



A redescription of the rare eucyclopine copepod *Eucyclops productus* Kiefer, 1939 (Multicrustacea: Copepoda: Cyclopoida: Cyclopidae) and a key to *Eucyclops* subgenera and species of China and adjacent areas

RUIRUI DING^{1,2}, FEIZHOU CHEN^{1,3*} & VICTOR R. ALEKSEEV⁴

¹State Key Laboratory of Lake Science and Environment, Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, Nanjing, P. R. China, 210008.

²University of Chinese Academy of Sciences, Beijing, P. R. China, 100049.

✉ realdrr@163.com; <https://orcid.org/0000-0002-8261-5222>

³Sino-Danish Centre for Education and Research (SDC), University of Chinese Academy of Sciences, Beijing, P. R. China, 100190.

⁴Zoological Institute of Russian Academy of Sciences, St-Petersburg, Russia, 199034.

✉ alekseev@zin.ru; <https://orcid.org/0000-0002-1968-2609>

*Corresponding author: ✉ feizhch@niglas.ac.cn; <https://orcid.org/0000-0002-4349-0172>

Abstract

The rare freshwater copepod *Eucyclops* (*Speratocyclops*) *productus* Kiefer, 1939 from Lake Mandongco, Tibet Autonomous Region, China, is redescribed. This species was originally found and described from a pond south of Chushul village, and many of the details did not meet modern standards for describing the species. In this paper, the morphological characteristics of this species are described in detail and compared with other members of the subgenus *Speratocyclops* species recorded in China. The key features of the species are: 1) long caudal rami, 2) the coxal seta of the fourth pair of legs armed with long hairs in the proximal part and short denticles in the distal part, 3) the inner spine of the fifth pair of legs long and strong. An identification key to 22 species of *Eucyclops* known from China and adjacent areas is also provided.

Key words: Cyclopoida, *Eucyclops productus*, Tibet, China, taxonomy, morphology, zooplankton

Introduction

The genus *Eucyclops* Claus, 1893 (Cyclopidae: Eucyclopinae) is one of the most common and taxonomically challenging genera among the Cyclopidae (Dussart & Defaye 2006; Reid & Williamson 2009; Mercado-Salas *et al.* 2016; Alekseev 2019). At present, more than 100 species are distributed worldwide, which are divided into 9 subgenera according to classical morphological features and micro characteristics (Dussart & Defaye 2006; Alekseev 2019). *Eucyclops productus* Kiefer, 1939 belongs to the subgenus *Speratocyclops* Alekseev, 2019 which contains 8 other species as well: *E. (S.) speratus* (Lilljeborg, 1901), *E. (S.) arcanus* Alekseev, 1990; *E. (S.) biwensis* Ishida, 1998; *E. (S.) dumonti* Alekseev, 2000; *E. (S.) leschermoutouae* Alekseev & Defaye, 2004; *E. (S.) troposperatus* Alekseev, Haffner, Vaillant & Yusoff, 2013; *E. (S.) delongi* Alekseev, Abramova & Chaban, 2019; *E. (S.) azorensis* Defaye & Dussart, 1991 (Alekseev 2019; Hołyńska *et al.* 2021). This subgenus contains freshwater species, mostly found in the littoral zone, and most of them are distributed in east and southeast Asia, of which *E. (S.) leschermoutouae* inhabits wells in the Balearic Islands in Europe, *E. (S.) azorensis* was described from the Azores in Atlantic, while *E. (S.) speratus* is widespread in the Palearctic (Lee *et al.* 2005; Dussart & Defaye 2006; Alekseev 2019). *Eucyclops (S.) productus* has been rarely recorded since it was first found in Chushul, south of Lake Bangongco (formerly as Pangong Tso). Its morphology description lacked several necessary details for taxonomic purposes up to now (Kiefer 1939), while the type specimens were partly destroyed due to severe desiccation, and missing details could not be observed. This determined the need for additional description of this species from the type locality habitat.

During the lake survey in Tibetan Plateau, some specimens of *E. (S.) productus* were collected from Lake Mandongco, Tibet Autonomous Region (*terra typica*). In this paper, the morphological characteristics of the antenna,

mouth appendages, swimming legs, and caudal rami from specimens are redescribed in detail and compared with the holotype specimen and the features of the same subgenus species in China.

Materials and methods

Eucyclops (S.) productus was collected from Lake Mandongco (N 33° 30′–33° 34′, E 78° 48′–79° 01′, altitude of 4303 m), Tibet Autonomous Region on August 10th, 2018 (Fig. 1). The lake lies in a long valley that connects the Chushul Valley to the Rudok Valley. Lake Mandongco has an area of 61.6 km² with a catchment area of 1400.4 km². The average annual air temperature is -4.0–2.0 °C and average precipitation is 50–75 mm. At the sampling time, the water temperature was 13.2 °C, pH 9.31, dissolved oxygen concentration 6.28 mg/L, conductivity 5980 µS/cm, salinity 4.29 ‰, and transparency 7.3 m. Eight female and seven male adults were obtained. All specimens are preserved in 4% formaldehyde and deposited in the Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences.

The specimens were examined and dissected under a Carl Zeiss optical microscope and then observed and drew using a Carl Zeiss microscope after mounting on slides. Species identifications and morphological terminology follow Kiefer and Alekseev (Kiefer 1939; Alekseev 2019).

To confirm species identification, type specimens from the Kiefer collection, stored in the Museum of Natural History in Karlsruhe, were studied.

Abbreviations used as follows: A1: antennule; A2: antenna; P1–P4: the first–fourth swimming legs; P5–P6: reduced legs 5 and rudimentary legs 6; bsp: basipodite; exp: exopodite; enp: endopodite; s1: innermost caudal seta; s2: inner caudal seta; s3: outer caudal seta; s4: outermost caudal seta; L/W: length-to-width ratio. The nomenclature for micromorphological patterns (rows of spinules and setules) of the antennary basis and the coxopodite and intercoxal plate of the fourth swimming legs follows Alekseev (Alekseev, 2019).

Taxonomy

Subclass Copepoda Milne-Edwards, 1840

Order Cyclopiformes Starobogatov, 1994

Family Cyclopidae Rafinesque, 1815

Subfamily Eucyclopinæ Kiefer, 1927

Genus *Eucyclops* Claus, 1893

Subgenus *Speratocyclops* Alekseev, 2019

Eucyclops productus Kiefer, 1939 (Figs. 1–6; Table 1)

Eucyclops productus Kiefer, 1939: 141–143, fig 15a–e (female)

Type locality. — Chushul, India

Material examined. — Lake Mandongco. 8 females, 7 males; NIGLAS 20000101–113; 1 female and 1 male dissected and mounted on slides (NIG 20180001–0002); all specimens collected by F.Z. Chen.

