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New data on the Western Palearctic distribution of *Eucyclops roseus* (Copepoda: Cyclopidae), with notes on its taxonomic relationships

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Abstract. *Eucyclops roseus* Ishida, 1997, a freshwater cyclopoid copepod recorded mainly in the warm temperate and dry regions of Asia and Eastern Africa, has so far been known to occur only in a few isolated localities in Europe and is considered to be an alien species in the continent. We herein present several new records of *E. roseus* in Ukraine and add some new occurrence data from Uzbekistan, Romania, and Hungary, where this species has been reported for the first time. *Eucyclops roseus* might have been misidentified in Europe in the past. Therefore, we provide a short morphological description with new data on morphometric variability based on the populations studied here. Light microscope photographs illustrate the diagnostic morphological characters. The morphological features distinguishing *E. roseus* from its close relatives (e.g., *E. serrulatus*) are discussed. The geographic distribution and habitat information suggest that the Black Sea basin is part of the native species range. Whether this region was relatively recently colonized or part of the historical distribution area requires verification from museum collections of *Eucyclops*, geographically wide-scale and long-term field collections, and population genetics studies on the genetic signatures of putative range shift.

Keywords: Black Sea drainage basin, Central Asia, Crustacea, alien species, human-modified water bodies.

Introduction

Eucyclops (~120 subspecies and species) live in various habitats, including standing and running, surface and subterranean, and fresh to hypersaline waters (Galassi 2001, Anufriieva et al. 2014, Alekseev 2019). The genus occurs worldwide and has diverse fauna in tropical and temperate/cold zones (Dussart & Defaye 2006, Alekseev & Defaye 2011, Hołyńska 2011). Recent studies conducted mainly in the Palearctic region and Mexico have greatly improved our knowledge about the diagnostic value of the morphological characters and biogeography of the genus (Ishida 2002, Alekseev et al. 2006, Chang 2009, Alekseev & Defaye 2011, Gutiérrez et al. 2013, Mercado-Salas et al. 2016). The taxonomic history of *E. roseus* is a good example of the rapid changes we currently experience in *Eucyclops* systematics.

Ishida (1997) originally described *E. roseus* from Okinawa Island (Japan, Ryukyus). In that same paper, he noted the synonymies of some Japanese records of *E. serrulatus* (Fischer 1851) and *E. speratus* (Lilljeborg 1901) with *E. roseus* and reported the occurrence of the latter species in Kyushu, Honshu and Hokkaido islands in Japan, Russian Far East (Primorsky Krai) and Northern Germany (Lower Saxony). Ishida (1997) assumed a broad geographic range in *E. roseus,* which subsequent publications have confirmed. The species has been found in Korea (Lee et al. 2005, Chang 2009), China (Xinjiang-Uygur Autonomous region) (Chertoprud et al. 2017), Russia (Siberia: Yakutia) (Hołyńska et al. 2021), South Iraq (Anufriieva et al. 2014), Ukraine (Crimea and Luhansk) (Anufriieva et al. 2014, Anufriieva & Shadrin 2016, Gaponova & Hołyńska 2019), Sudan (Idris & Mohamed 2015), and in Kenya (Lake Victoria and Lake Naivasha) (Ishida 1998).

In a global overview of the *Eucyclops serrulatus* group, Alekseev & Defaye (2011) changed the taxonomic rank of *E. roseus* from species to subspecies, recognizing *E. roseus* as a taxon subordinate to *E. agiloides* (G. O. Sars, 1909) described initially from Eastern Africa (Lake Victoria and Tanganyika) (Sars 1909). However, the limited information on the nominotypical subspecies' morphology and geographic distribution renders this taxonomic decision problematic (see Anufriieva et al. 2014). Hołyńska et al. (2021) redescribed *E. agiloides* s. str. and reinstated the species rank for *E. roseus*.

Insufficient knowledge of the native range limits hampers the interpretation of the occurrence records outside the known distributional area. Applying this to *E. roseus*, isolated occurrences of the species in the Black Sea basin can be explained by different processes, such as: i. current introduction by humans, or ii. long-distance dispersal by birds; iii. or recent range extension driven by climate change; or iv. the species is a native yet previously unnoticed component of the European fauna. Different processes may have other implications for nature conservation and planning. Current range extension (Anufriieva et al. 2014) versus long-distance dispersal by birds (Anufriieva & Shadrin 2016) were assumed to yield the insular distribution pattern of *E. roseus* in Ukraine. We herein report numerous new occurrence records of *E. roseus* in Ukraine and the neighboring countries, document the diagnostic morphological characters in the populations examined, and discuss the distributional pattern and habitat preferences of the species in the world and the region under study. Faunistic studies supported by up-to-date taxonomy may provide essential distributional data on the species range shifts caused by climate warming in Eastern Europe (The Sixth National Communication of Ukraine on climate change, 2013; United Nations Climate Change: Seventh National Communications, 2017–2018).

