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Invasive mysids (Crustacea: Malacostraca: Mysida) in Hungary: distributions and dispersal mechanisms

Péter BORZA[1,2,*], Attila CZIROK[3], Csaba DEÁK[4], Márk FICSÓR[5], Valér HORVAI[3], Zsófia HORVÁTH[1], Péter JUHÁSZ[6], Krisztián KOVÁCS[7], Tamás SZABÓ[6] and Csaba Ferenc VAD[1,2]

1. Department of Systematic Zoology and Ecology, Eötvös Loránd University, Pázmány Péter sétány 1/C, H-1117 Budapest, Hungary.
2. Danube Research Institute, Hungarian Academy of Sciences, Jávorka Sándor utca 14., H-2131 Göd, Hungary.
3. South Transdanubian Regional Environmental Nature Conservation and Water Management Inspectorate, Laboratory, Papnövelde utca 13., H-7621 Pécs, Hungary.
4. Laboratory of the Trans-Tisanian Environmental Protection, Nature Conservation and Water Authority, Hatvan utca 16., H-4025 Debrecen, Hungary.
5. North Hungarian Environmental, Nature Conservation and Water Management Inspectorate, Measurement Center, Mindszent tér 4., H-3530 Miskolc, Hungary.
6. BioAqua Pro Environmental Protection Service Provider and Counselling Ltd., Soó Rezső utca 21., H-4032 Debrecen, Hungary.
7. North Transdanubian Regional Environmental, Nature Conservation and Water Management Inspectorate, Laboratory, Török Ignác utca 68., H-9028 Győr, Hungary.
* Corresponding author: P. Borza, E-mail: borzap@gmail.com

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Abstract. By now three invasive Ponto-Caspian mysid species have established self-sustaining populations in Hungary: *Limnomysis benedeni*, *Hemimysis anomala*, and *Katamysis warpachowskyi*. At present, *L. benedeni* has the widest distribution of the three species in the country; it occurs in all of the three major rivers (Danube, Tisa, Drava) as well as in the Lake Balaton and other rather isolated waters, while *H. anomala* and *K. warpachowskyi* currently occur only in the water system of the Danube (*sensu stricto*). The occurrences in the recently revised samples date back the arrival of *H. anomala* to 1997, almost seven years earlier than the first previously known occurrence. Based on their habitat preferences, it is probable that the two recently appeared species have not exploited their potential; their distribution is limited by geographical and hydrological barriers. On the other hand, it is probable that *H. anomala* and *K. warpachowskyi* will never have a distribution as wide as *L. benedeni* already has in this area. Our records of *L. benedeni* in numerous isolated recreational fishing ponds (reservoirs and gravel-pit lakes) imply the functioning of an effective dispersal mechanism independent of navigation, which in our opinion could only be fish stocking. We can assume that this dispersal vector is available for the two recently appeared species as well, enabling them to colonize otherwise inaccessible parts of the drainage basin. As a preventive measure, we recommend the filtering of the water pumped into fish transporting tanks.

Keywords: dispersal vectors; fishing ponds; fish stocking; *Hemimysis anomala*; *Katamysis warpachowskyi*; *Limnomysis benedeni*; Ponto-Caspian.

Introduction

Mysid crustaceans are primarily marine organisms; of the more than 1000 species described only less than 10% inhabit freshwaters (Porter et al. 2008). The global distribution of freshwater species is not even; the rich endemic Ponto-Caspian crustacean fauna featuring many euryhaline species being one of the most important sources (Porter et al. 2008). They natively inhabit the lower, slow-flowing reaches of the rivers emptying into the Black, Azov, and Caspian Seas. Since they are poor swimmers, their ability to spread against currents characteristic for the upper river sections is very limited (Wittmann 2007, Wittmann & Ariani 2009). However, due to unintentional (passive transportation by ships) and deliberate human activity (introductions) some species surpassed their range limits and have become established in several rivers and lakes throughout Europe and even in North America.

