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Current invasions of East Asian cyclopoids (Copepoda, Cyclopoida) in Europe: new records from eastern Ukraine

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Abstract: The East Asian freshwater cyclopoid copepods *Mesocyclops pehpeiensis* (Hu, 1943) and *Eucyclops roseus* Ishida, 1997, which are new for Europe, were recorded from samples collected in the water bodies of the city of Lugansk, eastern Ukraine. In 2012 the same species of cyclopoids, new or rare for Europe, were found in Crimean ponds where there is no human agency that could lead to introductions of alien species. Long-distance transportation by birds, probably, is the more plausible explanation for their appearance in Lugansk. These alien species were found in newly formed water bodies without stable communities, which may serve as a jumping-off place for further distribution of East Asian cyclopid copepods across Europe.

Key words: Alien species, *Eucyclops roseus*, *Mesocyclops pehpeiensis*, Ukraine

Invasions of alien species are one of the greatest ecological threats to the earth's biodiversity and human well-being (Richardson, 2011). Aquatic nonindigenous animals worldwide includes at least 30 planktonic copepod species in fresh, marine, and brackish waters (Grigorovich et al., 2002; Ferrari and Rossetti, 2006; Reid, 2007; Shadrin, 2013; Sukhikh et al., 2013). Copepods play an important ecological role in aquatic ecosystems, occupying different ecological niches in aquatic food webs and contributing to biogenic element cycles; this is why invasions of alien copepods may cause shifts in a whole ecosystem's functioning and dynamics. Cyclopidae are one of the largest and most diverse groups of copepods in inland waters, playing an important role in food webs in different water bodies (Monchenko, 2003). Data on alien cyclopoid species are slowly accumulated (Reid and Reed, 1994; Suárez-Morales et al., 2005, 2011; Temnykh and Nishida, 2012). In 2012–2013 we found 3 East Asian cyclopoid species in Crimea (Anufriieva et al., 2014). Those alien predator cyclopids are new incomers in Europe, and, probably, change the zooplankton composition, altering ecosystem functioning in European waters. Despite the fact that in general the fauna of free-living Cyclopoida in Ukraine was studied well enough (Monchenko, 2003), it has not been studied previously in Lugansk. The aim of our paper is to describe and discuss new data on the fauna of Cyclopoida in eastern Ukraine, emphasizing the occurrence of East Asian cyclopoids.

The materials examined were collected from water bodies in the city of Lugansk (48°34′N, 39°18′E), eastern Ukraine, which is located at the confluence of the rivers Lugan and Olkhovaya. Zooplankton samples were obtained from freshwater habitats in serially connected biological ponds of Lugansk's municipal wastewater treatment systems, which include rectangular ponds (every pond area is 35,000 m^2 in I system, and 14,000 m^2 in II system), and the rivers Lugan and Luganchik during July 2013. All these water bodies are in an area of about 6 km^2. First 100–150 L of water was filtered through 110-µm mesh-size plankton net. Then samples were fixed and preserved in 4% buffered formalin solution. In situ temperature was measured at the time of sampling using a portable temperature meter (PHH-830). Cyclopoid specimens were dissected in glycerin under an Olympus SZ-PT stereomicroscope. Dissected specimens were mounted in glycerin and the semipermanent slides were sealed with nail polish. Identifications and measurements were made under a light Carl Zeiss Axio Scope A1 microscope at 40 and 100× magnifications. The specimens were identified following Einsle (1996), Ishida (1997), and Hołyńska (2003). The morphometric measurements were taken following Koźmiński (1936). The specimens of *Eucyclops roseus* Ishida, 1997 and *Mesocyclops pehpeiensis* (Hu, 1943) were deposited in the zooplankton collection at the Institute of Marine Biological Research (IMBR), Sevastopol, Crimea. Parameters of regression equations

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(accumulation curves) and correlation coefficients were calculated in Excel; the confidence level of the correlation coefficients was determined from Müller et al. (1979). Random permutations of data were made online to calculate accumulation curves (http://www.webcalculator.co.uk/statistics/rpermute3.htm).

Up to 6 species of Cyclopoida were identified (Table). Only 1–3 species of Cyclopoida occurred in each sample. *Eucyclops roseus*/*E.* cf. *roseus* was in 8 samples. We found *M. pehpeiensis*, *Thermocyclops dybowskii* (Lande, 1890), and *Paracyclops fimbriatus* (Fischer, 1853) twice and *E. macrurus* (Sars G.O., 1863) and *Macrocyclops albidus* (Jurine, 1820) only once. Ponds in the I system may be characterized by very slow water exchange with obvious signs of phytoplankton blooms. All other samples were taken in water bodies with current water where the water transparency was higher. Temperature ranged from 21 to 23 °C. In the I system of ponds the species composition of Cyclopoida, as well as other animals, was not same in all ponds; there were also some differences from other water bodies (Table 1).