Material and Methods

Samples were collected from various types of freshwater bodies (rivers, ponds, pools) in the basins of rivers that belong to the Black

Sea basin on the territory of Ukraine, Romania, and Hungary. Detailed collection information is provided in the species description. We also examined historical material of *Eucyclops* collected by the late V. I. Monchenko in Ukraine and Uzbekistan and deposited in the Schmalhausen Institute of Zoology NAS of Ukraine.

Adult females and males were fully dissected under a stereomicroscope (Ulab XY-B2T and Olympus SZ11) and mounted in glycerine. The specimens were measured, and the diagnostic characters were verified using Olympus BX51 and Bresser BioScience compound microscopes. The widths of the third endopodal segment of leg 4, the genital double-somite, and the cephalothorax were measured across their widest parts. Photos were taken with a Canon IOS 5D Mark II camera attached to an Olympus BX51 microscope (IEE) and Leica DM5000 B Microscope (MIZ). Helicon Focus 5.0 software was applied for focus stacking.

Microsoft Encarta World Atlas 2001 was used to illustrate the geographic distribution of *E. roseus*.

Abbreviations used in the text:
Morphological abbreviations:
Caudal seta II – anterolateral
Caudal seta III – posterolateral
Caudal seta IV – outer terminal
Caudal seta V – inner terminal
Caudal seta VI – terminal accessory
Caudal seta VII – dorsal
enp 1–3 – first to third endopodal segment
exp 1–3 – first to third exopodal segment
P1–P4 – first to fourth swimming legs
Institutional acronyms:
IEE − Institute for Evolutionary Ecology NAS of Ukraine, Kyiv
IZAN – I.I. Schmalhausen Institute of Zoology NAS of Ukraine, Vladyslav I. Monchenko Collection, Kyiv
MIZ – Museum and Institute of Zoology PAS, Warsaw

Results

Order Cyclopoida Burmeister, 1835
Family Cyclopidae Rafinesque, 1815

Eucyclops roseus **Ishida, 1997**
Figs 1−4

Major synonymies

Eucyclops roseus Ishida, 1997: 350−354, figs 1−3.

Eucyclops roseus – Ishida 1998: 24.—Ishida 2002: 47−48, fig.12.—Lee et al. 2005: 139−143, figs 1−3.—Chang 2009: 394−397, 619−620, figs 208−209.—Anufriieva et al. 2014: 114−117, figs 2−3.—Idris & Mohammed 2015: fig. 14.—Anufriieva & Shadrin 2016: 282−284.—Chertoprud et al. 2017: 566, tables 1−2.

Eucyclops agiloides roseus: Alekseev & Defaye 2011: 61.—Alekseev 2019: 499.

Eucyclops serrulatus var. *proximus*: Monchenko 1972: 80.

? *Eucyclops agiloides*: Monchenko 2003: 79−80, 83, 87.

? *Eucyclops agiloides*: Alekseev & Monchenko 2011: 10−11

? *Eucyclops serrulatus*, Clade IV: Hamrová et al. 2012: 761, fig. 3, table 2.

Material examined

Hungary

(1) Békés County, Szarvas, Fisheries Research Institute, “Belsőtelep” experimental fishpond (46°51'30"N 20°31'12"E), “B6”, leg. M. Hołyńska 29.05.1992, 2 females (Hołyńska Collection).

Romania

(2) Sibiu County, Mediaş, pond near Buzd (46°09'55"N 24°23'56"E), leg. K. Constantinescu 18.06.2017, 2 females (IEE: 18.06.2017/5,6).

(3) Iasi County, Bogonos (47°13'21"N 27°26'2"E), partially dry pond, leg. G. Chisamera & V. Gavril 29.06.2017, 1 female (IEE: 29.06.2017/1).

Ukraine

(4) Kyiv: Orikhuvatski ponds (50°23'18"N 30°30'14"E), leg. M. Prokopuk 21.07.2020, 6 females (IEE: 21.07.2020/1-5,7) and 1 male (IEE: 21.07.2020/6); Holosiivski ponds (50°22'46"N 30°30'59"E): leg. L. Gaponova & A. Kolosiuk 27.07.2016, 3 females (IEE: 27.07.2016/1-3); leg. M. Prokopuk 07.07.2020, 1 female (IEE: 07.07.2020/1); pond near village Khotov (50°19'53"N 30°28'00"E), leg. L. Gaponova 17.05.2010, 1 female (IEE: 17.05.2010/1).

(5) Vinnytsia, Southern Bug River, near dam (49°14'14"N 28°28'47"E): leg. L. Gaponova & A. Kolosiuk 31.03.2013, 1 female (IEE: 31.03.2013/1); leg. L. Gaponova & A. Kolosiuk 19.05.2013, 1 female (IEE: 19.05.2013/3) and 1 male (IEE: 19.05.2013/2); leg. L. Gaponova & A. Kolosiuk 10.10.2015, 1 female (IEE: 25.02.2016/2).

(6) Uman, Sofiyivka park, shallow pond (48°45'39"N 30°13'46"E), leg. L. Gaponova & A. Kolosiuk 11.07.2015, 6 females (IEE: 14.07.2015/1, 15.07.2015/1-5).