Redescription. Female (Figs. 2–4). Body length (exclusive of caudal setae) 1200–1620 µm (n=8). Except for the orange genital double somite, other parts of the body grayish brown. Cephalothorax about 1.1 times longer than width, with the greatest width close to the posterior end (Fig. 2A). The length of the genital double somite slightly longer than the width, which is similar to the inverted trapezoid. Pediger V with a hair-like setae on lateral margins (Fig. 2D). Anal plate slightly convex. Posterior margin of anal somite with row of spinules.

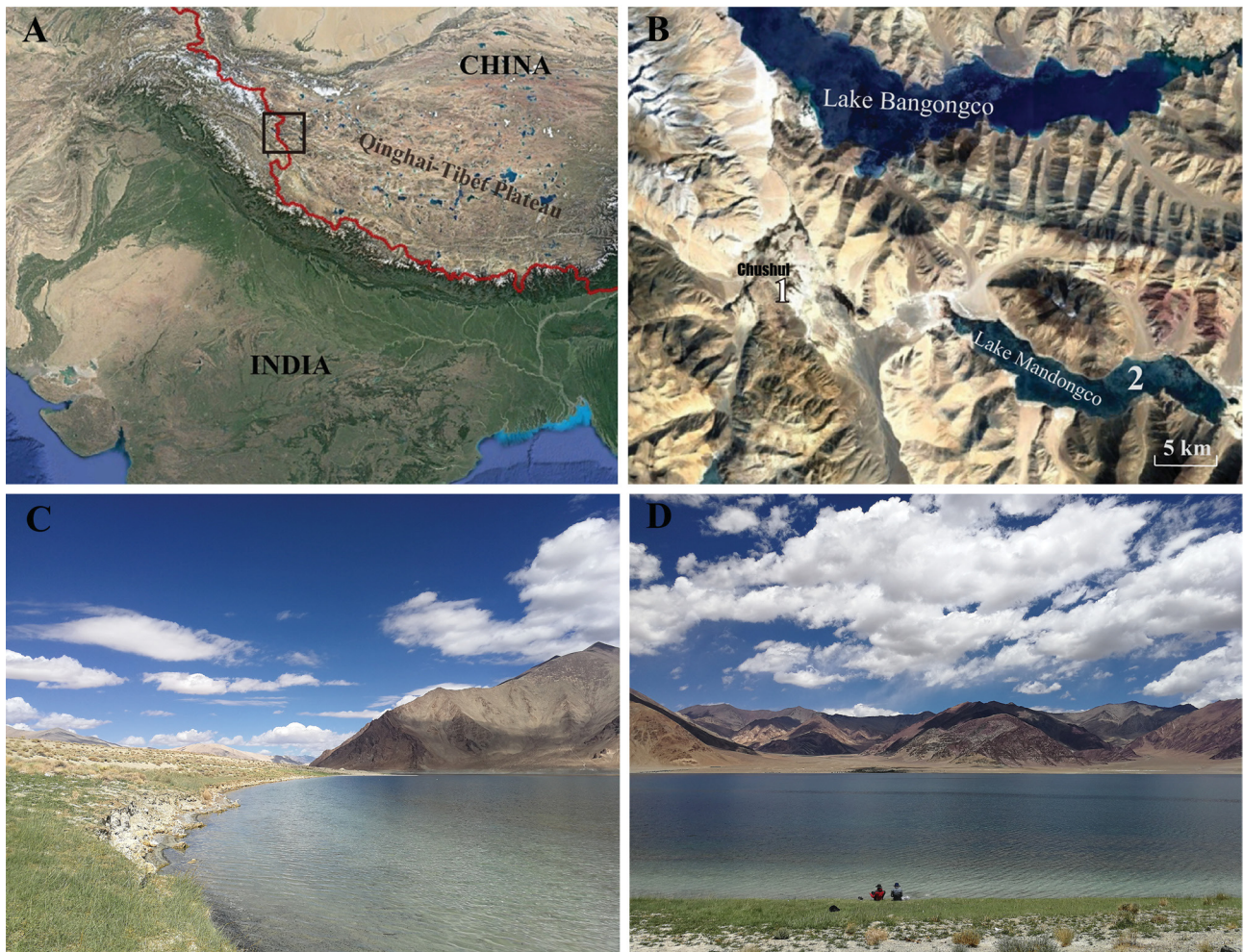


FIGURE 1. Records of *Eucyclops productus* Kiefer, 1939. A: recorded area; B: Type locality, pond in Chushul village (1) and new locality Lake Mandongco (2); C, D: photos of Lake Mandongco. (Maps modified from Google maps. Photos by Feizhou Chen.).

Caudal rami (Fig. 2C) slender and slightly divergent, 7–8 times longer than wide. Caudal rami bearing slightly reduced *serra* (row of spinules along lateral margin), extending along about two thirds of ramus length and six terminal setae at the distal part of the ramus, more or less plumose. Proportions of the length of the four distal setae: 1/4.23–5.43/7–7.79/1.12–1.33 (from s1 to s4). Dorsal caudal seta shorter, and innermost seta longer than outermost seta.

Antennule (Fig. 2B) 12–segmented, short, hardly reaching posterior border of cephalothorax, with a smooth/finely serrate hyaline membrane at three last segments. Setation of A1 segments beginning from the first: 8/4/2/6/4/2/2/3/2/2/3/7+1 (Arabic: seta, Roman numeral: aesthetasc). First segment of A1 with a row of long spinules.

A2 (Fig. 3A, C) 4–segmented (composed of basipodite and 3–segmented endopodite), setation of segments beginning from basipodite: 3/1/9/7. Frontal side ornamentation of A2 basipodite (Fig. 3B): a group of small spinules (groups N9) at the insertion of medial setae, a group of spinules (group N8) proximal to it, few spinules (group N7) at exopodal seta and three rows of spinules (groups N10, N11, N12) at the lateral margin. Caudal side ornamentation of A2 basipodite (Fig. 3D): consists of oblique proximal and longitudinal lateral groups of spinules (groups N3, N4, N5); hair–setules (groups N1, N2) absent at distal margin.

Mandible (Fig. 3F–G) short and small. Gnathobase of the mandible with 10 large blunt or pointed teeth. On the palp one small and two long setae with a row of spinules around them.

Maxilla (Fig. 3I) praecoxa bearing two long strong setae and short transverse row of spinules on the opposite margin. Maxilla setation as typical for *Eucyclops*.

Maxillule (Fig. 3H) biramous, praecoxa with seven strong spines and a short strong seta. Basal excite with seven differing length setae and a spine. Maxillulary palp smooth, not armed with spinules.

