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A new interstitial cyclopoid copepod from a sandy beach on the western shore of Lake Baikal, Siberia

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Abstract

A new species of cyclopoid copepod, *Diacyclops biceri* sp. nov., is described from Lake Baikal. It was found in the interstitial water of a sandy beach at Buchta Peschanaya on the western shore of the central basin of Baikal. The new species is unique in possessing 2-segmented endopods in swimming legs 3 and 4. Swimming legs 2 to 4 have 3-segmented exopods. The slender body form, the lack of the antennal exopodal seta, and the presence of a secondary 'pseudosomite' anterior to the genital double somite of the adult female are interpreted as adaptations to the interstitial habitat. The harpacticoid *Epactophanes richardi* Mrazek was found in the same interstitial habitat as *D. biceri*.

Introduction

Lake Baikal has a rich copepod fauna comprising a total of 120 described species and subspecies, of which 32 are cyclopoids (Mazepova, 1978; Flössner, 1984), 69 are harpacticoids (Okuneva, 1989), 6 are calanoids, 10 are siphonostomatoids and 3 are poecilostomatoids (Kozhov, 1963; Markevich, 1956). More than half of these taxa are endemic to Lake Baikal. During an expedition to Lake Baikal in July 1991 we took the opportunity to sample the interstitial fauna at Buchta Peschanaya (Sand Bay) on the western shore of the central basin of Baikal. This was regarded as an unpromising habitat since the beach water freezes to a minimum depth of 1 m during the winter. Copepods have not previously been reported from this habitat in Baikal. Two copepods were present, a cyclopoid and an harpacticoid. The cyclopoid represents a new species of *Diacyclops* Kiefer and both sexes are described below in detail.

The harpacticoid was identified as *Epactophanes richardi* Mrazek, previously reported from the Maloye More (Small Sea) region of Baikal by Okuneva (1989) and from small streams entering Baikal by Sterba (1967). This species is typically found in damp moss and has been regarded as hypervariable (Lang, 1935, 1948). According to Dussart (1967) the typical habitat of this species is damp moss, although it has been reported from springs and subterranean water. Some of the differences reported between the morphs of this polymorphic species are taxonomically significant in many other harpacticoid genera. Given this, the range of habitats exploited by the so-called cosmopolitan species suggests to us the possibility that *E. richardi* is a complex of closely related species that is in need of revision.

Materials and methods

Material was collected from interstitial water in the sandy beach by excavating a hole about 30 cm deep about 50 cm up the beach from the water line. Water seeping into the hole was filtered through a fine mesh net. Any copepods were fixed in formalin and later transferred into 80% ethanol. Copepods were dissected in lactophenol and examined as temporary mounts in lactophenol using interference contrast on an Olympus BH-2 microscope. All drawings were made with the aid of a camera lucida. Some details were added to the drawings from scanning electron micrographs. The terminology proposed by Huys & Boxshall (1991) is adopted.

Copepods for scanning electron microscopy were washed in distilled water, postfixed in 1% Osmium Tetroxide, washed in distilled water containing a surfactant (1 drop in 100 ml), sonicated for 5 s, washed in distilled water and then dehydrated through graded acetone. After critical point drying specimens were mounted on stubs and sputter coated with palladium. Observations were made on an Hitachi S800 electron microscope and were used to verify light microcope observations. All type material is stored in the collections of The Natural History Museum, London.

Description

Diacyclops biceri sp. nov.

Adult Female. Body cyclopiform, with 4-segmented prosome and 5-segmented urosome (Fig. 1A). Prosome ovoid, with first pedigerous somite fully incorporated into cephalothorax; maximum width of prosome about twice as wide as genital double somite. Rostrum posteroventrally directed, truncate distally, ornamented with pair of sensilla (Fig. 2B). Urosome approximately as long as prosome; comprising fifth pedigerous somite, genital double somite and 3 free abdominal somites (Fig. 1B). Genital double somite slightly longer than greatest width; ornamented with 3 pairs of sensilla on dorsal surface and bearing copulatory pore mid-ventrally. Seminal receptacles subdivided into broad anterior and posterior lobes (Fig. 1C). Gonopores paired, located dorsolaterally; egg sacs each containing 2 eggs. Anterior part of genital double somite separated off as secondary 'pseudosomite' (arrowed in Fig. 1B). Anal somite bearing pair of dorsal sensilla and operculum with smooth posterior margin. Body length 0.32 mm, from tip rostrum to posterior margin of caudal rami, excluding caudal setae.