(7) Dnipro, oxbow lake near Dnieper River (48°26'58"N 35°04'25"E), leg. L. Gaponova & A. Kolosiuk 26.09.2016, 3 females (IEE: 26.09.2016/1-3).

(8) Kryvyi Rih, Fedor Mershavtsev Park, Inhulets River (47°53'49"N 33°19'43"E), leg. T. Shupova 10.09.2015, 1 female (IEE: 10.09.2015/1).

(9) Majaky, Dniester River, shoal (46°24'54"N 30°15'32"E), leg. L. Gaponova & A. Kolosiuk 17.05.2013, 4 females (IEE: 17.05.2013/1,2,5,8).

(10) Crimea, Arabatskaya Strelka, Strelkovoye village (45°54'00"N 34°52'48"E), originally labeled as *Eucyclops serrulatus*, 2 females, №3 and №4 (IZAN: Monchenko Collection).

Uzbekistan

(11) Samarkand oblast, sample №89, Agalyk River, 10−15 km from Samarkand city, scraped from a rock in the river bed, 02.02.1962 (locality information from Monchenko 1972), originally labeled as *Eucyclops serrulatus* v. proximus, 2 females, №5 and №6, (IZAN: Monchenko Collection).

Other material examined

Eucyclops serrulatus (Fischer, 1851)

Ukraine

Middle Dnieper: 2 females, №7 and №8 (IZAN: Monchenko Collection).

Hungary

Békés County, Szarvas, Fisheries Research Institute, “Belsőtelep” experimental fishpond, (46°51'30"N 20°31'12"E), “B6”, leg. M. Hołyńska 29.05.1992, 1 female (Hołyńska Collection).

Diagnosis

Female. Total body length (without caudal setae): 950−1190 μm; prosome length/urosome length: 1.2−1.6;

cephalothorax length/width: 1.0−1.3; genital double-somite length/width: 0.8−0.9. The posterolateral margin of pediger 5 with hairs (Fig. 1A). Seminal receptacle as typical of the genus. Ventral surface of genital double-somite with 2 posterolateral sensilla. Posterior edge of genital double-somite with hyaline frills, coarsely serrated on the ventral surface and finely dentate or wavy dorsally. Anal somite (Fig. 1B) bearing a row of small spinules on the posterior margin and 2 sensilla on the dorsal surface. The anal operculum is distinctly convex (Fig. 1C).

Caudal rami (Fig. 1 B) are slightly divergent without hairs on the inner margin, 4.2−6.5 times as long as wide. A longitudinal row of spinules ("serra") is present along most of the outer edge of each ramus (Fig. 1B). Posterolateral (III) caudal seta (Fig. 1B) with a row of short spinules on the outer margin and longer setules on inner margin; spinules present at the insertion of seta.

Seta II is 0.1−0.25 times as long as the caudal rami, inserted at a distance of 0.16−0.24 ramus length measured from the posterior end on the ventral surface. The relative length of setae VII, VI, V, and IV in comparison to the length of caudal seta III: 0.7−1.0, 0.9−1.3, 4.5−7.0, and 3.3−5.3, respectively. The relative length of setae VII, VI, V, IV, and III compared to the length of caudal rami: 0.3−0.6, 0.4−0.8, 2.7−3.6, 1.8−2.5, and 0.4−0.7, respectively. Seta V is 0.8−1.1 times as long as the urosome. Dorsal seta (VII) 10−17 % of the length of caudal seta V and 16−27% of the length of caudal seta IV.

