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Research Article

# Recent update of mysid (Mysida) species composition in the Dnieper Reservoir, South-Eastern Ukraine, a source of several crustacean invaders to European waters

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## Abstract

The Dnieper Reservoir has significantly contributed as a primary source of invasive Ponto-Caspian crustaceans of Europe; therefore, the mysid populations it sustains are central to the research of invasion histories. However, the reservoir remains a waterbody susceptible to changes including the advent of new species. Mysid investigations in 2012–2014 revealed five species, *Limnomysis benedeni*, *Paramysis lacustris*, *P. intermedia*, *P. bakuensis* and *Katamysis warpachowskyi*, inhabiting the Dnieper Reservoir, and one species, *L. benedeni*, known to occur in the Dnieper-Donbass Canal. Including the previously reported *Hemimysis anomala*, the currently known mysid fauna of the Dnieper Reservoir consists of six species. Two of the species, *P. intermedia* and *P. bakuensis*, are reported from the reservoir for the first time. Currently, the dominant species in the shallow littoral zone are *L. benedeni* and *P. intermedia*, while *P. lacustris* mostly occurs in offshore depths. Two out of six occurring species, *L. benedeni* and *P. lacustris*, were deliberately introduced into the middle reaches of the Dnieper River, which must have contributed to their establishment in the reservoir. Meanwhile most of remaining four species, presumably, have invaded the Dnieper Reservoir by shipping. However, possibilities of an accidental introduction of these species or their historical presence in some habitats of the middle reaches of the Dnieper River may not be excluded. In conclusion, there have been rather significant changes in documented species composition of mysids in the reservoir, altering the scientifically valuable source populations of European invasions.

**Key words:** mysids of Dnieper, Ponto-Caspian peracaridans, artificial water bodies, invasion history

## Introduction

Some species of Ponto-Caspian mysids are among the most highly successful aquatic invaders, which have been recently expanding their distribution area within Europe and have even invaded North American waters (Bij de Vaate et al. 2002; Brooking et al. 2010; Borza and Boda 2013). This expansion has been greatly facilitated by connecting European river basins with artificial canals, enabling natural spread, as well as introductions via inland and marine shipping. However, deliberate translocations of a few mysid species, undertaken in the middle of the 20th century, also contributed to the dispersal of Ponto-Caspian mysids; the Baltic Sea basin was first invaded by these mysids following a deliberate translocation from the Dnieper Reservoir to the Kaunas Reservoir, located on the Nemunas River in Lithuania (Arbačiauskas 2002; Arbačiauskas et al. 2011). Similarly, a few Ponto-Caspian amphipods were translocated from the Dnieper Reservoir, and currently all these peracaridan invaders are expanding their invasive ranges in the Baltic Sea basin (Arbačiauskas and Gumuliauskaitė 2007; Arbačiauskas et al. 2011). Thus, the Dnieper Reservoir can be considered a primary source of several peracaridan invaders of European waters, and therefore it is an important reference for invasion biologists. Furthermore, the Dnieper River, with its reservoirs, is a part of one of the most important invasion routes in Europe, the central invasion corridor (Bij de Vaate et al. 2002; Karatayev et al. 2008).

Historically, Ponto-Caspian mysids occurred up to the rapids of the Dnieper River at Zaporizhia city. The mysids *Paramysis lacustris* (Czerniavsky, 1882) (= *Mesomysis kowalevskyi* Cherniavsky,

1882) and *Paramysis ullskyi* (Czerniavsky, 1882) (= *Metamysis strauchi* Cherniavsky, 1882) inhabited the river pools just below the rapids (Zhuravel' 1950) and the mysid *Limnomysis benedeni* Cherniavsky, 1882 was present in the oxbow lakes (Zhuravel' 1955). It was concluded that upstream dispersal of these mysids (and of other mysid species inhabiting the lower reaches and the estuary of the river, see Zhuravel' (1950)) had been previously prevented by the Dnieper Rapids and the dam built after the construction of the Dnieper Hydroelectric Power Plant.