Caudal ramus (Fig. 1A–B) about 2.25 times longer than wide, in dorsal view. Only 6 setae present; seta I absent. Seta II located on dorsal surface about 65% of distance along ramus. Setae III and VI about equal in length, less than half as long as ramus. Setae IV and V well developed, with V not quite twice as long as IV. Seta VII slightly longer than ramus, located on ramus close to posterior margin. Inner margin of ramus smooth.

Antennule (Fig. 2A) short, 11-segmented, reaching only half distance to posterior margin of cephalothorax; number of setation elements as follows: 6, 3, 8, 3, 1 + 1 spine, 2, 3, 2 + aesthetasc, 2, 2 + aesthetasc, 7 + aesthetasc. Posterior margin setae present on segments 9, 10 and 11. Most long setae sparsely plumose, short setae naked. Proximal segment lacking ornamentation.

Antenna (Fig. 1D) 5-segmented, comprising unarmed coxa, basis and 3-segmented endopod. Exopodal seta absent. Basis bearing 2 spinulose setae around inner distal angle and ornamented with spinule row along outer margin. First endopodal segment with inner distal seta and patch of surface spinules. Second endopodal segment with 6 setae, of which 2 on inner margin and 4 arranged along inner part of distal margin; penultimate seta well developed, curved and ornamented with tiny denticles along concave margin; segment ornamented with spinules along outer margin. Third endopodal segment armed with 7 setae around apex, of which 6 more or less curved and bearing tiny denticles along concave margin and 1 sparsely plumose; ornamented with spinule row along outer margin.