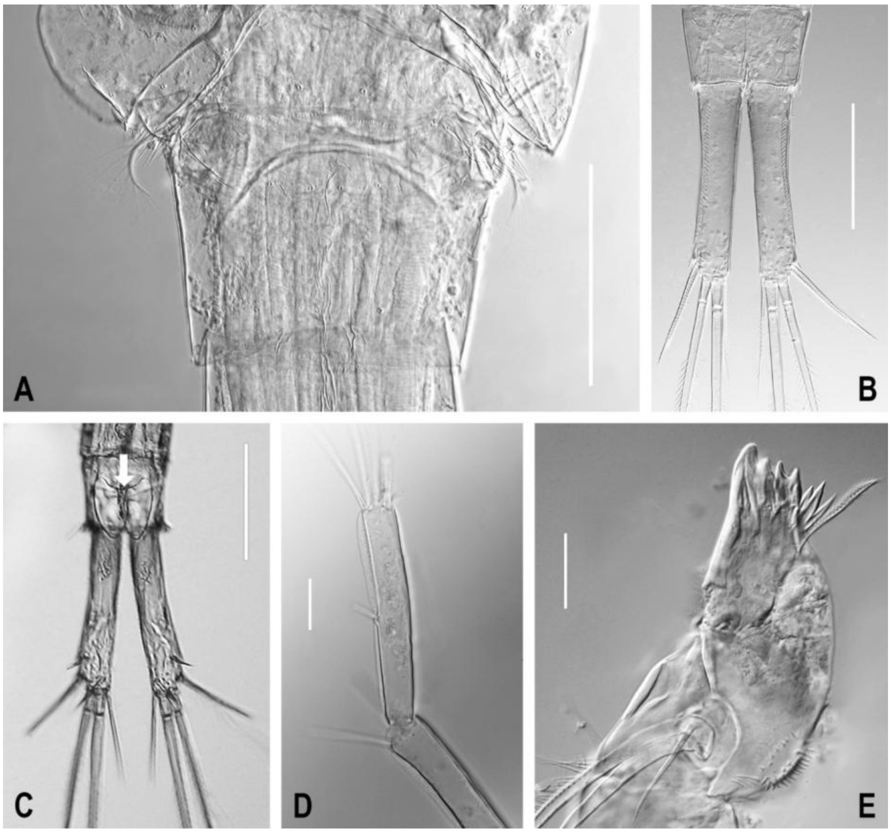

Figure 1. *Eucyclops roseus* Ishida, 1997, female.
A – Pediger 4−5 and genital double-somite, dorsal (oxbow lake, Dnipro).
B – Caudal rami, ventral (Orikhuvatski ponds, Kyiv).
C – Anal somite and caudal rami, dorsal (Orikhuvatski ponds, Kyiv); note convex anal operculum (arrow).
D – Antennule, last two segments with the hyaline membrane (Holosiivski ponds, Kyiv).
E – Mandible (oxbow lake, Dnipro). Scale bars = 100 µm (A-C) and 20 µm (D – E).

Antennule 12-segmented, reaching posterior margin of pediger 2. Last three antennular segments with finely serrate hyaline membrane, a membrane 1.8−3.7 µm in width (Fig. 1D). Terminal segment of the antennule is 5.3−7.2 times as long as wide.

Antennal coxobasis, surface ornamentation on the frontal surface (Fig. 2A) composed of two groups (I−II) of long hair-like spinules near distal margin, length of spinules on average 1/3 sometimes 4/10 of coxobasis length; three oblique and parallel rows (IV−VI) in proximal half, spinules shorter than those in groups I and II; longitudinal rows of spinules along lateral (III) and medial (VII) margins (see Fig. 2A−B).

Caudal surface of antennal coxobasis with groups 1−9 and 11, group 10 sometimes present (Fig. 2B−D). Distalmost spinule in group 1 conspicuously long, sometimes twice as long as other spinules (4−7). Spinules (6−9) at the height of exopodal seta (group 2) robust, distalmost spinule sometimes longer than others. Spinules in groups 3 and 4 similar in size. Spinules in row/arc near the insertion of medial setae (group 6) smaller than those in groups 1 and 2. Other components of the ornamentation (groups 5, 7−10) in the medial half and near the proximal margin of the segment are small/tiny.

Mandible (Fig. 1E) with reduced palp bearing two long plumose setae and one short naked seta. Near the mandibulary palp, a few long spinules are arranged in a transverse row, and numerous smaller spinules in an oval pattern are present on the anterior surface.

Maxillulary palp two-segmented (Fig. 3A). Proximal article of palp with 3 medial setae and 1 lateral seta; anterior surface with a circular row of 8−16 minute spinules (Fig. 3A, B). The distal segment of palp, armed with 3 setae (Fig. 3A).

Spine formula of exp3 in P1−P4, 3–4–4–3. P1 basipodite with medial seta reaching insertion of medial (inner) proximalmost seta of enp3 (Fig. 4A); basipodite seta with short setules proximally and slightly longer setules more distally. P1 intercoxal sclerite is naked on the caudal surface. Caudal surface of P2−P4 intercoxal sclerites with a transverse row of hairs (Fig. 5 A–C), pilosity most dense in P4 (Fig. 5C), sometimes absent in P2. Hair-like spinules arranged in 1-1 group present on the frontal surface of P1−P4 intercoxal sclerites (see P1 in Fig. 4A).

Caudal surface ornamentation of P4 coxopodite (Fig. 5C) is typical of the genus. Coxopodal seta with heteronomous setulation (Fig. 5C): setules long in the proximal half and short in the distal half; on lateral margin, setules are sometimes absent or discontinuous ("gap") in the proximal half of seta. First and second exopodal segments laterally pilose in P1−P4 (see P2 in Fig. 5A). P4 enp3 1.9–2.4 times as long as wide; inner apical spine 1.3–1.5 times longer than the outer apical spine, and 1.1–1.3 times as long as segment (Fig. 4B); inner (medial) and outer (lateral) setae not reaching the tip of the longer apical spine. P5 is one-segmented and armed with three elements: medial spine, apical and lateral setae 1.6−2.4, 2.5−3.4, and 1.4−1.9 times as long as the segment, respectively. Spinules are present at the insertion of the medial spine.