While in Eastern and Northern Europe intentional introductions played a dominant role in their spread (Mordukhai-Boltovskoi 1979, Arbačiauskas 2002, Grigorovich et al. 2002), in Central and Western Europe mysid species have expanded their ranges without deliberate human contribution. In the latter region three species have established self-sustaining populations: *Limnomysis benedeni* Czerniavsky, 1882; *Hemimysis* *anomala* G. O. Sars, 1907; and *Katamysis warpachowskyi* G. O. Sars, 1893 (Fig. 1). *L. benedeni* was first recorded outside its native range in 1946 in the Middle Danube, Hungary (Woynárovich 1954). It was first observed to spread in the Upper Danube in the 1980s (Wittmann 1995), then in the 1990s – due to the construction of the Main-Danube Canal in 1992 – it reached the River Rhine (Geissen 1997), and it is still spreading in Western Europe (Wittmann & Ariani 2009). A genetic analysis of native and invasive populations indicated the Danube Delta as the most probable source of the invasion, and the relatively high genetic diversity in the colonized waters allowed the conclusion that more than one invasion waves could have been involved (Audzijonyte et al. 2009).

The range expansion of *H. anomala* in Northern and Central Europe was noticed in the 1990s (Salemaa & Hietalahti 1993, Schleuter et al. 1998). More recently the species has reached the Mediterranean Sea in France (Wittmann & Ariani 2009), and it has also been found in England (Holdich et al. 2006), Ireland (Minchin & Holmes 2008), and even in North America (Pothoven et al. 2007), showing an extremely high spreading potential. A genetic analysis (Audzijonyte et al. 2008) has proven that two different lineages have been involved in the European range expansion; one originating from the intentionally introduced populations of Lithuania, and another that spread through the Danube-Main-Rhine system, while only the latter has reached England and America. In Hungary it was first recorded in 2005 (Wittmann 2007), but later it was also found in samples collected in 2004 (Borza 2008).

K. warpachowskyi was first observed in the Austrian, Slovakian, and Hungarian reaches of the Danube in 2001 (Wittmann 2002). Later it was recorded in the Croatian, Serbian (Wittmann 2007), and also in the German sections (Wittmann 2008). Recently, the species has been found outside the Danube basin, in Lake Constance (Hanselmann 2010) projecting its further spread in the Rhine basin. A single specimen of a fourth species, *Paramysis lacustris* (Czerniavsky, 1882) was recorded in Vienna by Wittmann (2007). However, this species has not been found again; therefore, this record probably indicates a failed establishment.

Mysids often play key roles in the ecosystems invaded; they serve as food source for fish (especially for the small size classes of predatory fish, which is the reason for their introduction into lakes and reservoirs; Woynárovich 1954), but negative impacts on the zooplankton have also been reported (Ketelaars et al. 1999); therefore, their distribution merits special attention. Most of the publications report range expansions at the global, continental, or regional scales (as summarized above), while their local distribution often gets less attention, although revealing the patterns and processes operating at this scale can lead to important conclusions. In this paper we aim to summarize all available occurrence data of invasive mysid species in Hungary, and discuss their current, potential, and realistic distributions in the light of their habitat preferences and presumable dispersal mechanisms.

Material and Methods

The records discussed here originate from the following sources: (1) sampling campaign of the first author focused on mysids (2006-2010; by hand net (450 µm mesh size); samples taken mostly by night to make the effective collection of the nocturnally active *H. anomala* possible, method described in detail in Borza (2009)); (2) records of the surveys of Regional Inspectorates for Environment, Nature, and Water; and BioAqua Pro Environmental Protection Service Provider and Counselling Ltd. (1995-2010; macroinvertebrate samples taken according to the AQEM protocol, AQEM Consortium 2002); (3) zooplankton survey in recreational fishing ponds between April and September 2010 (hand net of 45 µm mesh size, 15 cm diameter, round); (4) Collection of Crustacea and Other Aquatic Invertebrates of the Hungarian Natural History Museum (1997-2006); (5) "kick and sweep" samples of the Joint Danube Survey 2 (August 2007) organized by the International Commission for the Protection of the Danube River (ICPDR); (6) records published by Borza (2007, 2008, 2009), Holló et al. (2008), Petri et al. (2009), and Wittmann (2007). The samples cover all the major publicly owned waters of Hungary (rivers, streams, canals, large lakes). The representative survey of the numerous fishing ponds throughout the country was not possible within the confines of this investigation; our efforts were concentrated to the Northern Medium Mountains (source (3)) and the vicinity of Budapest (source (1); altogether 40 ponds).

