see table II) and is the only one within this group of species without spinules at the base of the inner setae of the male antennary coxobasis, and without medial, subdistal spinules on the coxa of the male P4 (see tables III–V). All the species of the genus display one suture in the fused ancestral antennulary segments XII–XIII and XIV in females, except for the cosmopolitan *P. chiltoni* and the Brazilian *P. punctatus*, which possess two sutures on this compound segment.

Paracyclops fiersi sp. nov. seems to be more related to the Peruvian *P. hardingi* and to the Brazilian *P. bromeliacola*. The relationships between these species are not clear. They share (i) the fusion of female antennulary ancestral segments VI–VII, VIII, IX–XI (actual segment 2), XII–XIII and XIV (actual segment 3 with suture line), XV and XVI–XX (actual segment 4), and separation of ancestral segments XXI–XXIII (actual segment 5) and XXIV (actual segment 6) (see table II), (ii) presence of setal element G and lack of setal element C on the male first antennulary segment, (iii) presence of elongated setules on the

fifth pedigerous somite, (iv) lack of surface spinular ornamentation on the anal cleft, (v) oblique spinular row close to dorsal caudal seta VII, (vi) lack of inner spinular ornamentation on the caudal rami, (vii) number of segments of the female antennule, (viii) shape (normal) of seta VIII of the female antenna, and (ix) presence of spinular ornamentation on the anterior surface of the antennary coxobasis (see tables III–V), but none of these are unique to these species. *Paracyclops fiersi* sp. nov., *P. hardingi* and *P. bromeliacola* differ in (i) the ornamentation of the female antennary coxobasis (without spinules at the base of the inner setae in *P. bromeliacola* and the new species, but with spinules in *P. hardingi*), (ii) the relative position of the posterior medial spinules on the female and male P1 coxa (subdistal in *P. hardingi*, but situated more proximally in the new species; the condition in *P. bromeliacola* is uncertain), (iii) the posterior medial spinules on the P2 coxa in both sexes (located subdistally in *P. hardingi* and *P. bromeliacola*, but absent in the new species), (iv) the posterior medial spinules on the female P3 coxa (subdistally in *P. hardingi*, but without such spinules in *P. fiersi* sp. nov. and *P. bromeliacola*), (v) the posterior medial spinules on the male P3 coxa (subdistally in *P. hardingi* and in the new species, but without spinules in *P. bromeliacola*), (vi) shape of the posterior subdistal, medial spinules on the P4 coxa in both sexes (small, conical subdistal spinules in *P. hardingi* and *P. bromeliacola*, but long and slender in *P. fiersi*).

KEY TO THE SPECIES OF *PARACYCLOPS* REPORTED FROM MEXICO

1a Caudal rami with inner spinular — setular — ornamentation; ♀ antennulary segment 3 with one suture; ♂ first antennulary segment without setal elements G and C; ♂ antennary coxobasis without spinules at the base of inner setae; ♂inner (third) element of P1 ENP3 setiform . . . . . *P. hirsutus* (state of Aguascalientes)

1b Caudal rami unornamented; ♀ antennulary segment 3 with one or two sutures; ♂ first antennulary segment with or without setal elements G and C; ♂ antennary coxobasis with spinules at the base of inner setae; ♂inner (third) element of P1 ENP3 spiniform 2

2a ♀ antennulary segment 3 with two sutures; ♂ first antennulary segment with setal element G, without setal element C . . . . . *P. chiltoni* (state of Campeche)

2b ♀ antennulary segment 3 with one suture; ♂ first antennulary segment with or without setal element G, with or without setal element C 3

3a Spinular row close to dorsal seta VII of caudal rami longitudinal; ♂ first antennulary segment without setal element G, with setal element C . . *P. poppei* (state of Aguascalientes)

3b Spinular row close to dorsal seta VII of caudal rami oblique; ♂ first antennulary segment with setal element G, without setal element C . . *P. fiersi* sp. nov. (southern state of Sinaloa)

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