Labrum comprising slender anterior part and

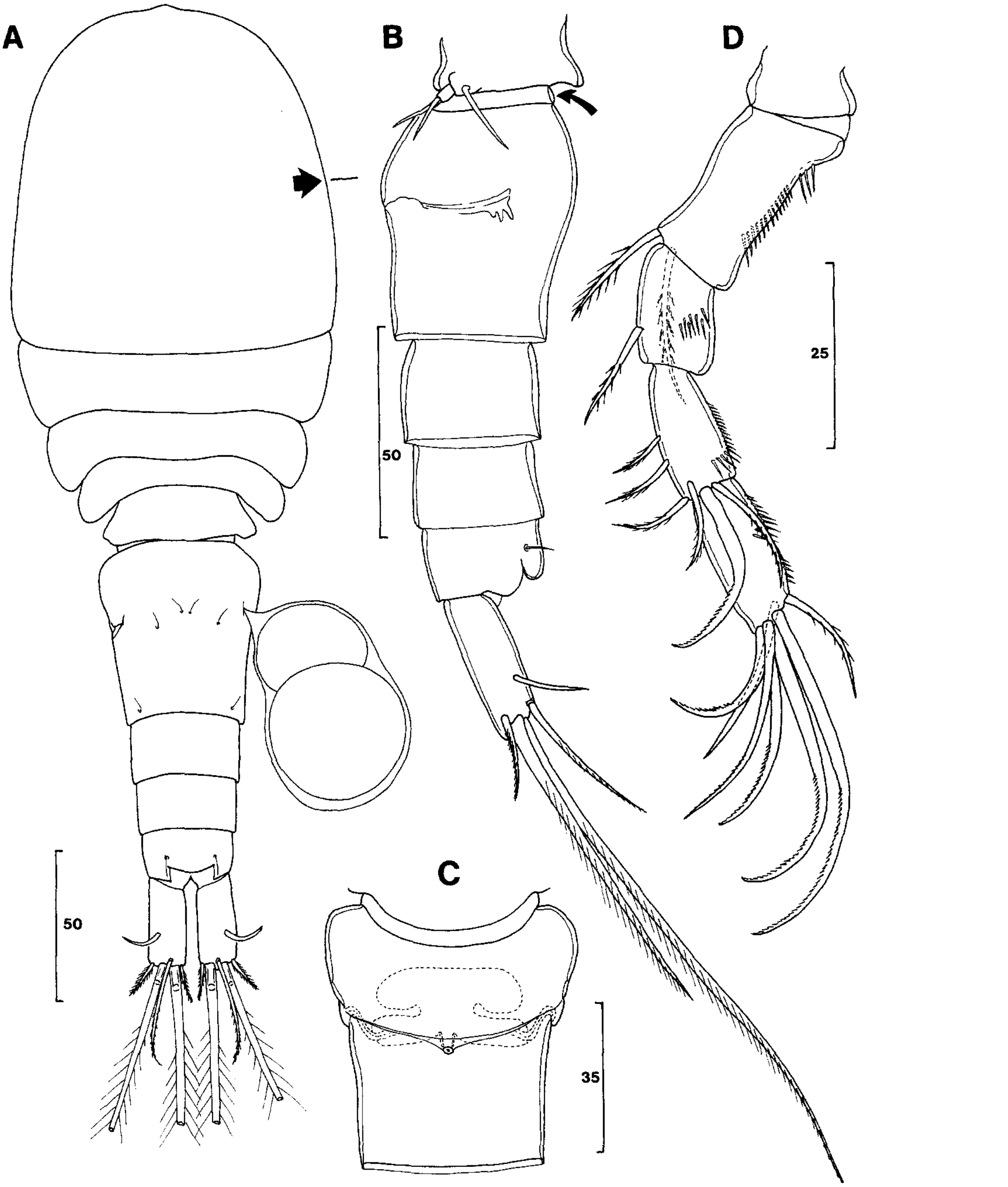

Fig. 1. *Diacyclops biceri* sp.nov. Adult female. A, Dorsal view, with arrowhead indicating length of antennule relative to cephalothorax; B, Urosome, lateral view with arrow indicating secondary 'pseudosomite' separated anteriorly from genital double somite; C, Genital double somite, ventral view; D, Antenna. All scales in μm.

broad posterior part (Fig. 2B). Posterior margin forming strong teeth; ventral surface ornamented with paired rows of long spinules.

Mandible (Fig. 2C) comprising well developed coxa with gnathobase and reduced palp. Gnathobasic blades mostly simple, dorsal seta hirsute. Palp represented by 3 setae, of which 2 long and plumose, the other short and naked. Long setae extending posteriorly parallel with lateral rim of dorsal cephalothoracic shield.