Recently, mysids have been of scientific interest as valuable and preferable fish-food animals. Thus, in an attempt to increase fish production, deliberate translocations of fish-food invertebrates, including mysids *L. benedeni* and *P. lacustris*, into different places of the middle reaches of the Dnieper, including parts of the Dnieper Reservoir, were launched in the late 1940s (Zhuravel' 1955, 1971, 1974). The third mysid species, *Hemimysis anomala* G.O. Sars, 1907, was detected in the reservoir in 1957; and Zhuravel' (1960, 1974) concluded that this species was accidentally introduced along with other fish-food invertebrates.

Since the last decades of the 20$^{th}$ century, specific investigations of mysids in the Dnieper Reservoir and adjacent water bodies have not been undertaken. Only two mysid species, *L. benedeni* and *P. lacustris*, were identified among the benthic invertebrates of the reservoir (Zagubizhenko 2000), and in another monograph only *L. benedeni* was noted to inhabit the Dnieper Reservoir whilst *P. lacustris* was reported from the Dnieper-Donbass Canal (originally referred as the Oril' Canal; Fedonenko et al. 2009). Nevertheless, an increase in mysid species richness is highly probable in the long-term as the reservoir is located in the vicinity of waters harboring native assemblages of Ponto-Caspian mysids. The purpose of this study was to investigate the recent species composition of mysids in the Dnieper Reservoir and the Dnieper-Donbass Canal, revealing previously unnoticed or newly established taxa, as well as currently dominating species.

## Material and methods

The Dnieper Reservoir was created when the Dnieper River was dammed at Zaporizhia city during 1931–1934. As a result, the Dnieper Rapids were inundated. The dam was destroyed during the World War II and was rebuilt by 1947. The reservoir is of 129 km length, 3.2 km average width, and of 8 m mean depth, with 53 m at its deepest. Recently, it has been classed a eutrophic water body with mean growing season water ion content of 350 mg $L^{-1}$, total phosphorus concentration of 0.27 mg $L^{-1}$, and chlorophyll *a* concentration of 26 mg $L^{-1}$ (Dvoreckiy and Ryabov 2001). The Dnieper-Donbass Canal was designed to supply Dnieper water to the Donbass region and the Kharkiv city. It was constructed during 1969–1981 and stretches along the floodplains of the Oril' River from the Dnieper River above the reservoir to the Donets River at Izium town. It is 263 km long and has a capacity of around 120 $m^3$ $s^{-1}$, which is conveyed by 12 pumping stations.

The study was performed during 2012–2014. Mysids were sampled in six sites along the reservoir and in one site of the canal (Table 1, Figure 1). Samples were collected by a 60 cm wide dredge modified for sampling of nektobenthic animals in the wadeable littoral zone, i.e. in 0.4–1.5 m depth. Dominating bottom substrates and overall macrophyte coverage of sampled habitats were described. In two sites of the reservoir, in Vovnihy village (VOV) and in the Prydniprovs'kyi district (PRY), mysids were additionally sampled from a boat, i.e. in 2–8 m depth. As a consequence of varying sampling effort, provided species lists mainly contribute to qualitative information and provided numbers of specimens are incomparable between study sites. The collected material is deposited in the Nature Research Centre, Lithuania.

## Results

Five mysid species, *L. benedeni*, *P. lacustris*, *Paramysis intermedia* (Czerniavsky, 1882), *Paramysis bakuensis* G.O. Sars, 1895 (=*Paramysis baeri bispinosa* Martynov, 1924) and *Katamysis warpachowskyi* G.O. Sars, 1893, were recorded in the Dnieper Reservoir and only one species, *L. benedeni*, was found in the Dnieper-Donbass Canal (Table 1, Figure 1). The richest mysid assemblages were detected in the Prydniprovs'kyi district (5 species, site PRY) and in Vovnihy village (4 species, site VOV) where the larger sampling effort was applied involving offshore depths greater than 2 m. With the exclusion of the mouth of the Samara River (SAM), where the only specimen was caught in the wadeable littoral zone, *P. lacustris* was only present in depths over 2 m (PRY and VOV). A similar depth-wise distribution was noticed for *P. bakuensis* (PRY).

The most widespread species were *L. benedeni* (all 7 study sites) and *P. intermedia* (5 sites). *Katamysis warpachowskyi* was recorded in 4 sites,


**Figure 1.** Geographic location of the Dnieper Reservoir and sampling sites in its vicinity (A) and sampling sites in the Dnieper Reservoir (B). Site codes correspond to those in Table 1.