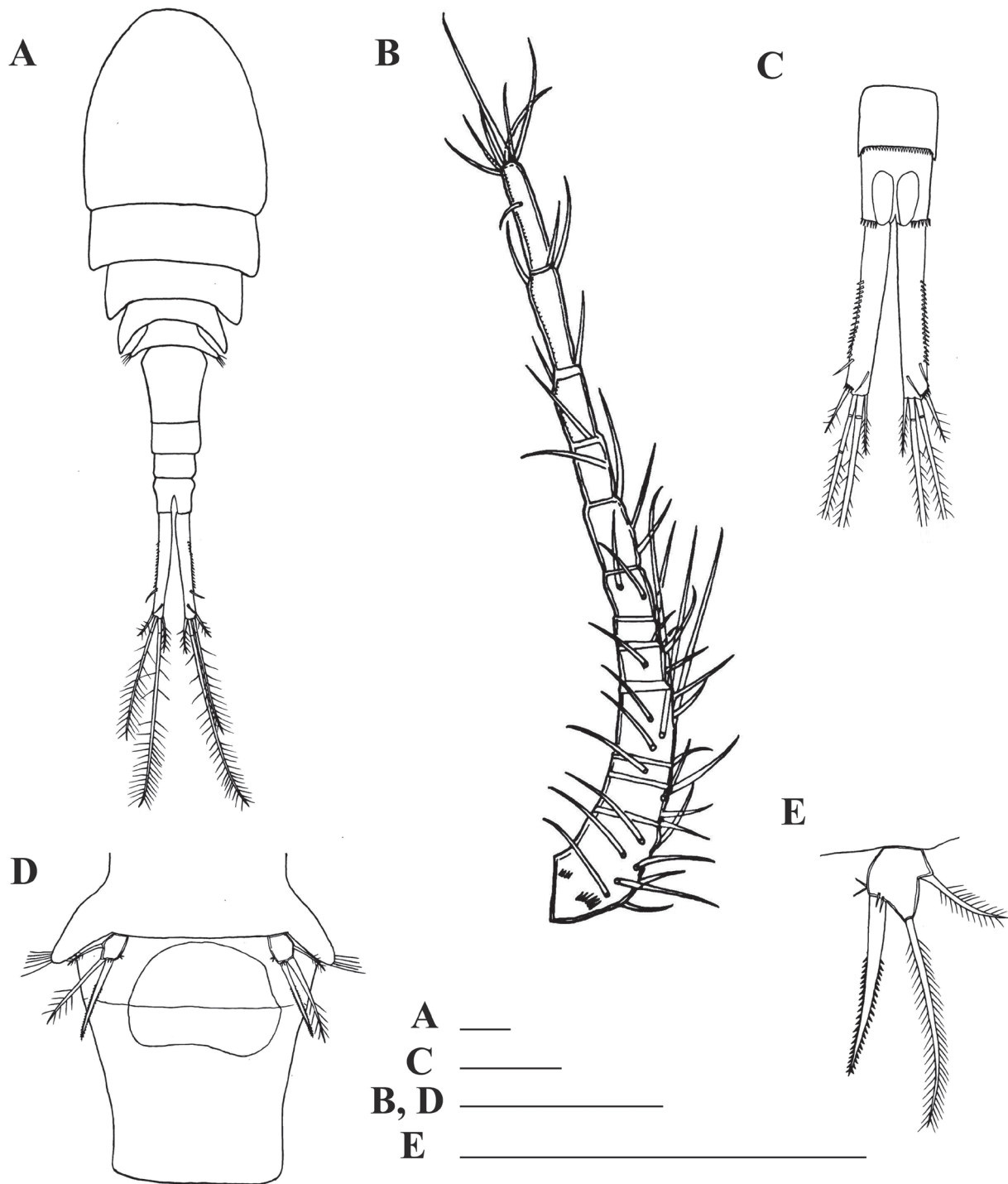


FIGURE 2. *Eucyclops productus* Kiefer, 1939, female. (A) habitus dorsally; (B) antennule; (C) caudal rami; (D) last segment of prosome with reduced leg 5 and genital double somite; (E) rudimentary leg 5. Scale bars: 0.2 mm.

Maxilliped (Fig. 3E) 4-segmented. Armament as typical for *Eucyclops*. Praecoxa with two strong setae in the middle part of the distal margin and a relatively small seta at the end of the same margin. Basis with a strong seta at the distal margin and a short spine at its surface with a group of short spinules at its base. The first segment of endopodite with a strong spine and a row of setules around the rudimentary rest of the last segment and the endopodite bearing a strong spine and two hairless setae.

Legs P1–P5 symmetrical. P1–P4 (Fig. 4) exo- and endopodites 3-segmented, exopodite spine formula 3/4/4/3. Distal segments of P1–P4 exopodites with five setae. Distal segments of P1–P3 endopodites with a spine and five setae.