To assess whether water pumps (used by fishermen to fill fish transport tanks, see "Discussion" for explanation) can bring up mysid specimens from the littoral zone of rivers, tests were performed on 21 October 2010 in the Danube main arm at Göd (47°40'43.08"N, 19° 7'29.83"E). The site can be characterized as a shallow bank typical of the Middle Danube with gravel-sand substratum. A Honda WA20 motor pump was used with the original accessory suction hose strainer (1 cm mesh size). The presence of mysids was checked in 10 replicate samples of approximately 240 litres each (4 litres per second for 1 minute), taken from 30-80 cm water depth. To assess survival rates, *L. benedeni* and *K. warpachowskyi* specimens collected by hand net in the winter harbour of Újpest (47°32'59.29"N, 19° 3'58.01"E; on 5 November 2010 by day) were transported to Göd and let through the pump mentioned above (with the same speed). After the procedure the proportion of viable, actively swimming individuals was determined.

Results

Limnomysis benedeni Czerniavsky, 1882 (Fig. 2a)

L. benedeni occurred in the whole course of the Danube River and in many of its sidearms and oxbows, in connected canals (Kiskunság area), in the lower reaches of some of its tributaries (Raba, Rabca, Sio) and also in the stream Karasica.

It is widely distributed in the River Tisa system; in the river itself its most upstream occurrence was detected in the headwater of the dam at Tiszalök (rkm 519), but some sporadic records indicate its presence in some canals (Dédai-Mitz, Lónyai) even more upstream in the river system. It is also present in the connected canal network of the Hortobágy-Nagykunság area, in the lower section of the River Zagyva, in the River Cris system, and in numerous oxbows.

In the River Drava its most upstream occurrence has been recorded at Vízvár (rkm 192), and it has also been found in some of its oxbows.

From Lake Balaton, where it was introduced successfully in 1950 (Woynárovich 1954), it penetrated into the recently reconstructed Kis-Balaton Water Protection System and into the lower section of the River Zala. It is also present in the second largest natural lake of the Carpathian Basin, the Fertő (Lake Neusiedl), but not in the third one, Lake Velencei. Its presence in several recreational fishing ponds (reservoirs and gravel-pit lakes) has also been proven; it occurred in 10 of the 40 investigated sites (Table 1).

Hemimysis anomala G. O. Sars, 1907 (Fig. 2b)

In the collection of the Natural History Museum two zooplankton samples (leg. László Forró) dating from 04.10.1997 contained juvenile specimens of *H. anomala.* The samples were taken in the most upstream part of the Hungarian Danube section, at Rajka and Doborgazsziget (Szigetköz area; rkm 1849, 1838).

In recent years the species has been found all along the Hungarian Danube reach and in the adjacent canal network of the Kiskunság area. It has also been recorded in the lower sections of the Benta stream (emptying into the Danube at Százhalombatta), and in the River Sio. In the night samples taken in the Lake Balaton and in the rivers Tisa and Drava (in the harbours of Siófok and Szeged, and on the rip-rap at Drávaszabolcs, respectively, where the first appearance of the species in these waters is most likely), *H. anomala* did not occur in the autumn of 2009.

Katamysis warpachowskyi G. O. Sars, 1893 (Fig. 2c)

K. warpachowskyi has been found in the whole course of the Hungarian Danube section. In the Szigetköz area it also occurred in many of the waters of the active alluvial floodplain and the protected area (sidearms, oxbows). It has been found in the Ráckevei-Soroksári Danube-arm and in the connected canal network of the Kiskunság area. Similar to *H. anomala*, in the autumn of 2009 it was present neither in the rivers Tisa and Drava, nor in Lake Balaton.

Water pump tests

The water pump sampling in the Danube at Göd yielded two mysid specimens (1 *L. benedeni*, 1 *K. warpachowskyi*); both were intact. In the survival test the proportion of actively swimming animals after pumping was exactly 50% (150/300) for *L. benedeni* and 82% (18/22) for *K. warpachowskyi*.

Discussion

Invasion history of *H. anomala*

The first record of *H. anomala* for Hungary in 2005 was published by Wittmann (2007), but later it has been found in samples from 2004, as well (Borza 2008). The occurrences in the recently revised samples of the Natural History Museum date back the arrival of the species to 1997, almost seven years earlier than the first occurrence previously known. These uncertainties about the appearance of the species are primarily attributable to its relatively low detectability by standard sampling practices due to its nocturnal activity, and underline the necessity of revising archive materials.