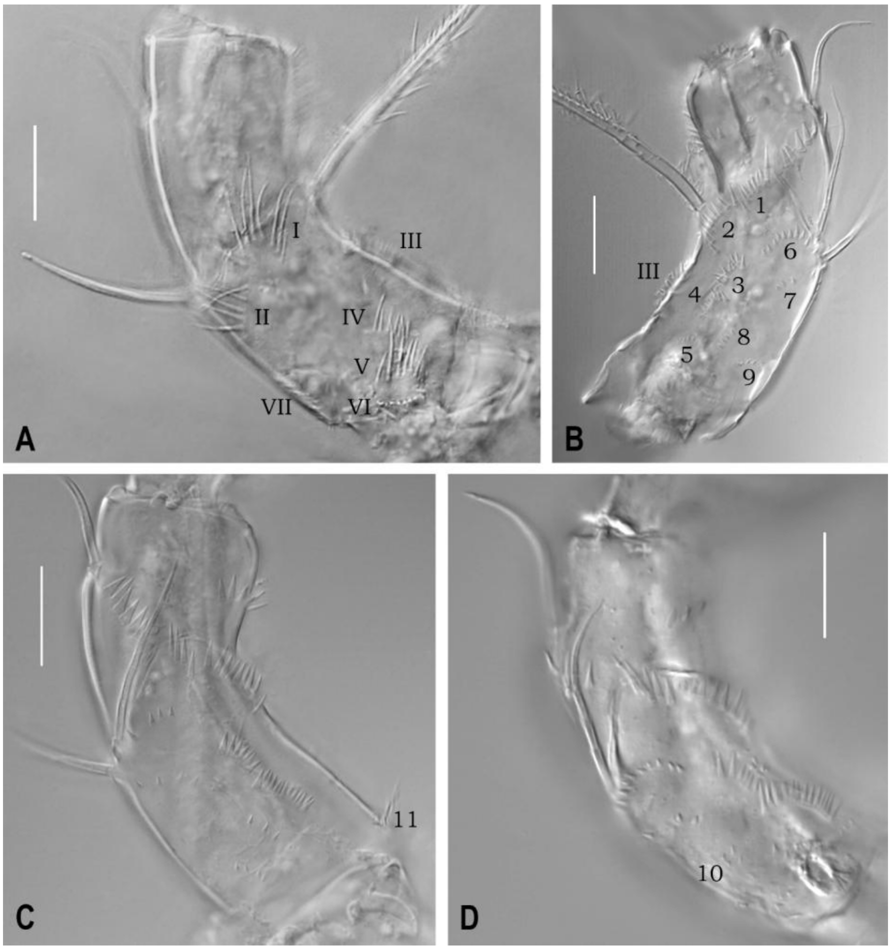

Figure 2. *Eucyclops roseus* Ishida, 1997, female.
A – Antennal coxobasis, frontal (shallow pond, Uman).
B−D. Antennal coxobasis, variation of the caudal surface ornamentation:
B – Dniester River (Majaky);
C – oxbow lake (Dnipro);
D – Agalyk River (Samarkand).
Scale bars = 20 µm.

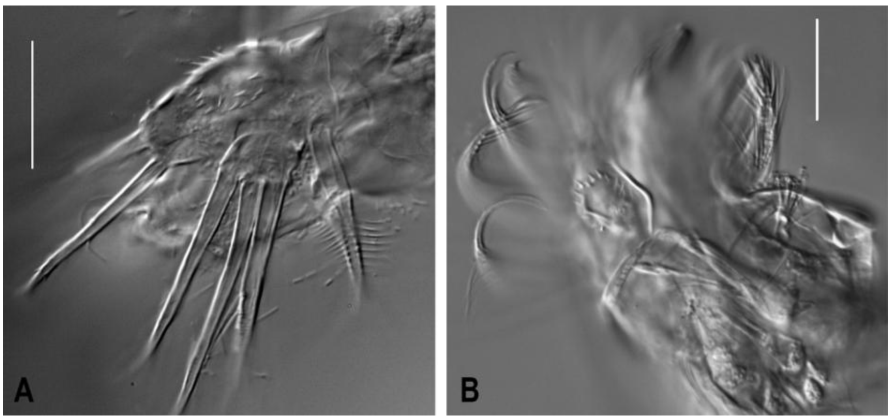

Figure 3. *Eucyclops roseus* Ishida, 1997, female.
A−B. Maxillulary palp with a circular pattern of spinules, a characteristic of the species:
A – Southern Bug River (Vinnytsia);
B – Agalyk River (Samarkand).
Scale bars = 20 µm.