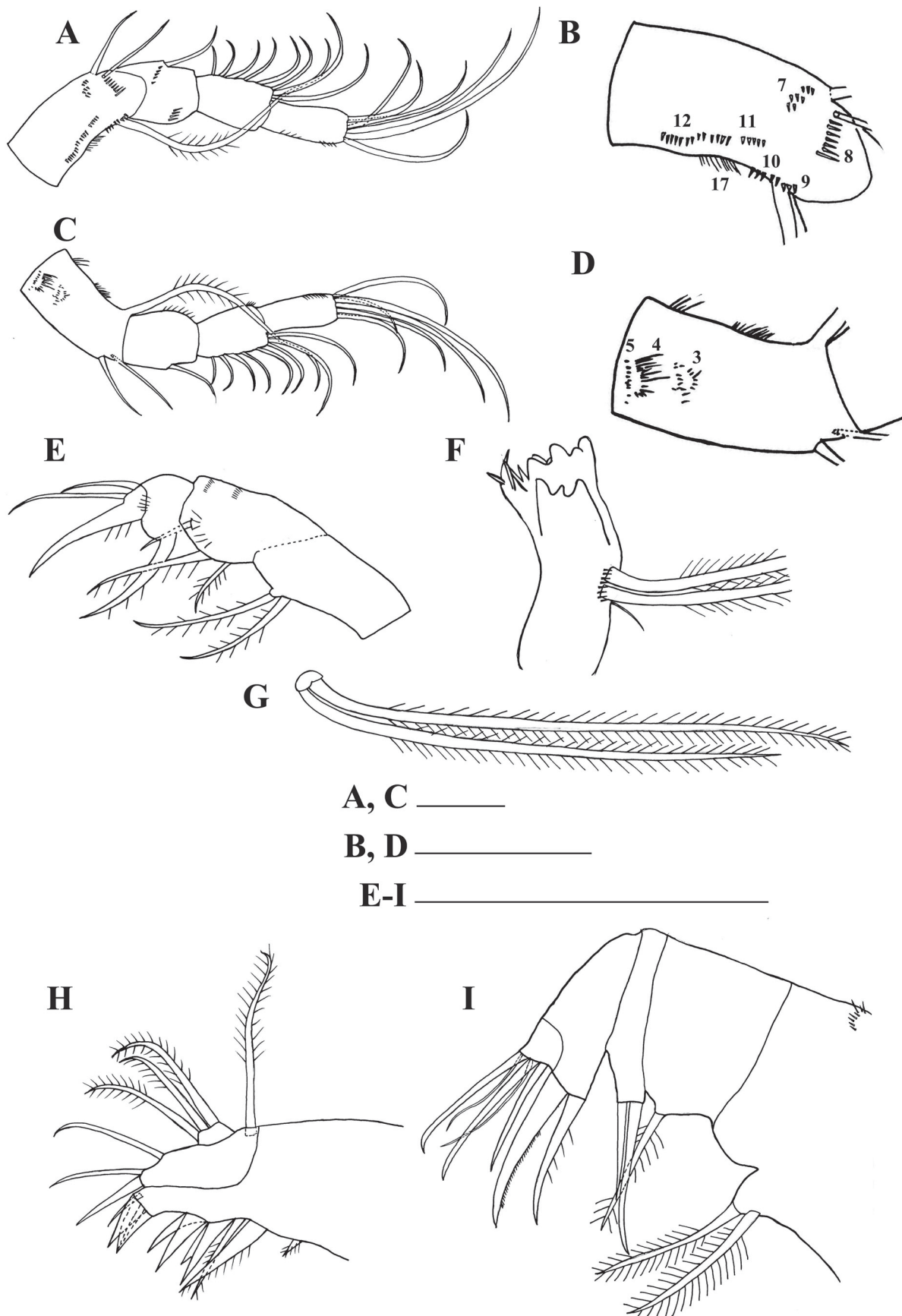


FIGURE 3. *Eucyclops productus* Kiefer, 1939, female: (A) antenna, frontal; (B) antenna basipodite, frontal; (C) antenna, caudal; (D) antenna basipodite, caudal; (E) maxilliped; (F–G) mandible; (H) maxillule; (I) maxilla. Scale bars: 0.2 mm.

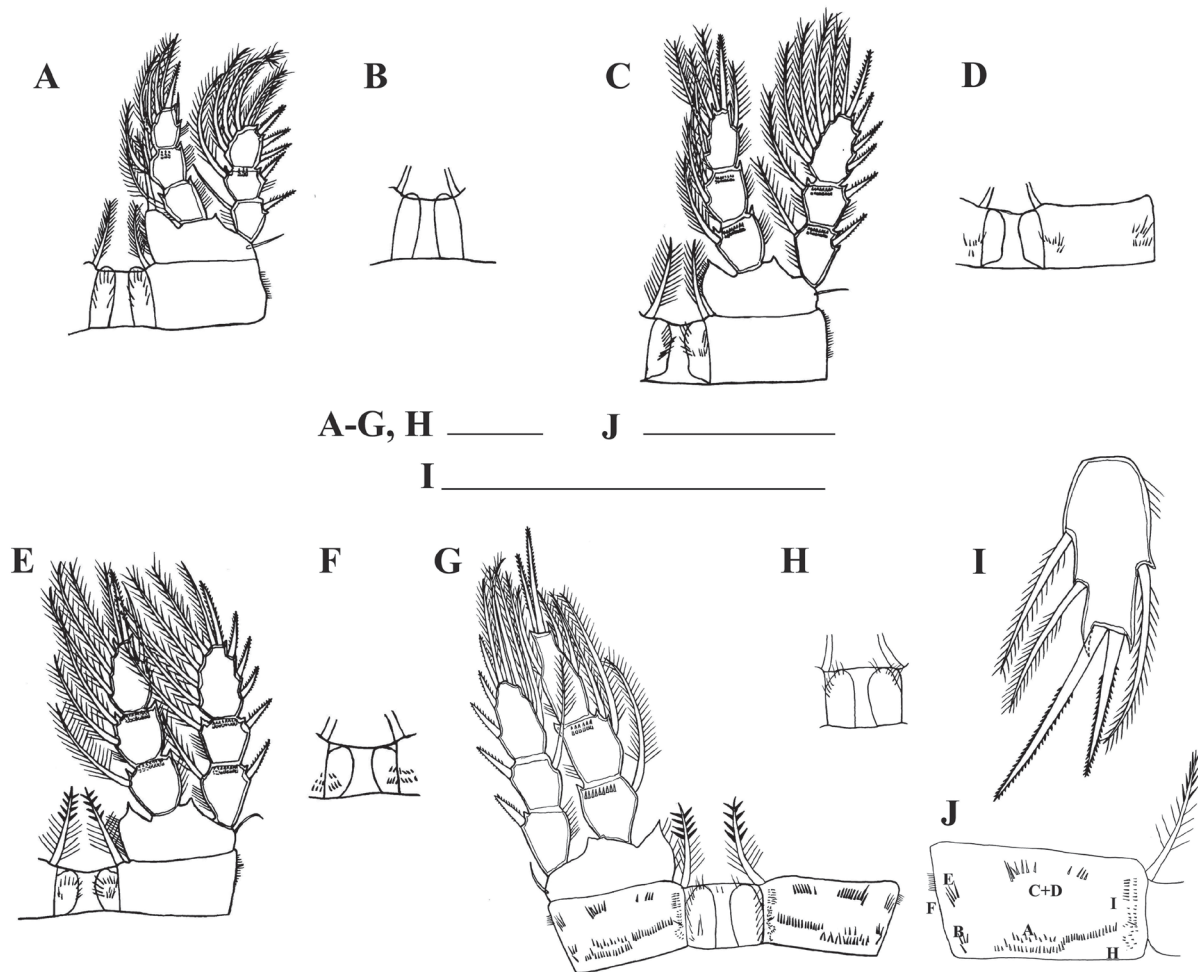


FIGURE 4. *Eucyclops productus* Kiefer, 1939, female: (A) leg 1, frontal; (B) leg 1 intercoxal plate, caudal; (C) leg 2, frontal; (D) leg 2 intercoxal plate and coxopodite, caudal; (E) leg 3, frontal; (F) leg 3 intercoxal plate, caudal; (G) leg 4, caudal; (H) leg 4 intercoxal plate, frontal; (I) leg 4 endopod; (J) leg 4 coxopodite and coxal seta, caudal. Scale bars: 0.2 mm.

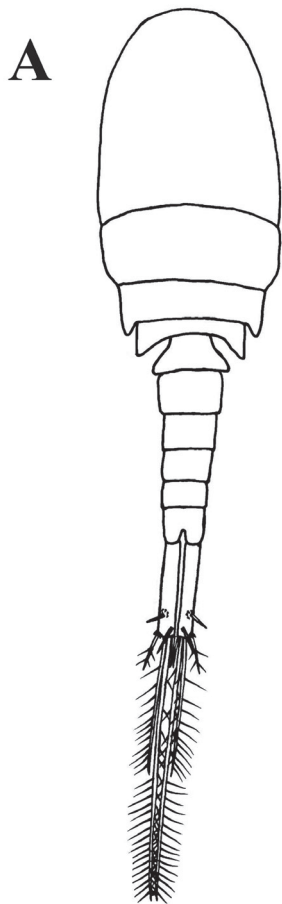
P1 intercoxal plate (Fig. 4A, B) frontally with rows of spinules on each side. Distal margin with two round projections. Coxopodite ornamented with a short row of hair–setules along lateral margin (group F). Coxal seta bearing dense hair–setae on both sides. Inner outgrowth of basipodite with long dense hair–setules. Spiniform inner seta of basipodite reaching middle of distal segment of endopodite.