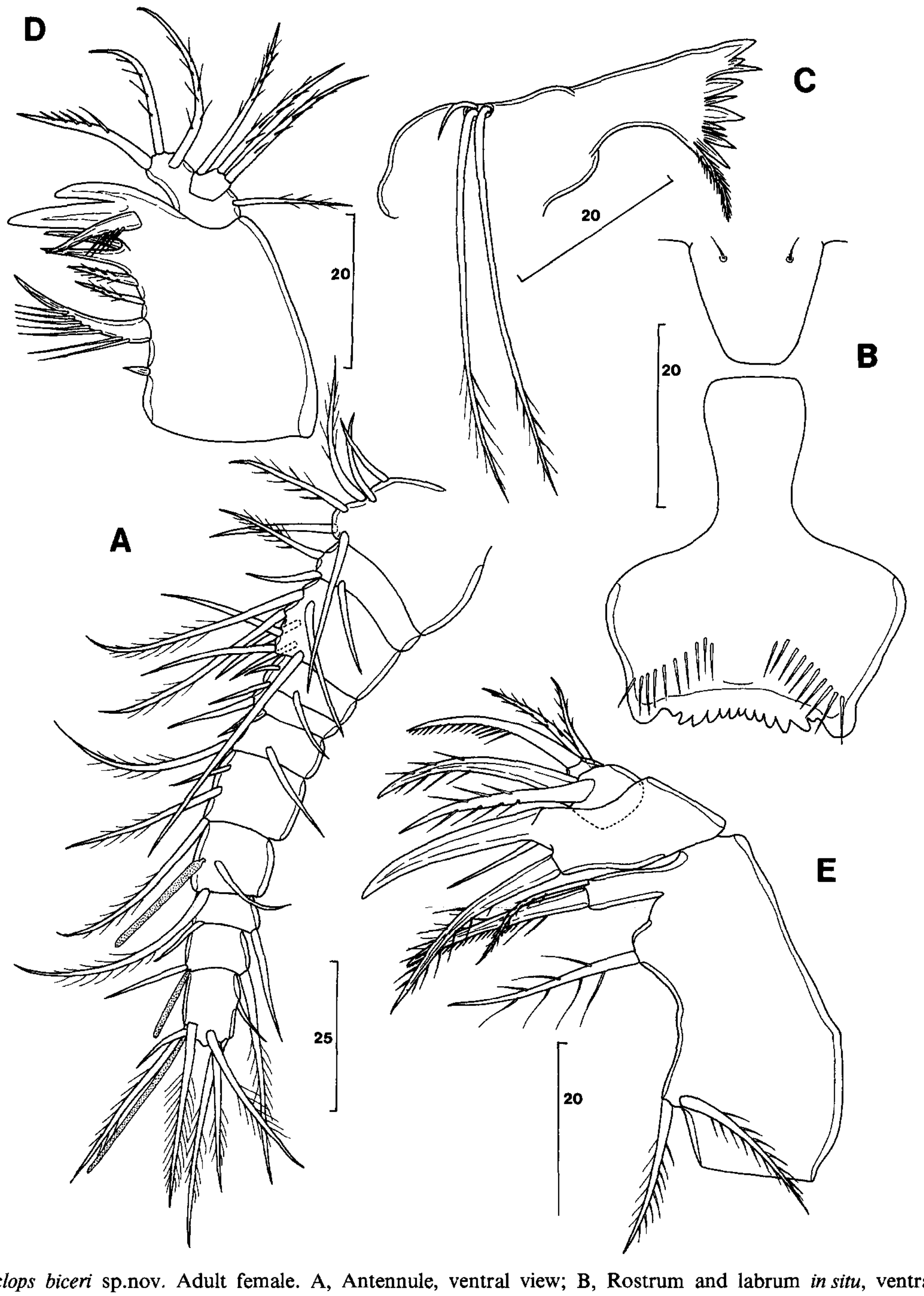

Fig. 2. Diacyclops biceri sp.nov. Adult female. A, Antennule, ventral view; B, Rostrum and labrum *in situ*, ventral view; C, Mandible, posteroventral view; D, Maxillule, posterior view; E, Maxilla, posterior view. All scales in μm.

Maxillule (Fig. 2D) comprising powerful praecoxa bearing reduced, 2-segmented palp. Praecoxal endite armed with 6 setae articulating at base and 3 spines fused to segment. Setae typically spinulose, spines naked. Proximal segment of palp derived from coxa and basis, bearing

3 inner margin setae and an outer seta representing exopod. Distal segment of palp representing endopod, armed with 3 sparsely plumose setae.

Maxilla (Fig. 2E) 4-segmented, comprising syncoxa, basis and 2-segmented endopod. Syncoxa bearing 3 endites; proximal endite armed with 2 plumose setae, middle endite represented by single seta, distal endite with well developed process carrying 2 apical elements. Basis drawn out into powerful claw and armed with 2 additional elements. First endopodal segment carrying 2 spinulose setae, second carrying 3 setae.

Maxilliped (Fig. 3A) 4-segmented, comprising syncoxa, basis and 2-segmented endopod. Syncoxa armed with 3 inner margin setae representing 2 vestigial endites. Basis armed with 2 inner setae, 1 of which spinulose; ornamented with 3 large spinules near inner margin and 2 transverse rows of spinules near outer distal angle. First endopodal segment bearing a single spinulose seta with 3 spinules around its base. Second endopodal segment with a spinulose seta and a short naked seta.

Swimming legs 1 to 4 each with 3-segmented protopod. Intercoxal sclerites unornamented. Praecoxa represented by triangular sclerite at outer proximal angle. Coxa armed with inner plumose seta and ornamented with rows of small spinules on anterior surface, adjacent to articulation with basis. Basis of all legs bearing outer angle seta with small integumental pore on anterior surface near its origin. Basis of leg 1 with inner margin setiform spine, almost as long as endopod, and ornamented with spinule row between rami. Leg 1 with 2-segmented rami, legs 2 to 4 each with 3-segmented exopod and 2-segmented endopod. Spine and seta formula as follows:

	coxa	basis	endopod	exopod
leg 1	0–1	1–1	0–1; 1, I + 3, 3	I–1; III, 1, 4
leg 2	0–1	1–0	0–1; 1, I + 1, 3	I–1; I–1; III, 1, 3
leg 3	0–1	1–0	0–1; 1, I + 1, 3	I–1; I–1; III, 1, 3
leg 4	0–1	1–0	0–1; 1, II, 2	I–1; I–1; III, 1, 3

Exopod of legs 2 to 4 bearing integumental pore on anterior surface between second and third outer margin spines. Similar pore present on second exopodal segment of legs 3 and 4, and near distal margin of second endopodal segment of legs 2 to 4. Outer margins of all endopodal segments ornamented with pinnule rows. Articulations between ramal segments all with partial rows of tiny spinules on anterior surface.