**Table 1.** Description of sampling sites in the Dnieper Reservoir and the Dnieper-Donbass Canal, lists of recorded mysid species, their numbers in samples (N) and habitat characteristics: sand (SA), silt (SI), stones (ST), abundant (over a half of bottom coverage) macrophytes (MA), sample includes catches from 2–8 m depth (>2).

| Code | Site | Coordinates | Date | Species | N | Habitat |
|---|---|---|---|---|---|---|
| VOV | in Vovnihy village | 48°07'54.4"N 35°05'12.3"E | 08-10-2012 | *L. benedeni* | >200 | SA, SI, >2 |
| | | | | *P. intermedia* | 173 | |
| | | | | *P. lacustris* | 5 | |
| | | | 21-05-2014 | *L. benedeni* | 139 | SA, SI, >2 |
| | | | | *P. intermedia* | 98 | |
| | | | | *P. lacustris* | 11 | |
| | | | | *K. warpachowskyi* | 6 | |
| BAS | at the mouth of the Bashmachka Stream | 48°07'28.2"N 35°03'26.0"E | 21-05-2014 | *K. warpachowskyi* | 31 | ST, SI |
| | | | | *L. benedeni* | 8 | |
| DIB | at Dibrova village | 48°17'42.21"N 35°11'00.89"E | 05-08-2013 | *L. benedeni* | 106 | SA, SI, MA |
| | | | | *P. intermedia* | 1 | |
| PRY | in Prydniprovs'kyi district, Dnipropetrovsk city | 48°23'55.1"N 35°08'09.4"E | 22-05-2014 | *P. lacustris* | 59 | SA, SI, >2 |
| | | | | *L. benedeni* | 21 | |
| | | | | *P. bakuensis* | 15 | |
| | | | | *K. warpachowskyi* | 14 | |
| | | | | *P. intermedia* | 2 | |
| SAM | in the mouth of the Samara River, Samara bay | 48°27'13.3"N 35°07'29.4"E | 22-05-2014 | *L. benedeni* | 5 | SA, SI, MA |
| | | | | *P. intermedia* | 1 | |
| | | | | *P. lacustris* | 1 | |
| DNI | in Dniprodzerzhyns'k city | 48°31'58.01"N 34°35'07.46"E | 15-08-2013 | *L. benedeni* | 93 | SA, SI, MA |
| | | | | *P. intermedia* | 2 | |
| | | | | *K. warpachowskyi* | 1 | |
| CAN | the Dnieper-Donbass Canal at Pereschepino village | 49°02'18.37"N 35°21'07.06"E | 22-05-2014 | *L. benedeni* | 117 | ST, SA |

although usually in low numbers relatively to other mysids (Table 1, Figure 1). *Paramysis lacustris* was found in 3 sites, while *P. bakuensis* was spotted in one.

According to the numbers of caught specimens, the shallow littoral zone (<1.5 m depth) of the reservoir was mostly dominated by *L. benedeni* (especially in habitats with abundant macrophytes), usually together with *P. intermedia*. *Katamysis warpachowskyi* only prevailed over *L. benedeni* on the stony bottom of the mouth of the Bashmachka Stream (BAS) (Table 1). The mysid *P. lacustris* dominated by number, in offshore depths of site PRY where all other species were also recorded (the shallow littoral zone here was only represented by *L. benedeni*). In site VOV, *P. intermedia* was the most abundant species in offshore depths.

## Discussion

Our results clearly show that the number of mysid species has increased in the Dnieper Reservoir since the 1950s, when only three species, *L. benedeni*, *P. lacustris* and *H. anomala*, were documented to inhabit the reservoir (Zhuravel' 1955, 1971). The mysid *H. anomala* was not present in our samples because the deep-water zone where the species was previously observed was not investigated; however, if it is included, at least six species, *L. benedeni*, *P. lacustris*, *P. intermedia*, *P. bakuensis*, *K. warpachowskyi* and *H. anomala*, currently inhabit the Dnieper Reservoir. Including the previously reported species (Fedonenko et al. 2009), the Dnieper-Donbass canal harbours at least two mysids, *L. benedeni* and *P. lacustris*; however, the presence of the two other species, *P. intermedia* and *K. warpachowskyi*, is very likely, especially in the section close to the Dnieper.