P2 intercoxal plate (Fig. 4C, D) frontally with rows of spinules on each side. Coxopodite ornamented with two groups of spinules and a short row of hair–setules along lateral margin (group F). Coxal seta bearing dense hair–setae on both sides. Inner outgrowth of basipodite with dense hair–setules.

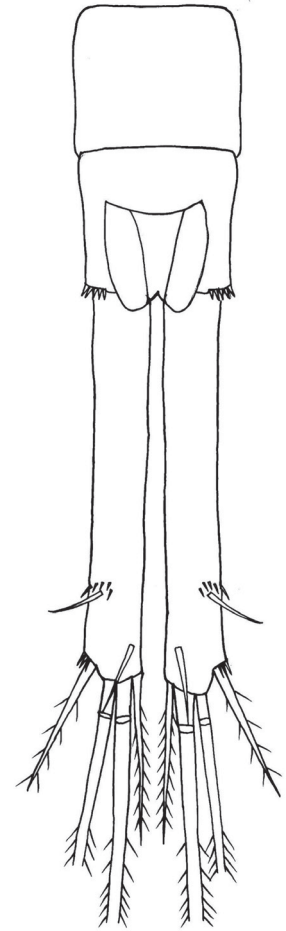
P3 intercoxal plate (Fig. 4E, F) frontally and caudally with rows of spinules on each side. Coxopodite ornamented with groups of spinules and a short row of hair–setules along lateral margin (group F). Coxal seta bearing long hairs proximally and short denticles distally. Inner outgrowth of basipodite with dense long hair–setules.

P4 intercoxal plate (Fig. 4G–H) frontally and caudally with rows of long spinules on each side (groups II, III), distal margin with rare hair–setules (group I). Coxopodite (Fig. 4G, J) ornamented with groups of spinules (groups A, B, C, D, E, H), a group of tiny spinules (group I) proximal to intercoxal plate and a short row of hair–setules along lateral margin (group F). Among them, groups C+D with a gap, group I small and dense, dot-like. Coxal seta (Fig. 4G, J) bearing long hairs proximally and short denticles distally. Inner outgrowth of basipodite with sparse hair–setules (Fig. 4G). P4enp3 (Fig. 4I) elongated, approximately 2.5 times as long as wide, bearing two strong distal spines; the inner spine approximately 1.4 times longer than the outer one.

P5 (Fig. 2E) 1–segmented, bearing of two setae and a spine. The inner spine long and strong with few fine hair–setules and small spinules at the base. The middle seta almost 2 times longer than outer one, and slightly longer than inner spine.



B

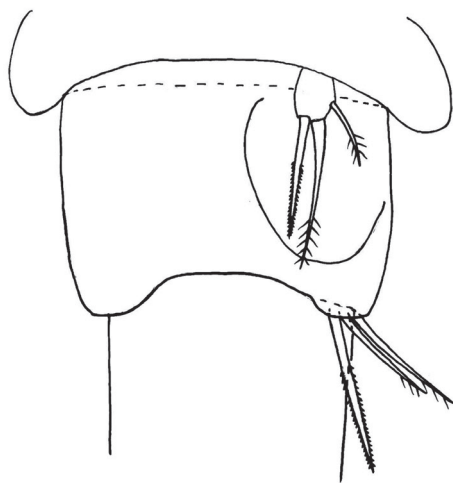


A —

B _____

C-E _____

C



D



E



FIGURE 5. *Eucyclops productus* Kiefer, 1939, male: (A) habitus, dorsally; (B) caudal rami, dorsally; (C) leg 5 and leg 6; (D) leg 4; (E) leg 4 intercoxal plate, frontal. Scale bars: 0.2 mm.