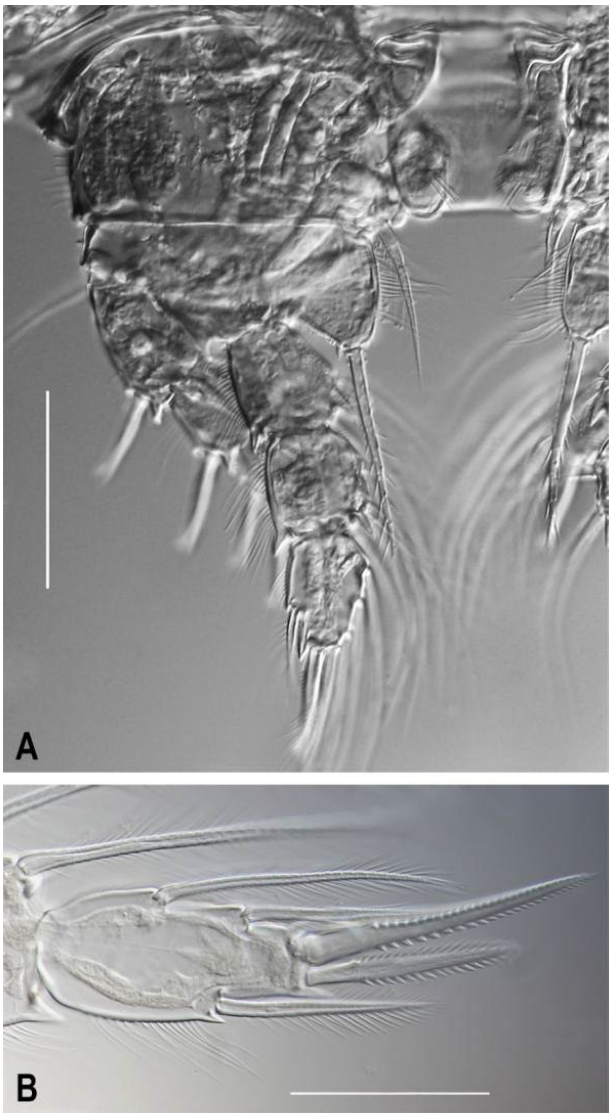

Figure 4. *Eucyclops roseus* Ishida, 1997, female. A – Leg 1, frontal (Holosiivski ponds, Kyiv). B – Leg 4, the third segment of endopodite (pond near Buzd). Scale bars = 50 µm.

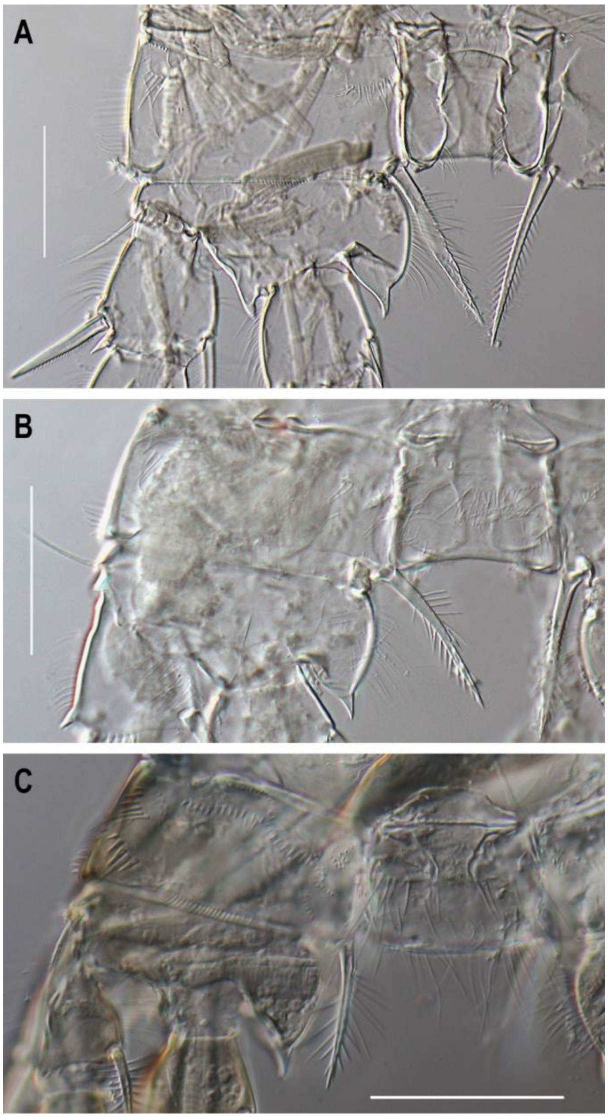

Figure 5. *Eucyclops roseus* Ishida, 1997, female. A – Leg 2 intercoxal sclerite, coxopodite, and basipodite, caudal (oxbow lake, Dnipro); the photo also shows some structures on the frontal surface (row of small spinules along the distal margin of coxopodite, and hairs arranged in two groups on the intercoxal sclerite). B – Leg 3 intercoxal sclerite, coxopodite and basipodite, caudal (pond, Bogonos). C – Leg 4 intercoxal sclerite, coxopodite, and basipodite, caudal (Holosiivski ponds, Kyiv). Scale bars = 50 µm.

Male (2 specimens). Total body length (without caudal setae): 770 µm; prosome length/urosome length: 1.0; cephalothorax length/width: 1.1. Caudal rami 3.7−4.3 times as long as wide. Seta II 0.3 times as long as caudal rami, inserted at a distance of 0.23−0.25 ramus length measured from the posterior end. Few robust spinules are present at the insertion of caudal seta II and III, yet "serra" is absent. The relative length of caudal setae VII, VI, V, and IV compared to caudal seta III: 1.2−1.3, 1.8, 9.4−11.9, and 5.7−6.4, respectively. The relative length of caudal setae VII, VI, V, IV, and III compared to caudal rami: 0.5−0.6, 0.8−0.9, 4.2−4.8, 2.5−2.6, and 0.4−0.5, respectively. Seta VII (dorsal) is 11−13 % of the length of seta V and 20−22 % of the length of seta IV.

