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RANGE EXPANSION OF PONTO-CASPIAN MYSIDS (MYSIDA, MYSIDAE) IN THE RIVER TISZA: FIRST RECORD OF PARAMYSIS LACUSTRIS (CZERNIAVSKY, 1882) FOR HUNGARY

BY

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ABSTRACT

In the River Tisza, the longest tributary of the Danube, Limnomysis benedeni Czerniavsky, 1882 had been the only mysid recorded until recently. In 2011, we found a few juvenile specimens of Hemimysis anomala G. O. Sars, 1907 in two daytime samples taken from the Hungarian river section. During the overnight survey in 2012 aimed at revealing the actual distribution of this nocturnally active species, its most upstream occurrence was detected at Szolnok (river km 334). Paramysis lacustris (Czerniavsky, 1882) was also found at every sampling site of the river downstream of Tiszabercel (rkm 568), representing the first record

of the species for the fauna of Hungary, and its most upstream self-sustaining population in the River Danube basin (1759 rkm from the Danube mouth). P. lacustris is the fourth Ponto-Caspian mysid species which began to expand its range spontaneously in the Danube catchment after L. benedeni, H. anomala, and Katamysis warpachowskyi G. O. Sars, 1893. Due to its zooplanktivory it can be anticipated to have a considerable effect on the composition and abundance of the zooplankton assemblages and it may also become an important food source of certain fish species, especially in the impounded reaches and in stagnant or slow-flowing backwaters. P. lacustris – similarly to H. anomala – shows a diel vertical migration, moving to shallow waters only by night, which calls for increased attention in order to reveal its possible future range expansions. Although the River Tisza itself is not connected directly to other river basins via canals, it may potentially contribute to the further spread of the species (e.g., via fish stocking).

ZUSAMMENFASSUNG

INTRODUCTION

Several of the mysid species endemic to the Ponto-Caspian region have expanded their distributional ranges considerably as a result of both deliberate and unintentional human activities (Bij de Vaate et al., 2002). Eight species served as popular objects of intentional introductions aimed at enriching the fauna of large reservoirs created during the 20th century in the former Soviet Union (Grigorovich et al., 2002), and three of these have also colonized formerly unattainable catchments within and even outside of continental Europe spontaneously, probably promoted by shipping.

The Danube river basin – being part of the so called „southern invasion corridor” (Bij de Vaate et al., 2002) – played a prominent role in the westward range expansion of these species. Limnomysis benedeni Czerniavsky, 1882 colonized the Hungarian reach of the River Danube already in the middle of the 20th century (Woynárovich, 1954), and after the opening of the Danube-Main-Rhine canal in 1992 it appeared in the Rhine and other connected West-European catchments (Geissen, 1997; Audzijonytė et al., 2009; Wittmann & Ariani, 2009). Hemimysis anomala G. O. Sars, 1907 was found at several sites in Hungary, Austria, and Germany first in 1997-98 (Schleuter et al., 1998; Wittmann et al., 1999; Borza et al., 2011). Meanwhile, another lineage of the species began to spread in the Baltic Sea (Salemaa & Hietalahti, 1993), and eventually mingled with the Danubian lineage in the Rhine (Audzijonytė et al., 2008). The species has since appeared in the British Isles (Holdich et al., 2006; Minchin & Holmes, 2008) and in North America (Pothoven et al., 2007), which populations could also be traced back to the Danube basin (Audzijonytė et al., 2008). The third species, Katamysis warpachowskyi G. O. Sars, 1893 was first found in the Austrian and Hungarian Danube section in 2001 (Wittmann, 2002). Since then it has reached the German stretch (Wittmann, 2008), and recently it was also detected in Lake Constance (Hanselmann, 2010).

Paramysis (Serrapalpisis) lacustris (Czerniavsky, 1882), similarly to the three species mentioned above, has been stocked into several reservoirs and lakes in the former Soviet Union, ranging from Lithuania to Tajikistan (Khmeleva & Baichorov, 1987). Although it established successfully in the target waters in most of the cases, its distribution remained rather local. For example, from the Kaunas reservoir in Lithuania it has colonized the downstream river section and the oligohaline Curonian Lagoon of the Baltic Sea, but has not crossed the borders of the country, as yet (Arbačiauskas, 2002; Arbačiauskas et al., 2011). In the Danube river basin its native range stretched to river km (hence: rkm) 624 (Wittmann, 2007); however, recently it was also detected in the Serbian reach upstream of the Iron Gates up to rkm 1300 (Paunović et al., 2007; Marković et al., 2012). Surprisingly, a single specimen of P. lacustris was found in an almost isolated backwater of the Danube in Vienna (Alte Donau) in 2004, but the species apparently failed to establish there (Wittmann, 2007).