Fifth legs (Fig. 4C) 2-segmented; protopodal segment bearing outer plumose seta and with integumental pore proximally on anterior surface. Exopodal segment about twice as long as wide; bearing 2 plumose setae distally, outer longer than inner and both longer than segment.

Sixth legs (Fig. B) represented by opercular plates closing off gonopores, bearing 3 spinous processes.

Adult Male. Body cyclopiform, as for female except urosome 6-segmented, comprising fifth pedigerous, genital and four free abdominal somites. Genital somite bearing paired genital apertures ventrally near posterior margin. First and second abdominal somites with pair of integumental pores ventrally. Anal somite with pairs of sensilla both on ventral (Fig. 4A) and dorsal surfaces. Posterior margin with spinule rows near base of caudal rami. Caudal rami (Fig. 4A) as in female. Body length about 0.36 mm, from tip rostrum to posterior margin of caudal rami.

Antennule digeniculate (Fig. 4B), indistinctly 16-segmented: segmental fusion pattern as follows I–V, VI–VII, VIII, IX, X, XI–XII, XIII, XIV, XV, XVI, XVII, XVIII, XIX–XX, XXI–XXIII, XXIV–XXV, XXVI–XXVIII. Distal geniculation in neocopepodan position between segments 13 (XIX–XX) and 14 (XXI–XXIII). Segment 9 (XV) bearing sheath partly enclosing segment 10 (XVI) and forming part of proximal geniculation. Setation as follows: I–V–8 + 3 aesthetascs, VI–VII–4, VIII–2, IX–1 + aesthetasc, X–2, XI–XII–3, XIII–1, XIV–2 + aesthetasc, XV–1 + sheath, XVI–2, XVII–2 + aesthetasc, XVIII–1 + aesthetasc, XIX–XX–2, XXI–XXIII–3, XXIV–XXV–2, XXVI–XXVIII–