The records from 1997 are in accordance with the conclusions of Audzijonyte et al. (2008), presuming an upstream range expansion of the species along the Danube-Main-Rhine system. However, it is not informative as to whether the spread was more continuous than could be inferred from the Austrian records from 1997/1998 (Wittmann et al. 1999) and the absence of the species in the samples from 2001-2004 in Hungary (Wittmann 2007), or the Hungarian records represent only the

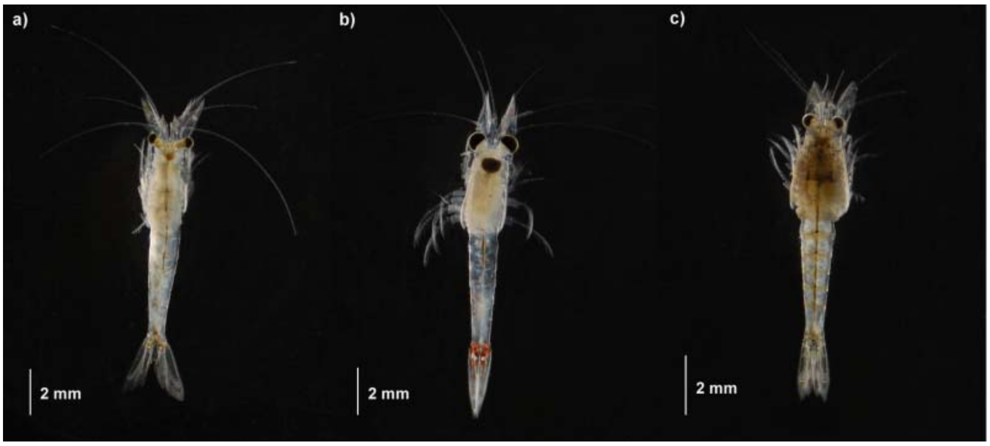
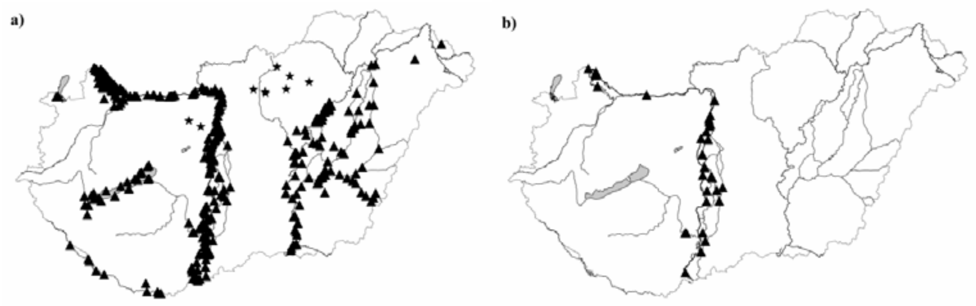


Figure 1. Invasive mysid species present in Hungary:
a) *Limnomysis benedeni*, **b)** *Hemimysis anomala*, and **c)** *Katamysis warpachowskyi* (overwintering specimens).



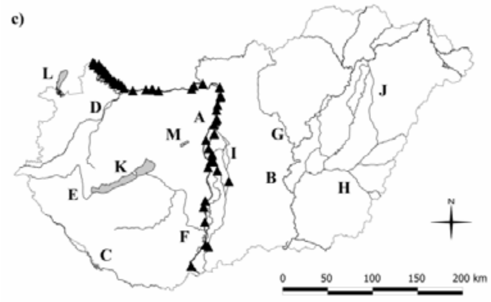


Figure 2. Distributions of
a) *Limnomysis benedeni*,
b) *Hemimysis anomala*, and
c) *Katamysis warpachowskyi* in Hungary.
[Asterisks represent records in fishing ponds.
Legends: A = River Danube, B = River Tisa, C = River Drava, D = River Raba, E = River Zala, F = River Sio, G = River Zagyva, H = River Cris, I = canal network of Kiskunság, J = canal network of Hortobágy-Nagykunság, K = Lake Balaton, L = Fertő (Lake Neusiedl), M = Lake Velencei]

Table 1. Records of *Limnomysis benedeni* in fishing ponds.