Frontal and caudal surface ornamentation of antennal coxobasis as in females. Maxillulary palp with spinules arranged in an oval pattern. The first and second exopodal segments bear hairs on the lateral margin in P1−P4.

P4 enp3 2.1–2.2 times as long as wide, the inner apical spine 1.4 times longer than the outer apical spine, and 1.1–1.3 times as long as the segment. P6 bearing three elements; medial spine longer than the median and lateral setae (accurate length proportions could not be verified as the setae/spine were partly broken).

Discussion

Eucyclops roseus can be distinguished from all the other *Eucyclops* species (6 spp.) occurring in Ukraine by the following characters of the adult female: i. "serra" extends beyond the middle point of the caudal ramus [vs. "serra" is shorter or absent in *E. persistens tauricus* Monchenko & Sopova, 1984 and *E. macrurus* (G.O. Sars, 1863)]; ii. the hyaline membrane is smooth/very finely serrated in the proximal half of the terminal (12th) antennular segment [vs. with distinct dents in *E. denticulatus* (Graeter, 1903) and *E. macruroides* (Lilljeborg, 1901)]; iii. long, hair-like spinules are present on the frontal surface of antennal coxobasis near the distal margin ("group I" in Fig. 2A) [vs. "group I" is absent in *E. denticulatus*, *E. macruroides*, *E. persistens tauricus*, *E. macrurus* and *E. speratus* (Lilljeborg, 1901)]; iv. an oblique row of spinules is present on the caudal surface of antennal coxobasis near the distal margin ("group 1" in Fig. 2B) [vs. "group 1" is absent in *E. denticulatus*, *E. macruroides*, *E. persistens tauricus*, *E. macrurus,* and *E. serrulatus*] (see Monchenko 1974, Chang 2009, Gaponova & Hołyńska 2019).

Eucyclops roseus can be misidentified as *E. serrulatus* if the surface microstructure characters are not included in the species identification. Beyond the spinule ornamentation on the caudal surface of the antennal coxobasis (see character "iv" above), these two species also differ in the lateral pilosity of the exopodal segments in P1−P4 (first and second exopodal segments are laterally pilose in P1−P4 in *E. roseus*, vs. hairs only present on P1 exp2 in *E. serrulatus*), and the surface ornamentation of the maxillulary palp (spinules are present and arranged in a circular or oval pattern in *E. roseus*, vs. spinules are absent in *E. serrulatus*). Another informative character is the shape of the anal operculum (distinctly convex in *E. roseus* vs. straight or slightly convex in *E. serrulatus*). This feature alone (being a continuous trait) is insufficient to allow reliable species identification. Yet, it may help in the quick recognition of putative *E. roseus,* even in undissected specimens. Some published records of *E. serrulatus* in the southern Palearctic, especially those in the older literature, may refer to *Eucyclops roses* (see Ishida 1997 or the records cited herein from Arabatskaya Strelka in Crimea and Samarkand region in Uzbekistan). In a phylogeographic study of the Eastern European populations of *E. serrulatus*, Hamrová et al. (2012) identified eight clades and hypothesized that some of the deeply divergent lineages would represent separate 'cryptic' species. Clade IV, in their phylogenetic reconstruction, included a population from Khotov Lake (pond) in the vicinity of Kyiv, Ukraine. This is the same locality, though the collection date provided in Hamrová et al. 2012 (April 2010) is slightly different, where we found *E. roseus* (May 2010). We speculate that Clade IV, including also a population from Hamburg in Germany, might be conspecific with *E. roseus* rather than *E. serrulatus*. It is worth mentioning that none of those morphological characters which are currently used to separate *E. roseus* from *E. serrulatus* (surface ornamentation of the antennal coxobasis and maxillulary palp, lateral pilosity of the exopodite in P1−P4, setulation of the medial seta of P1 basipodite) was verified by the authors in the identification of the species (see Hamrová et al. 2012, p. 758). We failed to find any note about voucher specimens deposited in the studies of Hamrová et al. (2012).