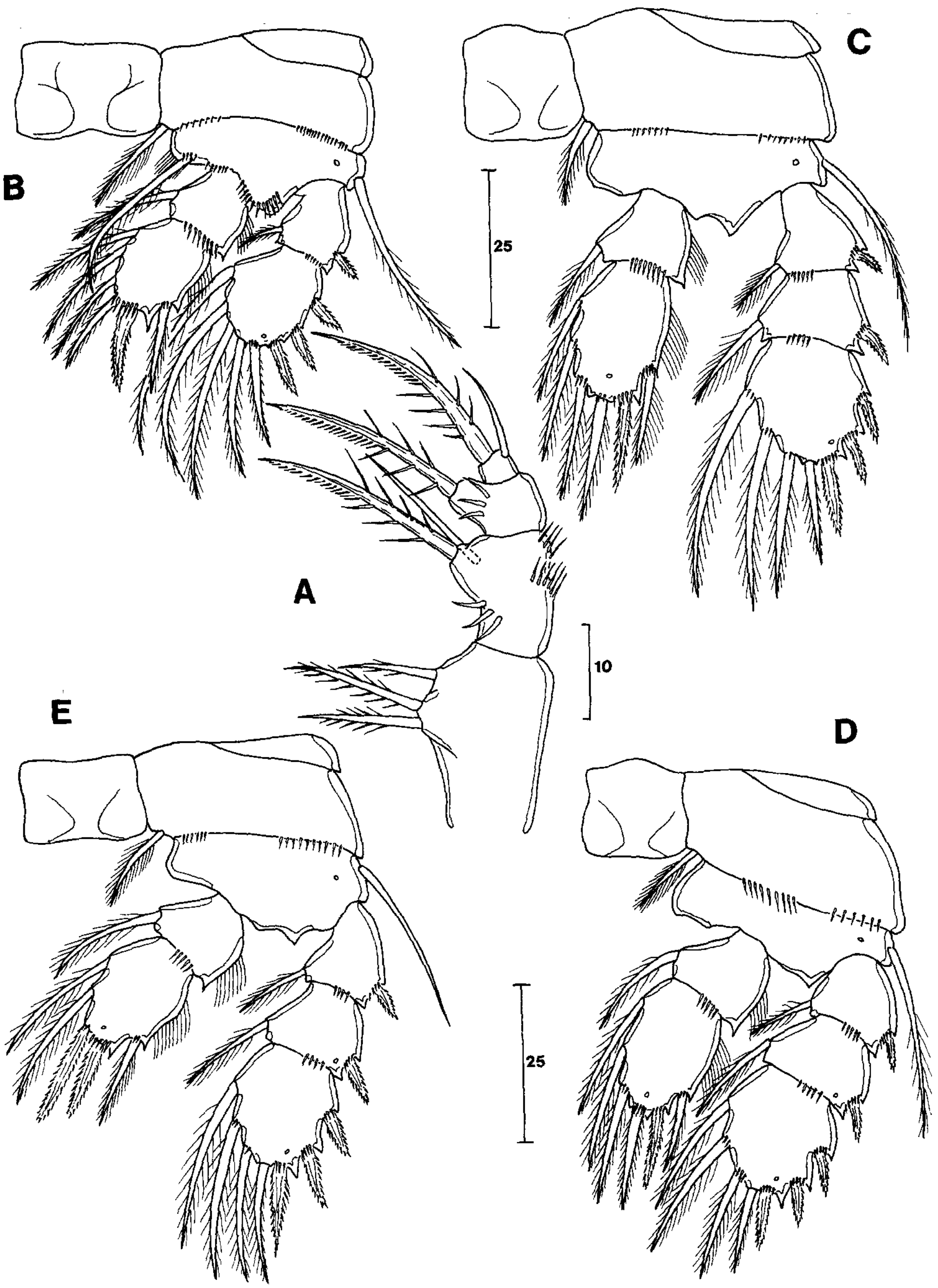

Fig. 3. Diacyclops biceri sp.nov. Adult female. A, Maxilliped, anterior view; B, Leg 1, anterior view; C, Leg 2, anterior view; D, Leg 3, anterior view; E, Leg 4, anterior view. All scales in μm.

6 + aesthetasc. Elements on anterior margins of segments 11 to 14 broad and flat, with striated surface and, typically, single pore.

All other appendages as in female except for sixth legs. Sixth legs (Fig. 4A) forming opercular plates closing off genital apertures and bearing 3 slender setae on small process.

Type material. Holotype ovigerous female, BMNH Reg. No. 1992.358; 18 female paratypes