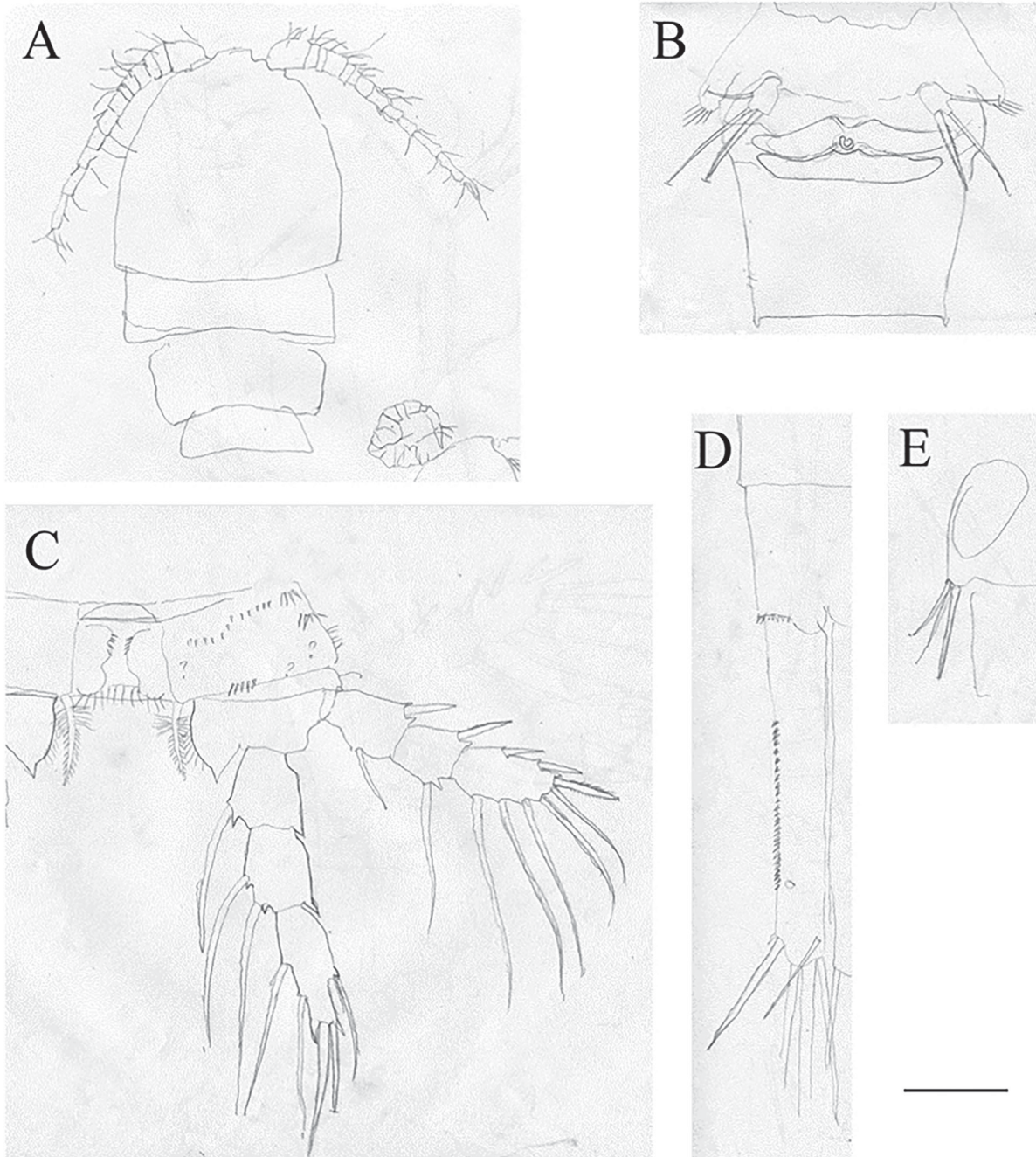


FIGURE 6. *Eucyclops productus* Kiefer, 1939. Drawings of Kiefer's type specimens (India, Chushul): (A) antennules, female and male (slide N2152); (B) genital double somite and reduced leg 5, female (slide N2718); (C) leg 4, female (slide N2152); (D) caudal ramus, female (slide N2151); (E) rudimentary leg 6, male (slide N2719). Scale bars: A: 0.2 mm; B-D: 0.05 mm.

Egg sacs bearing about 12–13 large eggs each.

Male (Fig. 5). Body length (exclusive of caudal setae) 1060–1180 μm ($n=7$). The body slenderer than in female. The body color same as in female. Cephalosome 1.1 times longer than wide (Fig. 5A). A1 14-segmented. Pediger V without lateral groups of setae. Caudal rami shorter than in female, without lateral *serra* (Fig. 5B). The characteristics of mouth appendages and P1–P5 similar to females. P4enp3 approximately 2.1 times as long as wide, and the inner spine 1.55 times as long as the outer one. Coxal setae of P4 same as female, armed with long hairs in proximal part and short denticles in distal part. Distal margin of P4 intercoxal plate with fewer hair-setules (Fig. 5E). P4 coxopodite ornamentation with merged groups C and D (Fig. 5D).

P6 (Fig. 5C) with two setae and a strong slightly longer spine, the length of spine 55–57 μm , almost reaching the distal border of the next somite. The length proportions from outer seta to inner spine: 1/0.94/1.22.

TABLE 1. Main morphological characteristics of subgenus *Eucyclops* (*Speratocyclops*) in China

	<i>Eucyclops productus</i>	<i>Eucyclops speratus</i>	<i>Eucyclops dumonti</i>	<i>Eucyclops arcanus</i>
Body length (♀)	1.20-1.62 mm (♀) 1.06-1.18 mm (♂)	1.00-1.40 mm (♀) 0.75-0.90 mm (♂)	0.93 mm (♀) 0.77 mm (♂)	1.00 mm (♀) 0.71 mm (♂)
Antennule (♀)	12-segmented, reaching the posterior of cephalothorax	12-segmented, reaching the posterior of cephalothorax	12-segmented, reaching the middle of cephalothorax	12-segmented, reaching the middle of Pediger 2
Caudal rami (♀)	Long, L: W=7-8:1	Long, L: W=5-8:1	Short, L: W=2.9:1	Short, L: W=3.5:1
P4 coxal seta (♀)	With long hairs in proximal part and short denticles in distal part	Homogenously covered with long hairs	Homogenously covered with long hairs	Homogenously covered with long hairs
P5 median seta: inner spine (♂)	1.1:1	1:1.8	1:1.5	2.3:1
P6 inner spine (♂)	1.39 times longer than the middle seta	Longer than the middle seta	2 times longer than the middle seta	2.2 times longer than middle seta

* ♀: female, ♂: male.

Discussion

Eucyclops (*S.*) *productus* was recorded only once, in a pond near Chushul village, south of Lake Bangongco (Kiefer 1939). According to Kiefer, it has very long caudal rami (L/W from 7.3 in male to 8.88 in female (Fig. 6D), being the reason, it was named “*productus*”). This time, we collected *E. (S.) productus* from Lake Mandongco, which is also located the south of Lake Bangongco on the Qinghai Tibet Plateau. This species is the first record in China. The original description provided not enough details considering taxonomically important today. But the details that were given by Kiefer (such as caudal rami length and proportions of caudal setae, appearance of *serra*, length of antennule and appearance of its hyaline membrane, distal margin of P4 intercoxal plate and coxal spine/seta, P5) (Fig. 6A-D), and comparing with type specimens allow us to attribute the specimens we found to this species.

According to Kiefer (Kiefer 1939), the ratios of female (Fig. 6D) and male caudal rami (L/W) were 8.88 and 7.3, respectively, caudal rami L/W of our specimens were 7–8 in female and 7 in male. Both the original (Fig. 6C) and current L/W ratios of P4:3 were nearly equal, close to 2.5. P6 spine for male in our specimen was about 55 µm, just between the original range of 54–57 µm (Fig. 6E).

To date, four species of subgenus *Speratocyclops* have been recorded in China: *E. (S.) arcanus*, *E. (S.) speratus*, *E. (S.) dumonti* and *E. (S.) productus* (Table 1). They could be separated by structure of caudal rami, inner spine of P5, P4 intercoxal plate, basipodite and coxal spine ornamentation.

Among these species, *E. (S.) speratus* is most similar with *E. (S.) productus* by its rather long caudal rami. But its P4 coxal spine/seta homogenously covered with long thin hairs and distal edge of P4 intercoxal plate bearing long dense hairs (Alekseev *et al.* 2006), while in *E. (S.) productus* this spine/seta heteronomously setulose.

E. (S.) dumonti also has a strong spine of P5 as *E. (S.) productus*, but its body smaller, caudal rami much shorter and inner outgrowth of P4 basipodite hairless (Alekseev 2000). P5 outer seta of *E. (S.) dumonti* is almost equal to P5 inner spine in length, while in *E. (S.) productus*, the spine is much longer than the outer seta.

E. (S.) arcanus has very short caudal rami (L/W about 3.5) (Alekseev 1990). Antennule of *E. (S.) arcanus* relatively long, reaching beyond the middle of Pediger 2, while in *E. (S.) productus*, it is short, hardly reaching the posterior margin of cephalothorax.

The groups of spinules of P4 intercoxal plate and coxopodite differ among species. Groups C+D spinules of *E. (S.) productus* is with gap, but not in the other three species. Group II of *E. (S.) dumonti* is small in size and extends to the middle of the intercoxal plate in a row, while in *E. (S.) productus*, it is long and arranged in an arc (Alekseev 2000). For *E. (S.) speratus*, groups A and H and group I of intercoxal plate are denser than *E. (S.) productus* (Alekseev 2019). Groups F and groups I+II are sparser in *E. (S.) arcanus* than *E. (S.) productus* (Alekseev 1990).