Alekseev & Defaye (2011) considered *E. roseus* as a subspecies of *Eucyclops agiloides* (type locality: Lake Victoria), yet the authors did not mention the geographic separation of the nominotypical subspecies and *E. roseus*. Instead, they defined the distribution of *Eucyclops agiloides* sensu lato as tropical and subtropical and hypothesized an introduction by the human agency from Africa to Germany during World War II to explain the occurrence of *E. roseus* in Lower Saxony (Oldenburg; ca. 53° N), the single European record known in that time. Based on the currently available distributional data, *E. roseus* is a warm temperate (mesothermal)−dry zone (the Köppen climate classification is applied here) species with a broad range stretching from East Asia in the east to Eastern Africa in the west (for more details see the Introduction). The southernmost published records are those from Okinawa (26° N) in Asia, Lake Victoria (Kisumu), and Lake Naivasha (1884 m a.s.l.) near the Equator in Kenya, Africa. The record from L. Victoria is the only one so far known from a region with a tropical climate. The northern limit of the distribution is insufficiently known. A single record from Siberia (central Yakutia, Amga River; the sample was collected in August 2010) (Hołyńska et al. 2021) might suggest that the species range extends as far north as 64 degrees in the Eastern Palearctic. We speculate that *E. roseus* can be very rare in this subarctic environment with an extreme continental climate − the Amga River is under ice from October to May. Numerous tropical and subtropical cladocerans are known to occur in Russian Far East (The Amur River Basin), but they do not reach central Yakutia (Kotov 2016, Garibian et al. 2019). Regarding the Eastern European distribution of *E. roseus* (Fig. 6), the northernmost record is from Kyiv (50.5° N). To identify the northern and western distribution limits in Europe, we need geographically wide-scale and fine-grained monitoring of *Eucyclops* in the European surface waters. Even though our collection based overwhelmingly on the senior author's private collection trips in Ukraine could not be extensive, it yielded numerous new records of *E. roseus,* which has so far been known from Crimea and Luhansk only (Anufriieva et al. 2014, Anufriieva & Shadrin 2016). *Eucyclops roseus* has been encountered in various waterbodies, such as large lakes (e.g., littoral zone in L. Victoria), reservoirs, fishponds, puddles, marshes, and bogs, streamlets and large rivers, in fresh and estuarine (e.g., the Shatt Al-Arab River) or even saline habitats (Kuchuk-Adjigol Lake in Crimea) (Ishida 1997, 1998, Lee et al. 2005, Chang 2009, Anufriieva et al. 2014, Anufriieva & Shadrin 2016). Korean researchers (Lee et al. 2005, Chang 2009), who currently have the largest environmental data set on *E. roseus*, have found a predilection for stagnant eutrophic waters and the littoral (or benthic) zone.

In Ukraine, Romania, and Hungary, the species has been encountered in different types of artificial and human-modified water bodies. *Eucyclops roseus* occurred most often in freshwater ponds in both urban (Kyiv and Uman in Ukraine) and rural (Buzd and Bogonos in Romania) areas. The species has also been found in an experimental fishpond in southeastern Hungary (Szarvas). *Eucyclops roseus* also occurred in running water: in the middle reach of the Southern Bug and the Inhulets River and the lower reach of the Dniester River. In all these cases, however, the species was collected from slowly running water among macrophytes in the littoral zone of the rivers. In Ukraine, where we have the most occurrence data, *E. roseus* has not yet been recorded in pristine areas (nature reserves) (Gaponova 2016, Gaponova 2020). However, other representatives of the genus did occur in these sites. From Uzbekistan, we identified the species in an old sample collected from a mountain river (Agalyk) (see Monchenko 1972). The wide distribution of *E. roseus* in Ukraine and its occurrence in Romania, Hungary, and Uzbekistan (and perhaps in the Lesser Caucasus and Talysh region, too, if we would include the *E. agiloides* records provided by Monchenko 2003) (Fig. 6), as well as the diversity of the habitats where the species has been encountered, rather suggest that the southern region of Eastern Europe might be part of the native geographic distributional area. Whether the species colonized this region relatively recently or *E. roseus* is an old yet overlooked component of the Eastern European fauna is difficult to say at this moment. In our material, the earliest known collection of the species in Eastern Europe came from Hungary (Szarvas) in 1992; therefore, we suspect that *E. roseus* may have already been present in Ukraine and Romania before that date. A revision of the *Eucyclops* material (especially those labeled as *E. serrulatus* or *E. speratus*) held in the European collections, more extensive fieldwork, and population genetics studies testing the genetic signatures of putative range shift are needed to explore the history of *E. roseus* in Europe.

Figure 6. Geographic distribution of *Eucyclops roseus* Ishida, 1997 in Eastern Europe and Central Asia. Filled yellow circles with black dot show original records: (1), Szarvas; (2), Mediaş; (3), Bogonos; (4), Kyiv; (5), Vinnytsia; (6), Uman; (7), Dnipro; (8) Kryvyi Rih; (9), Majaky; (10), Strelkovoye; (11), Agalyk River, vicinity of Samarkand. Filled yellow circles without dot show literature data in Ukraine: (12), Sevastopol, pool; (13), Kuchuk Adjigol, lake; (14) Luhansk, pond. (12) and (13) from Anufriieva et al. 2014, and (14) from Anufriieva & Shadrin 2016. Filled yellow circles with cross show records under the name *E. agiloides*, supposedly referring to *E. roseus*: (15) Chatyr-Dag (Ukraine, Crimea), spring; (16) Tarkhankut Peninsula (Ukraine, Crimea), stream and spring; (17) Shahbuz forest (Azerbaijan, Lesser Caucasus), wet meadow; (18) Gasmalyan (Azerbaijan, Talysh, Zuvand), stream. (15) from Monchenko 2003, and (16)−(18) from Alekseev & Monchenko 2011.

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