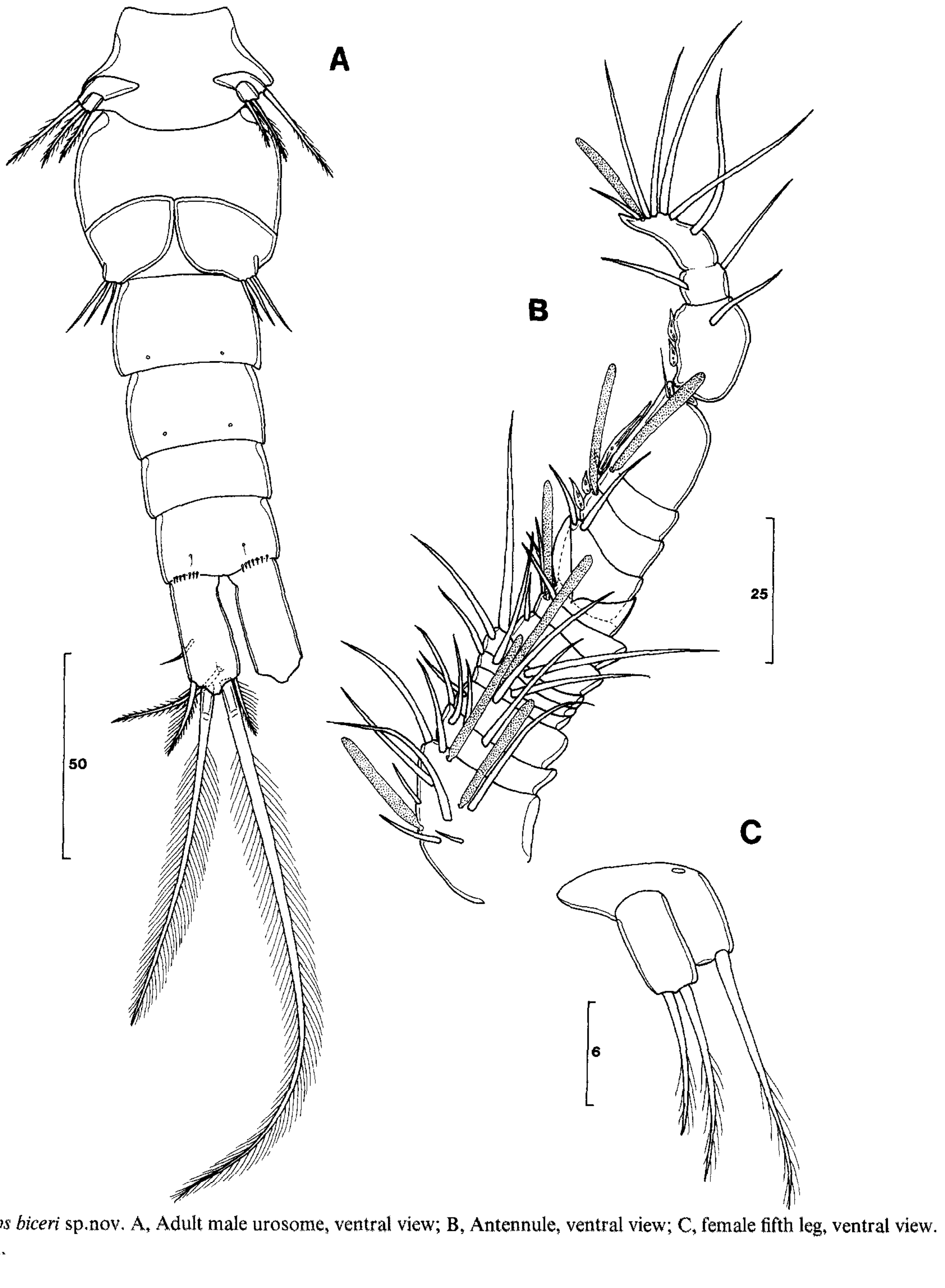

Fig. 4. Diacyclops biceri sp.nov. A, Adult male urosome, ventral view; B, Antennule, ventral view; C, female fifth leg, ventral view. All scales in μm.

(2 dissected) BMNH 1992.359-376 and 6 male paratypes (1 dissected) BMNH 1992.377-382. Collected from interstitial water on sandy beach at Buchta Peschanaya, Lake Baikal, Siberia.

Etymology. This species is named *biceri* after the newly established Baikal International Centre for Ecological Research, based at the Limnological Institute in Irkutsk.

Discussion

The new species can readily be placed in the subfamily Cyclopinae on the basis of the setation of the fifth legs. The segmentation of the fifth legs and the structure of the caudal rami indicate that the new species belongs in the *Acanthocyclops-Diacyclops* complex. The validity of the separation of *Acanthocyclops* and *Diacyclops* was questioned by Rylov (1948) and Mazepova (1978) in her monograph of the Baikalian cyclopoids recognised only *Acanthocyclops*· Dussart & Defaye (1985) accepted both as valid genera. There is clearly some overlap between these genera as currently diagnosed and the complex is in urgent need of revision. The new species conforms well to the diagnosis of *Diacyclops* in the segmentation of the first swimming legs and in the setation of the fifth legs. We, therefore, place the new species in *Diacyclops*, although we recognise that this placement may change after revision. The Baikalian species of *Acanthocyclops* and *Diacyclops* are listed in Table 1.

The new species differs from all known species of *Diacyclops* in the segmentation of the swimming legs. Several species of *Diacyclops* from Lake Baikal have 2-segmented rami on leg 1 and a 2-segmented endopod combined with a 3-segmented exopod on leg 2. For example, *Diacyclops spongicola* (Mazepova, 1961), a specialised associate of sponges of the genera *Baicalospongia* and *Lubomirskia*, has this segmentation pattern. However, the new species is unique in the possession of 2-segmented endopods and 3-segmented exopods on legs 3 and 4. All Baikalian species of *Acanthocyclops* and *Diacyclops* (see Table 1) have both rami 3segmented in legs 3 and 4. Another unusual character of the new species is the relatively slender body form, a character shared with *D. spongicola*.