Although our qualitative sampling is insufficient to draw robust conclusions on patterns of composition and abundance of mysid assemblage in the reservoir, it may be concluded that recent dominant species in the shallow littoral zone are *L. benedeni* and *P. intermedia*. The mysid *K. warpachowskyi* is quite common and may prevail in habitats with stony bottoms. The larger-bodied species *P. lacustris* and *P. bakuensis* seem to inhabit deeper waters where *P. lacustris* might dominate in numbers.

*Limnomysis benedeni* has presumably invaded the reservoir due to deliberate introductions. In 1948, it was introduced into the Samara Bay of the Dnieper Reservoir (previously known as Lake Lenin) which formed in the lower reaches of the Samara River. Later the species was also translocated to some places in the middle Dnieper reaches above the reservoir (Zhuravel' 1955, 1965). In contrast, the mysid *P. lacustris* dispersed into the lower and central parts of the reservoir naturally from the river pools downstream to the rapids during 1932–1937 (Zhuravel' 1955). Its further dispersal upstream, however, was considered to be restricted by high flow velocity, and thus, starting in 1949, it was deliberately introduced into different sites of the middle reaches of the river (which later were transformed into reservoirs), including the Samara Bay and Dnieper tributaries (Zhuravel' 1965, 1974). The material for introductions of both mysid species was usually collected in the lower reaches and within the delta of the Dnieper, its tributary, the Inhulets River, and in the Dnieper Reservoir itself (Pligin and Emel'yanova 1989). Due to translocations, these mysids species are currently widely distributed over the whole Dnieper reservoir cascade: they inhabit the Dnieper tributaries, the small reservoirs of the Krivbass region (Lubyanov 1960; Zhuravel' 1974; Zagubizhenko 1986) and they have even dispersed up to the upper reaches of the Dnieper in Belarus (Semenchenko et al. 2009).

The species *H. anomala* and *K. warpachowskyi* are listed in the Red Book of Ukraine as endangered species (Dovgal' 2009; Samchishina 2009). *Hemimysis anomala* was first recorded in the reservoir in 1957 and it was considered that the species was accidentally introduced along with amphipods and molluscs from the Inhulets River, the tributary of the lower Dnieper harbouring the species (Zhuravel' 1960, 1974). Recent status of this species in the Dnieper Reservoir remains unexplored. During the 1980s, the species was not observed and it was concluded that the species was threatened by increased pollution, followed by oxygen depletion in deep waters (Pligin and Emel'yanova 1989). Nevertheless, *H. anomala* has proved to be a plastic species capable to inhabit various environments in its invasive range (Stubbington 2012); thus it must still be present in the reservoir, albeit detection of this nocturnal, i.e. avoiding daylight, species warrants deep-water and night-time sampling in appropriate habitats. Another Red Book species, *K. warpachowskyi,* was first recorded in the Dnieper Reservoir in 2007, in the area of the Dnipropetrovsk city (Novitsky 2010). The current survey suggests this species is rather common and can even be locally abundant.

Two mysid species, *P. intermedia* and *P. bakuensis*, are firmly reported for the Dnieper

Reservoir for the first time. *Paramysis intermedia* is already among the dominant mysid species in the reservoir, which may suggest that its invasion (or establishment) was not very recent. It remains unclear whether this species was previously known in the Dnieper Reservoir. Based on personal investigations, Pligin et al. (2013) report the detection of *P. intermedia* in the upstream reservoirs of Kremenchug, Kanev and Kiev in 1992, 1994 and 2006, correspondingly, and suggest species presence in the Dnieper Reservoir since 1937, but provide an inappropriate reference. Thus, *P. intermedia* has probably been overlooked during the last decades; it may have been possible since externally it resembles *P. lacustris*, although the two species are easily distinguishable by the shape of the telson. *Paramysis bakuensis*, on the other hand, is the restored name of the former subspecies *P. baeri bispinosa* (Daneliya et al. 2007). This species was once mentioned as rarely occurring in the Samara Bay of the Dnieper Reservoir (Pligin and Emel'yanova 1989) but that has not been confirmed in a summarising overview on Ponto-Caspian macroinvertebrates inhabiting the cascade of Dnieper reservoirs (Pligin et al. 2013). Therefore, we consider that *P. bakuensis* was only found to inhabit the reservoir in the current study (in 2014), however in just one study site in Prydniprovs'kyi district, thus its status remains unclear and warrants further investigation.