Date	Locality	Latitude (N)	Longitude (E)	Collectors
24.04.2010	Palotás	47°48'38.03"	19°35'42.99"	Zs. Horváth, Cs.F. Vad
24.04.2010	Rózsaszentmárton	47°46'22.72"	19°46'28.47"	Zs. Horváth, Cs.F. Vad
24.04.2010	Szücsi	47°47'17.44"	19°46'6.21"	Zs. Horváth, Cs.F. Vad
26.04.2010	Recsk	47°56'20.92"	20° 8'18.38"	Zs. Horváth, Cs.F. Vad
26.04.2010	Mátraterenye	48° 2'3.21"	19°56'52.38"	Zs. Horváth, Cs.F. Vad
26.04.2010	Markaz	47°48'36.16"	20° 4'51.22"	Zs. Horváth, Cs.F. Vad
27.04.2010	Ostoros	47°52'42.22"	20°25'26.63"	Zs. Horváth, Cs.F. Vad
12.05.2010	Dunakeszi	47°36'14.40"	19° 7'34.39"	P. Borza
10.06.2010	Biatorbágy	47°26'16.01"	18°48'52.96"	P. Borza
10.06.2010	Bicske	47°29'52.98"	18°38'18.20"	P. Borza

downstream drift from the Austrian populations. In the light of our results the absence of the species in the surveys mentioned above can be explained by its still low abundance and/or sporadic occurrence in the early stage of its invasion.

Current and potential distributions

At present, *L. benedeni* has by far the widest distribution of the three species in Hungary; it occurs in all of the three major rivers (Danube, Tisa, Drava) as well as in the Lake Balaton and other rather isolated waters, while at present *H. anomala* and *K. warpachowskyi* occur only in the water system of the Danube (*sensu stricto*). This is in accordance with the dates of their arrival; *L. benedeni* has had much more time to disperse, and by now we can assume that, taking considerable waters into account, it has approached its potential range in this area. Contrarily, based on the habitat preference of the two recently appeared species it is probable that they have not exploited their potential; their distribution is limited by geographical and hydrological barriers.

H. anomala is essentially a nocturnally active semi-pelagic species, seeking shelter by day. According to the observations of the last years' survey, *H. anomala* inhabits rip-raps providing daytime refuge in the Danube but only with moderate currents. The highest abundance of the species has been observed in artificial inlets with rip-rap embankments (i.e. winter harbours), where they are protected from currents entirely. The records in the Kiskunság have shown that the riparian reed belt can also provide suitable shelter for the species, given the water is relatively deep and well-oxygenated (Borza 2009), while other publications (Borcherding et al. 2006, Dumont 2006) indicate that deep gravel-pit lakes are suitable for the species as well. Based on these observations it can be assumed that some sites of the River Tisa system would be suitable for the species, i.e. the winter harbour of Szeged and the headwaters of dams (Kisköre, Tiszalök, and those of the River Cris), while the relatively fast-flowing Hungarian reach of the River Drava, devoid of dams and inlets, is not tolerable for it. The deep harbours of the Lake Balaton would definitely be favourable for *H. anomala*, and it is also conceivable that it could colonize the reed belt. The rip-rap embankments of the lake are very wave-exposed, therefore, its successful establishment in this habitat-type is dubious, as well as whether the offshore zone of the lake is deep enough for the species.

The habitat preference of *K. warpachowskyi* can be characterised by its affinity to solid surfaces (i.e. stones, gravel, deposits of bivalve shells, coarse detritus), or – from the other point of view – the avoidance of sandy and muddy substrates. This feature significantly limits the range of waters potentially available for the species; however, as our records from the canals of Kiskunság show, waters not abound with suitable habitats are also able to support the species. Taking this consideration into account, it is probable that, similarly to *H. anomala*, *K. warpachowskyi* would also be able to form self-sustaining populations outside its present range, i.e. in the Lake Balaton and in the Tisa and Drava rivers.

Although we can assume that the two recently established species would be able to colonize new areas, it is probable that *H. anomala* and *K. warpachowskyi* will never have a distribution as wide as *L. benedeni* already has in this area. The ability of *L. benedeni* to inhabit relatively shallow, still waters with submerged vegetation and muddy substrata, characteristic of isolated lakes and oxbows, seems to be unique among the three species.