Several other *Eucyclops* species have similar long slender caudal rami and smooth hyaline membrane in the

last segments of antennule as in *E. (S.) productus*: *Eucyclops (E.) elegans* (Herrick, 1884) (Americas), *Eucyclops (Sar.) porrectus* Kiefer, 1932 (Lake Ohrid, Southeastern Europe). But *E. elegans* has long distal setules on A2 basipodite (groups N1, N2), therefore it belongs to different subgenera *Eucyclops (Eucyclops)* (Mercado-Salas & Suárez-Morales 2014; Alekseev 2019). *E. porrectus* P5 armed with short and thin inner spine; therefore, it belongs to subgenera *Eucyclops (Sarsicyclops)* (Kiefer 1932; Alekseev 2019).

Previous studies have showed that the most of *Eucyclops* live in the littoral zone with aquatic macrophytes (Monchenko 1974; Dussart 1969). In contrast, *E. (S.) productus* inhabits pelagic zone of this alpine rift lake. Most of *Eucyclops* also belongs to freshwater fauna, only few species were described from brackish water such as *E. (M.) maritimus*, Alekseev et Monchenko, 1991. In our study, Lake Mandongco was also brackish water body. Many *Eucyclops* species were found in eutrophic lakes, when *E. (S.) productus* inhabits typical oligotrophic one (Monchenko 1974; Lee *et al.* 2005).

Key to *Eucyclops* subgenera and species of China and adjacent areas

The key includes also subgenera still not found in this area but possible after more profound faunistic research.

1. Antennule 11-segmented **Subgenus *Mrazekicyclops***
(Not found in this area but possible in underground water)
- Antennule 12-segmented 2
2. Caudal rami with denticles on dorsal surface or hair-setae at inner margin **Subgenus *Cilioicyclops***
E. (C.) permixtus Kiefer, 1928 [Kangra Valley, Western Himalayas, India]
- Caudal rami without hairs on inner margin or denticles on dorsal surface 3
3. Caudal rami very short ($L/W < 2.7$) **Subgenus *Breviramocyclops***
(Not found in this area but possible in underground water)
- Caudal rami longer ($L/W > 2.7$, usually more than 3) 4
4. Distal setae of P4enp3 long, extending above tips of nearest spines **Subgenus *Subterrocyclops* (5)**
– Distal setae of P4enp3 short, usually shorter than nearest spine or sometime only outer seta can reach distal end of adjacent spine, but never longer than it 7
5. Caudal rami with much reduced *serra*, there are only 3–4 spinules above lateral set
..... *E. (Sub.) chivahensis* Lindberg, 1960 [Lake Shiva, Badakhshan Province, Afghanistan]
- Caudal rami with developed *serra* 6
6. Caudal rami with *serra* of small equal spinules; L/W about 4. P4enp3 distal spines not less than segment length. Female body size without caudal setae more than 1 mm *E. (Sub.) nagasaki* Ueno, 1934 [Cave, Japan]
- Distal spinules of caudal rami *serra* noticeably larger than proximal ones; L/W ratio of caudal rami about 3. P4enp3 distal spines noticeably shorter than segment length. Female body size without caudal setae less than 1 mm
..... *E. (Sub.) bryophilus* Lindberg, 1950 [moss near the waterfall, Shillong, Assam, India]
7. Caudal rami smooth with only few spinules above lateral seta **Subgenus *Macrurocyclops* (8)**
- Caudal rami with more or less developed *serra* extending along outer edge 9
8. Caudal rami very long, L/W 8–10. Caudal dorsal seta shorter than outermost seta
..... *E. (M.) macrurus* (Sars G.O., 1863) [Palearctic]
- Caudal rami much shorter, L/W about 5. Caudal dorsal seta longer than outermost seta
..... *E. (M.) defectus* Lindberg, 1937 [Pachmarhi, Central India]
9. Leg 5 with very small inner spine shorter than leg segment **Subgenus *Sarsicyclops***
[Not found in this area but possible in underground water]
- Leg 5 with larger inner spine longer than leg segment 10
10. Antennule with denticulate hyaline membrane at distal segments (10th and/or 11th and/or 12th)
..... **Subgenus *Denticyclops* (11)**
- Antennule with smooth/finely-serrated hyaline membrane or without it 15
11. The 10th and 11th segments of antennule with denticulate hyaline membrane, the 12th segment with smooth hyaline membrane *E. (D.) taiwanensis* Sukhikh, Alekseev, 2015 [Abvil Lake, Taiwan Province, China]
- All three distal segments of antennule with denticulate hyaline membrane 12
12. Caudal rami long, L/W 5.5 and more 13
- Caudal rami shorter, L/W less than 5.5. Spines of swimming legs wide, conspicuously spatulate 14
13. Hyaline membrane of the 12th segment of antennule with small denticles of the same size
..... *E. (D.) macruroides* (Lilljeborg, 1901) [Palearctic]
- Proximal part of hyaline membrane of the 12th segment of antennule with 8–12 large denticles, distal part of the membrane with much smaller denticles *E. (D.) denticulatus* (Graeter, 1903) [Palearctic]
14. Distal segments of antennule with hyaline membrane reduced to tiny separate teeth (sometimes visible only as small dots). Caudal rami with lateral *serra* of spinules significantly increasing distally. Innermost caudal seta usually bare, sometimes with rare hairs. Inner spine of P5 short, nearly equal to segment length; this spine thin, not more than 2 times wider than adjacent setae *E. (D.) euacanthus* (Sars G.O., 1909) [Africa, Asia, Australia]

- Distal segments of antennule with wide serrated hyaline membrane. Caudal rami with lateral *serra* of small spinules. Innermost caudal seta densely plumose. Inner spine of P5 noticeably longer than segment; this spine very thick, 3–4 times wider than adjacent setae *E. (D.) microdenticulatus* Lindberg, 1940 [Small ponds and streams, Gujarat, Maharashtra, Tamil Nadu, South West India]
- 15. Antenna basipodite with hair–setae near distal border (groups N1, N2) **Subgenus *Eucyclops* (16)**
- Antenna basipodite without groups N1, N2 of hair–setae **Subgenus *Speratocyclops* (17)**
- 16. P4 coxal spine homogenously plumose on both sides *Eucyclops (E.) agiloides* (Sars G.O., 1909) *s. lat.* [Africa, Asia]
- P4 coxal spine inner margin with continuous hairs, while outer margin with “gap” (hairs/denticles missing at the middle of margin) *Eucyclops (E.) serrulatus* (Fischer, 1851) *s. lat.* [Palearctic]
- 17. In caudal rami innermost seta shorter than outermost seta *E. (S.) leschermoutouae* Alekseev et Defaye, 2004 [well in Balearic Islands, Europe]
- Innermost caudal seta longer than or subequal to outermost seta **18**
- 18. Caudal rami long, L/W > 5. **19**
- Caudal rami shorter, L/W < 5. **20**
- 19. Inner spine of leg 5 very strong, knife-like, L/W > 6. **19**
- Inner spine of leg 5 weak, seta-like, L/W about 5 *E. (S.) biwensis* Ishida, 1998 [Lake Biwa, Japan]
- 20. Caudal rami L/W 6–8. P4 coxal spine homogenously covered with long thin hairs; P4 intercoxal plate with long dense hairs on distal edge. *E. (S.) speratus* (Lilljeborg, 1901) [Palearctic]
- Caudal rami L/W > 8. P4 coxal spine with short denticles distally and long hairs proximally; P4 intercoxal plate with few rare hairs on distal edge *E. (S.) productus* Kiefer, 1939 [North India, Western China]
- 21. Inner outgrowth of P4 basipodite hairless *E. (S.) dumonti* Alekseev, 2000 [Eastern Siberia, Mongolia, China, Thailand]
- Inner outgrowth of P4 basipodite with hairs **22**
- 22. Caudal rami L/W < 4. Innermost caudal seta subequal to outermost seta (1.1–1.2: 1) *E. (S.) arcanus* Alekseev, 1990 [Eastern Siberia, Mongolia, Northern China]
- Caudal rami longer, L/W > 4.2. Innermost caudal seta noticeably longer than outermost seta (1.4–1.8:1) **23**
- 23. P4 intercoxal plate with hairless distal margin. *E. (S.) troposperatus* Alekseev et Yusoff, 2013 [City ponds in Dumen, Sumatra, Indonesia]
- P4 intercoxal plate with setules at its distal margin **24**
- 24. P4 intercoxal plate with long-hair setules at its distal margin *E. (S.) azonrensis* Defaye & Dussart, 1991 [Azores, Madeira, North Africa]
- P4 intercoxal plate with short stiff setules at its distal margin. *E. (S.) delongi* Alekseev, Abramova, Chaban, 2019 [Eastern Siberia, China?]