The relationship between the observed cyclopoid species richness and the number of samples may be described by the following equation (R = 0.962, P = 0.001):

$$y = 2.094 \ln(x) + 0.937, \quad (1)$$

where y is the number of observed species and ln (x) is logarithm of the number of analyzed samples.

This function corresponds to one of many possible orderings of 10 samples. Ten more accumulation curves for different orderings of the samples were calculated to evaluate possible species richness for 500 samples, which was estimated as 12–14 species. Of course, if we had used samples from different seasons we may have had a larger number of species. This value is only a minimal rough estimate of the expected diversity, and it means that 14%–33% of all cyclopoid species are aliens here.

Eucyclops roseus and *M. pehpeiensis* are both East Asian forms (Anufriieva et al., 2014). Local records of these species are the third in Europe. Prior to this *E. roseus* was found in Germany in 1996 (Ishida, 1997) and later in East and West Crimea (Anufriieva et al., 2014); *M. pehpeiensis* was found in a warm water pool in the botanical garden in Vienna (under the name *Mesocyclops ruttneri* Kiefer, 1981, a younger synonym of *M. pehpeiensis*) and in East Crimea (Anufriieva et al., 2014). Both species were found in ponds where there is no human agency that could lead to introductions of the alien species. Long-distance transportation by birds seems to be a more plausible explanation for their appearance in Lugansk as well as in Crimea (Anufriieva et al., 2014). There are the migratory

Table. Species composition in different samples in Lugansk's water bodies (July 2013).

Water body	Species	Associated groups of animals
1 pond in I system	*Eucyclops* cf. *roseus* Ishida, 1997	Cladocera
2 pond in I system	*Eucyclops* cf. *roseus* Ishida, 1997 *Eucyclops roseus* Ishida, 1997	Cladocera
3 pond in I system	*Eucyclops* cf. *roseus* Ishida, 1997 *Eucyclops roseus* Ishida, 1997 *Mesocyclops pehpeiensis* (Hu, 1943)	Cladocera
4 pond in I system	*Eucyclops roseus* Ishida, 1997 *Eucyclops* cf. *roseus* Ishida, 1997 *Paracyclops fimbriatus* (Fischer, 1853)	Cladocera
5 pond in I system	*Eucyclops* cf. *roseus* Ishida, 1997 *Mesocyclops pehpeiensis* (Hu, 1943)	Cladocera, dipteran larvae, plecopteran larvae
6 pond in I system	*Eucyclops* cf. *roseus* Ishida, 1997 *Paracyclops fimbriatus* (Fischer, 1853)	Cladocera, dipteran larvae, plecopteran larvae
1 pond in II system	*Thermocyclops dybowskii* (Lande, 1890)	Cladocera
2 pond in II system	*Macrocyclops albidus* (Jurine, 1820)	Plecopteran larvae, chironomid larvae
River Lugan	*Eucyclops macrurus* (Sars G.O., 1863) *Eucyclops* cf. *roseus* Ishida, 1997 *Thermocyclops dybowskii* (Lande, 1890)	Cladocera
river Luganchik	*Eucyclops roseus* Ishida, 1997 *Eucyclops* cf. *roseus* Ishida, 1997	Cladocera, plecopteran larvae

routes of different aquatic birds from Asia to South Europe and Africa passing through Crimea and eastern Ukraine (Khomenko and Shadrin, 2009). *Mesocyclops pehpeiensis* has been found in several localities in North and Central America (Suárez-Morales et al., 2005) outside its native distributional range, which hints that some dormant stage resistant to a lack of free water might exist and may be transported by birds. The biological properties of the potential colonizers determine their success in a new environment, but an invaded ecosystem's 'immunity' also influences the success of an alien. Destabilized or new ecosystems with low species richness have very low ecological resilience (Gomoiu et al., 2002; Parkers and Duggan, 2012). In Lugansk, as well as in Crimea, cyclopoid alien species were found in newly formed water bodies without stable communities, which may serve as a jumping-off place for further distribution of East Asian cyclopid copepods across Europe.

Species composition variation of copepods may have significant effects on population, community, and ecosystem dynamics (Hausch et al., 2013). *Mesocyclops pehpeiensis* is a predator form, which naturally influences the density and species composition of their preys: cladocerans, rotifers, and dipteran larvae (Sarma et al., 2013). This cyclopid may change the zooplankton composition in its new habitats, destabilizing ecosystems and opening doors for new incomers (Richardson, 2011).

At least 5 other species of planktonic copepods from the East Asian region were recorded in European waters in recent years (Ferrari and Rossetti, 2006; Temnykh and Nishida, 2012; Alfonso et al., 2014; Anufriieva et al., 2014; Sabia et al., 2014). Does that mean that this is a general trend? If yes, what is the reason for this? *Eucyclops roseus* and *M. pehpeiensis* are thermophilic species; therefore, the occurrence of these cyclopids may indicate the effect of climate warming on the copepod fauna in Europe, although we need to collect more data to verify this hypothesis over a wider time scale.

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