Dispersal mechanisms

The "realistic" range of a species, i.e. to which extent it can approach its potential range, depends on the dispersal mechanisms available. Natural ways of migration in the mysid species in question are limited by their poor swimming ability. Our records of *L. benedeni* in the lower reaches of some of the tributaries of the Danube and of *H. anomala* in the artificial, slow-flowing part of the Benta stream near the mouth can be most likely attributed to the flood dynamics of the river, swelling the tributaries at high water levels and so enabling the species to enter into them without resistance. On the contrary, the presence of *H. anomala* in the Sio, about 20 river km away from the mouth, probably indicates active migration in this slow-flowing lower section of the river. However, further active spread of the species in the river is not probable, given the conditions in the upper sections are rather characteristic of a stream in most of the year (shallow, fast-flowing water), and the short periods of increased water discharge from the Lake Balaton involving strong currents do not seem to favour its upstream migration, either.

The human-assisted vectors associated with mysid range expansions include transport by ships (in ballast and bilge water, or on cooling water filters), unintentional releases with other animals and plants, and aquarist trade (summarized by Wittmann & Ariani 2009). These are obviously not equivalent; they involve different donor and target waters, and operate on different spatial scales. Although ballast water may be the most efficient long-distance vector, after the arrival in a river system it cannot facilitate further spread into more or less isolated waters (tributaries, oxbows, lakes). Ship traffic on the Tisa, Drava, and Sio rivers is weak and rather incidental, being restricted mainly to small passenger ships and yachts not using ballast water, although transport in other parts, e.g. in bilge water, or on cooling water filters cannot be excluded. Albeit the contribution of aquarist trade may be realistic in certain relations, its role can be regarded as rather haphazard.

Our records of *L. benedeni* in numerous isolated recreational fishing ponds imply the functioning of an effective dispersal mechanism independent of navigation. In our opinion fish stocking is the only conceivable vector that could provide explanation for these observations. While the most important game fishes in Hungary, common carp (*Cyprinus carpio* Linnaeus, 1758), pike-perch (*Sander lucioperca* Linnaeus, 1758), pike (*Esox lucius* Linnaeus, 1758), etc. are usually raised in aquacultures under intensive conditions probably not tolerable for mysids (as some of our negative samples indicate), whitefish are often restocked from large rivers and lakes (Danube, Tisa, Balaton). Unfortunately, direct investigation of fish transports was not possible for us, but the information gained from personal communications by anonymous fishing associations allows us to evaluate the probability of mysids to be transported to fishing ponds in this manner.

The fish are transferred to the ponds in tanks on lorries. Although the fish are put into the containers by hand nets of large mesh size or by hand, the tanks are usually (but not in all of the cases) filled up from the source water by motor pumps. Although in some cases mosquito nets are used to filter the water, in other cases only the accessory strainers of the water pumps are applied, which are easily permeable for all size classes of mysids. As our results show, pumping is not harmless for the animals, nonetheless a considerable proportion of them survive the procedure. The conditions in the water of the tanks are not hostile; the water is usually artificially oxygenated. The fish transported are usually large specimens of cyprinids (e.g. common bream, *Abramis brama* Linnaeus, 1758) which are not typical predators of mysids (Specziár et al. 1997), so the consumption of them by the stressed fish during the transport is not likely. After the arrival at the destination, fish are flushed into the ponds on slides along with the water. In summary, there are no conditions that could be identified as drastic mortality factors; mysids can be assumed to have a realistic chance of surviving a fish stocking transport.

The presence of mysids in fishing ponds is *per se* noteworthy, since these are the ecosystems where their effect is the most directly perceptible for the society. However, once successfully established in a reservoir, the subsequent drift in the discharging stream (as exemplified by the presence of *L. benedeni* in the Karasica stream downstream of a reservoir) also enables the species to colonize otherwise inaccessible parts of drainage basins; or, if established in an oxbow – of which many are utilized and maintained by anglers – floods can flush the animals directly into the river. In our opinion this is the most probable scenario of how *L. benedeni* may have spread into the Tisa and Drava basins (of course, other explanations cannot be excluded with full certainty, either).