Acknowledgements

We thank Li Yun, Gao Yiming for kind help with material collection, Wang Qianhong for modifying the map and anonymous referees for commenting on the manuscript. This work was supported by the National Natural Science Foundation of China (31870448), the Investigation of Basic Science and Technology Resources of China (2017FY100300) and the Second Tibetan Plateau Scientific Expedition and Research (2019QZKK0202).

References

- Alekseev, V.R. & Defaye, D. (2004) *Eucyclops leschermoutouae* sp. n. from Majorca, Balearic Islands (Crustacea, Copepoda: Cyclopidae). *Zoosystematica Rossica*, 12 (2), 163–169.
<https://doi.org/10.31610/zsr/2003.12.2.163>
- Alekseev, V.R. & Chaban, O.A. (2021) New records of continental cyclopids (Crustacea: Copepoda: Cyclopiformes) from Eastern Siberia and Russian Far East. *Arthropoda Selecta*, 30 (4), 503–520.
<https://doi.org/10.15298/arthsel.30.4.06>
- Alekseev, V.R. (1990) *Eucyclops arcanus* sp. n. (Copepoda, Cyclopoida) iz vodoemov pribakal’ya i Bol’shezemel’sko tundry. *Eucyclops arcanus* sp. n. (Copepoda, Cyclopoida) from waterbodies of Bolshezemel’skaya tundra and Prebaikalia. *Zoologicheskii Zhurnal*, 69 (1), 135–139.
- Alekseev, V.R. (2000) *Eucyclops dumonti* sp. nov. from Central Mongolia. *Hydrobiologia*, 441, 63–71.
<https://doi.org/10.1023/A:1017592005551>
- Alekseev, V.R. (2019) Revision of the genus *Eucyclops* (Claus, 1893) and subfamily Eucyclopininae of the world fauna. *Arthropoda Selecta*, 28 (4), 490–514.
<https://doi.org/10.15298/arthsel.28.4.03>
- Alekseev, V.R., Dumont, H.J., Pensaert, J., Baribwegure, D. & Vanfleteren, J.R. (2006) A redescription of *Eucyclops serrulatus* (Fischer, 1851) (Crustacea: Copepoda: Cyclopoida) and some related taxa, with a phylogeny of the *E. serrulatus*-group.

- Zoologica Scripta*, 35 (2), 123–147.
<https://doi.org/10.1111/j.1463-6409.2006.00223.x>
- Dussart, B.H. & Defaye, D. (2006) *World directory of Crustacea Copepoda of inland waters. II – Cyclopiformes*. Backhuys Publishers, Leiden, 354 pp.
- Dussart, B.H. (1969) *Les Copépodes des eaux continentales d'Europe occidentale. Tome II: Cyclopoïdes et Biologie*. N. Boubée et Cie, Paris, 292 pp.
- Einsle, U. (1985) A further criterion for the identification of species in the genus *Cyclops* s. str. (Copepoda, Cyclopoida). *Crustaceana*, 49, 299–309.
<https://doi.org/10.1163/156854085X00611>
- Hołyńska, M., Sługocki, L., Ghaouaci, S. & Amarouayache, M. (2021) Taxonomic status of Macaronesian *Eucyclops agiloides azorensis* (Arthropoda: Crustacea: Copepoda) revisited – morphology suggests a Palearctic origin. *European Journal of Taxonomy*, 750, 1–28.
<https://doi.org/10.5852/ejt.2021.750.1357>
- Kiefer, F. (1932) Neue Süßwassercopepoden aus Jugoslawien. I. Cyclopiden. *Zoologischer Anzeiger*, 101 (1–2), 49–60.
- Kiefer, F. (1939) Scientific Results of the Yale North India Expedition, Biological Report No.19, In: Kiefer, F. (Ed), *Memoirs of the Indian Museum*. Manager of Publications, Delhi, pp. 83–203.
- Lee, J.M., Min, G.S. & Chang, C.Y. (2005) *Eucyclops serrulatus* species group (Copepoda, Cyclopoida, Cyclopidae) from South Korea. *Korean Journal of Systematic Zoology*, 21, 137–156.
- Mercado-Salas, N.F. & Suárez-Morales, E. (2014) Morphological variation of *Eucyclops elegans* (Herrick, 1884) (Copepoda: Cyclopoida) in the Americas and comments on records of *Eucyclops conrowae* Reid, 1992. *Journal of Natural History*, 48 (33–34), 2007–2026.
<https://doi.org/10.1080/00222933.2014.897766>
- Mercado-Salas, N.F., Suárez-Morales, E. & Silva-Briano M. (2016) Taxonomic revision of the Mexican *Eucyclops* (Copepoda: Cyclopoida) with comments on the biogeography of the genus. *Journal of Natural History*, 50 (1–2), 25–147.
<https://doi.org/10.1080/00222933.2015.1061715>
- Monchenko, V.I. (1974) *Shchelepnoroti tsiklopodiny, tsiklopi (Cyclopidae)*. *Fauna Ukrainy*. Vidavnistvo Naukova Dumka, Kiev, 1–452 pp.
- Reid, J.W. & Williamson, C.E. (2009) Copepoda. In Thorp, J.H. & Covich, A.P. (Eds.), *Ecology and Classification of North American Freshwater Invertebrates (Third Edition)*. Academic Press, New York, pp. 829–899.
<https://doi.org/10.1016/B978-0-12-374855-3.00021-2>