In modern taxonomic accounts of cyclopid species there is often almost no description or illustration of the mouthparts (antennae to maxillipeds). Important characters may thus be overlooked. There are, for example, two unusual setation features in the mouthparts of the new species. The exopodal seta is absent from the antenna, and the apical segment of the maxilliped bears only 2 elements instead of the more usual 3. As pointed out by Pesce & Galassi (1985) the exopodal seta is often lost from the antenna in subterranean and benthic cyclopids. Reid (1992) also found the exopodal seta absent in *D. albus*

Table 1. Species of *Acanthocyclops* and *Diacyclops* reported from Lake Baikal. Nomenclature according to Dussart & Defaye (1985) showing names used by Mazepova (1978) in brachets, if different.

Acanthocyclops notabilis Mazepova 1950
Acanthocyclops profundus profundus Mazepova 1950
Acanthocyclops profundus tomilovi Mazepova 1978 +
Acanthocyclops rupestris Mazepova 1950
[= *Acanthocyclops rupestris rupestris* Mazepova 1950]
Acanthocyclops intermedius Mazepova 1952
Acanthocyclops signifer Mazepova 1952
[= *Acanthocyclops rupestris signifer* Mazepova 1952]
Acanthocyclops similis Flössner 1984
Diacyclops bicuspidatus (Claus 1857)
[= *Acanthocyclops bicuspidatus* (Claus 1857)]
Diacyclops bisetosus (Rehberg 1880)
[= *Acanthocyclops bisetosus* (Rehberg 1880)]
Diacyclops languidoides improcerus (Mazepova 1950)
[= *Acanthocyclops improcerus* Mazepova 1950)]
Diacyclops languidoides jasnitskii (Mazepova 1950)
[= *Acanthocyclops jasnitskii* Mazepova 1950)
Diacyclops languidoides moravicus Sterba 1956
[= *Acanthocyclops galbinus* Mazepova 1961]
**Diacyclops languidoides elegans* (Mazepova 1961)
[= *Acanthocyclops elegans* Mazepova 1961]
Diacyclops languidoides konstantini (Mazepova 1961)
[= *Acanthocyclops konstantini* Mazepova 1961]
Diacyclops arenosus (Mazepova 1950)
[= *Acanthocyclops arenosus* Mazepova 1950]
Diacyclops incolotaenia (Mazepova 1950)
[= *Acanthocyclops incolotaenia* Mazepova 1950]
**Diacyclops elegans* (Mazepova 1961)
[= *Acanthocyclops elegans* Mazepova 1961]
Diacyclops galbinus (Mazepova 1961)
[= *Acanthocyclops galbinus* Mazepova 1961]
Diacyclops spongicola (Mazepova 1961)
[= *Acanthocyclops spongicola* Mazepova 1961]
Diacyclops versutus (Mazepova 1961)
[= *Acanthocyclops versutus* Mazepova 1961]
Diacyclops talievi (Mazepova 1970)
[= *Acanthocyclops talievi* Mazepova 1970]
Diacyclops neglectus Flössner 1984

* *Acanthocyclops elegans* Mazepova 1961 is included twice in Dussart & Defaye (1985), as a species of *Diacyclops* and as a subspecies of *Diacyclops languidoides*.

\+ Not in Dussart & Defaye (1985).

Reid, a meiofaunal species from North America, but this species retains 3 setae on the apical segment of the maxilliped.

The interstitial habitat is not common in the Cyclopidae. The slender body form and relatively small swimming legs are obvious adaptations to this habitat. Another is the presence of a small secondary 'pseudosomite' separated off from the anterior end of the genital double somite in the female only. Huys & Boxshall (1991) reported similar modifications in the females of some interstitial harpacticoids and interstitial cyclopinid cyclopoids. This is the first report of such a feature in a freshwater copepod and the first in the family Cyclopidae. It can be interpreted as an adaptation to their interstitial habitat, allowing a greater range of urosomal movements.

The male antennules possess a well developed sheath on the segment homologous with XV of the ancestral copepod (cf. Huys & Boxshall, 1991). The setae on the segments around the distal geniculation are highly modified. They are flattened and are attached to the segment by a short stalk. The surface is ornamented with longitudinal ridges and there is typically a single pore. Similar setae were photographed by Huys & Boxshall (1991) in other cyclopid males. They presumably form part of a mate recognition system that operates either during copulation or precopulatory mate guarding.

The occurrence of copepods in the interstitial water close to the surface of the beach is interesting. This water is frozen to a depth in excess of 1 m during the Siberian winter. The interstitial copepods presumably migrate, either vertically downwards to remain below the frozen stratum, or obliquely downwards and out into sediment of the bed of the lake. They probably combine this overwinter migration with a diapause.

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