Deliberate introductions have resulted in the establishment of *L. benedeni* and contributed to the establishment of *P. lacustris* in the Dnieper Reservoir (n.b. in the field diary of Zhuravel' from 1944–1948, there are notes on occurrence of *P. lacustris* and *L. benedeni* in the Dnieper Reservoir, however, only natural spread of *P. lacustris* over the reservoir has been referred is his publications). *Hemimysis anomala* must have been introduced accidentally. Meanwhile, the vectors of invasion of other mysid species can only be speculated. It seems that mysids *K. warpachowskyi*, *P. intermedia* and *P. bakuensis* invaded the reservoir after the period of mass deliberate introductions. The ship traffic in the Dnieper became possible after the construction of the Dnieper reservoir cascade and is now very intense (Semenchenko et al. 2015); hence, inland shipping could be the principal vector of these invasions. On the other hand, the possibility of accidental or even deliberate introductions of these mysids should not be excluded. It was mentioned that *P. intermedia* and even *P. bakuensis* (referred as *P. baeri*) had been translocated to some places in the Dnieper basin above the reservoir and even into the reservoir itself (Pligin and Emel'yanova 1989). All of these mysids, whether they were accidentally or deliberately translocated, may have remained overlooked for an extended period of time due to low densities or insufficient research effort. Finally, the probability of undocumented historical presence of these species in some habitats of the middle reaches of the Dnieper above the rapids may not be excluded; cf. mysids have been detected in the middle reaches of the Southern Bug River above the rapids preventing upstream migration (Arbačiauskas and Šidagytė unpubl. results), and this seems to be within their natural distribution (M. Son pers. communication).

The Dnieper Reservoir was a source of *L. benedeni* and *P. lacustris* introduction into the Baltic Sea basin, specifically into the Kaunas Reservoir, in 1960. These species have further expanded their invasive range through deliberate introductions and natural dispersal, and this expansion is still ongoing (Arbačiauskas 2002; Arbačiauskas et al. 2011). The bloody-red mysid *H. anomala*, which is currently expanding its range in North European waters, is actually an emigrant from the Dnieper Reservoir as well. In 1959, this species was first translocated from the Dnieper Reservoir to the Simferopol Reservoir in Crimea (Zhuravel' 1960), then in 1961, it was transferred to the Kaunas Reservoir in Lithuania (Arbačiauskas 2002) and spread further into the Baltic Sea and westward to the Rhine Delta (Audzijonyte et al. 2007). Thus, the Dnieper Reservoir is an important source habitat when tracing invasion pathways of some mysid invaders by molecular markers.

Concerning the mysid *P. lacustris*, it should be noted that the closely related species *Paramysis sowinskii* Daneliya, 2002 was recently described from other parts of Ponto-Caspian basin (Daneliya 2002). The later species has often been confused with *P. lacustris*. Molecular study of specimens recently collected in the Dnieper Reservoir and in a few Lithuanian water bodies (Audzijonyte, Baltrūnaitė and Arbačiauskas unpubl. results) has proved that mysids previously transferred to Lithuania and currently inhabiting the Dnieper Reservoir indeed belong to the species *P. lacustris*.

The contemporary mysid fauna of the Dnieper Reservoir consists of six species. Such species richness approaches the richness of natural mysid assemblages of the region, and further detection of a few other species may be predicted. New species can already be present in the reservoirs

and their detection warrants a further mysid-oriented research. It should be noted that although it has never been recorded in the Dnieper Reservoir, the presence of one more mysid species, *P. ullskyi,* can be expected, as it was historically present in the river pools downstream of the rapids (Zhuravel' 1955) and currently occurs downstream, in the Kakhovka Reservoir (Pligin et al. 2013; Arbačiauskas and Novitskiy 2014).

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