We can assume that this dispersal vector is available for the two recently appeared species as well. Our record of *K. warpachowskyi* in the water pump samples provides evidence that the species can be pumped into the tanks with the water taken from typical shallow banks. Although *H. anomala* usually cannot be found in such habitats, specimens swept away by currents (as in drift net samples; Wittmann 2007) may still be sucked in by pumps. Should the water be taken on rip-raps, the probability of transporting the two recent newcomers would be even higher. Based on their habitat preferences, their chance to successfully establish in the lakes can be estimated lower as compared to *L. benedeni*; however, some of these waters (e.g. relatively large, deep reservoirs) may be suitable especially for *H. anomala*. Since this species may have negative impacts for the ecosystems invaded due to its zooplankton consumption (Ketelaars et al. 1999), which could be of high concern especially in the economically important Lake Balaton, we make a proposal for filtering the water pumped into fish tanks as a preventive measure. For this purpose we recommend a canvas bag attached to the discharge hose of the pump. In addition, we would like to draw attention to the necessity of monitoring recreational fishing ponds – usually ignored in biodiversity surveys – , which are integral parts of the water network, and can function as intermediate stations of range expansions.

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References

AQEM Consortium (2002): Manual for the application of the AQEM system. A comprehensive method to assess European streams using benthic macroinvertebrates, developed for the purpose of the Water Framework Directive. Version 1.0. www.aqem.de/mains/products.php, accessed on 04.11.2010.

Arbačiauskas, K. (2002): Ponto-Caspian amphipods and mysids in the inland waters of Lithuania: history of introduction, current distribution and relations with native malacostracans. pp.104-115. In: Leppäkoski, E., Gollasch, S., Olenin, S. (eds.) Invasive aquatic species of Europe – distribution, impacts and management. Kluwer Academic Publishers.

Audzijonyte, A., Wittmann, K.J., Väinölä, R. (2008): Tracing recent invasions of the Ponto-Caspian mysid shrimp *Hemimysis anomala* across Europe and to North America with mitochondrial DNA. Diversity and Distributions 14: 179-186.

Audzijonyte, A., Wittmann, K.J., Ovcarenko, I., Väinölä, R. (2009): Invasion phylogeography of the Ponto-Caspian crustacean *Limnomysis benedeni* dispersing across Europe. Diversity and Distributions 15: 346-355.

Borcherding, J., Murawski, S., Arndt, H. (2006): Population ecology, vertical migration and feeding of the Ponto-Caspian invader *Hemimysis anomala* in a gravel-pit lake connected to the River Rhine. Freshwater Biology 51: 2376-2387.

Borza, P. (2007): Contribution to the Macroinvertebrate Fauna of the Hungarian Danube. III. Mysid Shrimps (Crustacea: Mysidacea). Folia Historico-naturalia Musei Matraensis 31: 125-129.

Borza, P. (2008): Recent Establishment of the Invasive Ponto-Caspian Mysid *Hemimysis anomala* in the Hungarian Part of the Danube River. Aquatic Invasions 3: 99-101.

Borza, P. (2009): Spread of invasive mysids (Crustacea: Mysida) in the River Danube water system: Ráckeve-Soroksári Danube arm, canal network of the Kiskunság. Acta Biologica Debrecina Supplementum Oecologica Hungarica 20: 21-26.

Dumont, S. (2006): A new invasive species in the north-east of France, *Hemimysis anomala* G.O. Sars, 1907 (Mysidacea). Crustaceana 79: 1269-1274.

Geissen, H.P. (1997): Nachweis von *Limnomysis benedeni* Czerniavski (Crustacea: Mysidacea) im Mittelrhein. Lauterbornia 31: 125-127.

Grigorovich, I.A., MacIsaac, H.J., Shadrin, N.V., Mills, E.L. (2002): Patterns and mechanisms of aquatic invertebrate introductions in the Ponto-Caspian region. Canadian Journal of Fisheries and Aquatic Sciences 59:1189-1208.

Hanselmann, A.J. (2010): *Katamysis warpachowskyi* Sars, 1877 (Crustacea, Mysida) invaded Lake Constance. Aquatic Invasions 5 (Suppl. 1): S31-S34.

Holdich, D., Gallagher, S., Rippon, L., Harding, P., Stubbington, R. (2006): The invasive Ponto-Caspian mysid, *Hemimysis anomala*, reaches the UK. Aquatic Invasions 1: 4-6.

Holló, I.P., Petri, A., Nagy-László, Zs. (2008): Contribution to the macroinvertebrate fauna of small watercourses and small and medium sized standing waters from south part of the Great Hungarian Plain. Acta Biologica Debrecina Supplementum Oecologica Hungarica 18: 191-201. [in Hungarian]

Ketelaars, H.A.M., Lambregts-van de Clundert, F.E., Carpentier, C. J., Wagenvoort, A.J., Hoogenboezem W. (1999): Ecological effects of the mass occurrence of the Ponto-Caspian invader, *Hemimysis anomala* G. O. Sars, 1907 (Crustacea: Mysidacea), in a freshwater storage reservoir in the Netherlands, with notes on its autecology and new records. Hydrobiologia 394: 233-248.

Minchin, D., Holmes, J.M.C. (2008): The Ponto-Caspian mysid, *Hemimysis anomala* G. O. Sars 1907 (Crustacea), arrives in Ireland. Aquatic Invasions 3: 257-259

Mordukhai-Boltovskoi, F.D. (1979): Composition and distribution of Caspian fauna in the light of modern data. Internationale Revue der Gesamten Hydrobiologie 64: 1-38.

Petri, A., Holló, I.P., Nagy-László, Zs. (2009): Contribution to the macroinvertebrate fauna of small and medium sized watercourses from southern part of the Great Hungarian Plain, part 2. Acta Biologica Debrecina Supplementum Oecologica Hungarica 20: 181-191. [in Hungarian]

Porter, M.L., Meland, K., Price, W. (2008): Global diversity of mysids (Crustacea-Mysida) in freshwater. Hydrobiologia 595: 213-218.

Pothoven, S.A., Grigorovich, I.A., Fahnenstiel, G.L., Balcer, M.D. (2007): Introduction of the Ponto-Caspian Bloody-red Mysid *Hemimysis anomala* into the Lake Michigan Basin. Journal of Great Lakes Research 33: 285-292.

Salemaa, H., Hietalahti, V. (1993): *Hemimysis anomala* G. O. Sars 1907 (Crustacea: Mysidacea) – Immigration of a Ponto-Caspian mysid into the Baltic Sea. Annales Zoologici Fennici 30: 271-276.

Schleuter, A., Geissen. H.P., Wittmann, K.J. (1998): *Hemimysis anomala* G. O. Sars 1907 (Crustacea: Mysidacea), eine euryhaline pontokaspische Schwebgarnele in Rhein und Neckar. Erstnachweis für Deutschland. Lauterbornia 32: 67-71.

Specziár, A., Tölg, L., Bíró, P. (1997): Feeding strategy and growth of cyprinids in the littoral zone of Lake Balaton. Journal of Fish Biology 51: 1109-1124.

Wittmann, K.J. (1995): Zur Einwanderung potamophiler Malacostraca in die obere Donau: *Limnomysis benedeni* (Mysidacea), *Corophium curvispinum* (Amphipoda) und *Atyaephyra desmaresti* (Decapoda). Lauterbornia 20: 77-85.

Wittmann, K.J., Theiss, J., Banning, M. (1999): Die Drift von Mysidaceen und Dekapoden und ihre Bedeutung für die Ausbreitung von Neozoen im Main-Donau-System. Lauterbornia 35: 53-66.

Wittmann, K.J. (2002): Weiteres Vordringen pontokaspischer Mysidacea (Crustacea) in die mittlere und obere Donau: Erstnachweise von *Katamysis warpachowskyi* für Ungarn, die Slowakei und Österreich, mit Notizen zur Biologie und zum ökologischen Gefährdungspotential. Lauterbornia 44: 49-63.

Wittmann, K.J. (2007): Continued massive invasion of Mysidae in the Rhine and Danube river systems, with first records of the order Mysidacea (Crustacea: Malacostraca: Peracarida) for Switzerland. Revue Suisse de Zoologie 114: 65-86.

Wittmann, K.J. (2008): Weitere Ausbreitung der pontokaspischen Schwebgarnele (Crustacea: Mysida: Mysidae) *Katamysis warpachowskyi* in der oberen Donau: Erstnachweis für Deutschland. Lauterbornia 63: 83-86.

Wittmann, K.J., Ariani, A.P. (2009): Reappraisal and range extension of nonindigenous Mysidae (Crustacea, Mysida) in continental and coastal waters of eastern France. Biological Invasions 11: 401-407.

Woynárovich, E. (1954): Vorkommen der *Limnomysis benedeni* Czern. im ungarischen Donauabschnitt. Acta Zoologica Academiae Scientiarum Hungaricae 1: 177-185.