Within the Danube river basin, evidently the Danube itself can be regarded as the main corridor of species invasions (e.g., Bódis et al., 2012); however, some Ponto-Caspian species have colonized the largest tributaries, as well (e.g., Žganec et al., 2009; Borza, 2011). In the Hungarian section of the River Tisza, L. benedeni appeared some time in the second half of the 20th century (according to Woynárovich (1954) it was still not present around 1950, but data from the following period are rather scarce), and had been the only mysid recorded until recently (Borza et al., 2011). Hereby we report on the finding of two additional species, H. anomala and P. lacustris.

MATERIAL AND METHODS

The 966 river km long River Tisza is the longest tributary of the Danube, entering it in Serbia at rkm 1215. Its catchment area (157 186 km^2) is also the largest among the tributaries, while its mean discharge (~ 800 m^3/s) is the second after the River Sava. It has two lowland impoundments at Kisköre (rkm 404, the so called „Lake Tisza") and at Tiszalök (rkm 518). It is renowned for its richness in suspended inorganic particles ("blonde Tisza"), for which the bed material is fine (clay, sand, mud) in most of its course (downstream of Vásárosnamény, rkm 686).

Samples were taken at altogether 15 sites of the River Tisza (between rkm 168 and 568) and some of its major tributaries with a hand net (mesh size: 450 µm, aperture: 40 x 30 cm, handle length 1.6-3.9 m) during daytime on the two occasions in 2011, and by night in

2012 to allow the effective collection of the nocturnally active H. anomala. The collected specimens were preserved in 96% ethanol.

P. lacustris (fig. 1) was identified based on Băcescu (1954), taking the modifications and supplementations of Daneliya (2002), Daneliya et al. (2007) and Daneliya & Petryashov (2011) into account. The most important features distinguishing P. lacustris from related species are the shape of its antennal scale and telson (fig. 2A-B). In addition, the ventral setae of the proximal segment of the mandibular palp are not roughly notched (fig. 2C), and the carpal segment of the pereiopod endopods bear less than 6 groups of setae on the ventral side (fig. 2D), distinguishing it from its closest relative, Paramysis (Serrapalpisis) sowinskyi Daneliya, 2002. Specimens of P. lacustris have been deposited in the Collection of Crustacea and Other Aquatic Invertebrates of the Hungarian Natural History Museum.

The body length of ovigerous females and mature males of P. lacustris was determined from the tip of the rostrum to the distal end of the telson without spines (total length, TL), based on digital pictures from lateral view with tpsDig2.14 picture analyzing software (Rohlf, 2009). A Welch test (t-test for unequal variances) was performed to test the difference between the TL of the genders statistically using R 2.11.0 (R Development Core Team, 2010). The brood of ovigerous females was counted under stereomicroscope (only presumably intact brood pouches).

RESULTS

Three mysid species could be identified in the samples (table I, fig. 3). A few juvenile specimens of H. anomala were already found in 2011, while during the survey in 2012 its most upstream occurrence was detected at Szolnok (rkm 334). P. lacustris was not found in 2011; however, in the 2012 survey it was recorded at every investigated site in the Tisza except for the most upstream location at Tiszabercel (rkm 568), where no mysids were present. Its most upstream occurrence in the river was at Tokaj (rkm 543), and it was also present in the River Bodrog, close to its mouth (rkm 1), but not in the River Körös at rkm 21. L. benedeni was present in all of the samples from the Tisza downstream of Tiszabercel as well as in the tributaries investigated.

Ovigerous females of P. lacustris (TL: 10.21 ± 0.72 mm (mean ± SD), n = 33, range: 8.97-12.46 mm) were significantly larger (Welch test, $t = -8.72$, $df = 42.74$, $p < 0.0001$) than mature males (TL: 8.76 ± 0.42 mm, n = 15, range: 8.06-9.81 mm). The fecundity of the animals ranged between 7 and 18 (12.17 ± 2.75, n = 29), it must be noted, however, that the brood of the largest female could not be counted.

DISCUSSION

Our records of H. anomala and P. lacustris are the first for the Tisza catchment, and in the case of the latter species they also represent the first record for the fauna of Hungary and the most upstream self-sustaining population in the Danube basin (in the River Bodrog at Tokaj, 1759 rkm from the Danube mouth). Considering the common occurrence of the species along a several hundred kilometres long reach of the river, it can be concluded that their actual appearance must have happened at least a couple of years ago. On the other hand, they have not been found in the rich material examined by Borza et al. (2011). Even if conventional macroinvertebrate samples – comprising the bulk of that material – cannot be regarded strictly as representative, the absence of the species in the nightly, mysid-focused samples taken at Szolnok and Szeged (on 06.viii.2009 and 25.x.2009, respectively; leg. Borza) allow the inference that they have probably not been overlooked for a longer period.

Their apparently abrupt appearance suggests that the species reached their most upstream occurrence by jump dispersal, as assumed in most long-distance mysid range expansions (e.g., Wittmann, 2002, 2007), and colonized the intermediate river section by drifting downstream. International shipping – the most obvious vector – is legally allowed on the river only since the joining of Hungary to the European Union in 2004. Since the characteristics of the river (e.g., narrow channel, hectic water level fluctuations) are not fortunate for shipping, the traffic is weak; there is only one international passenger ship which regularly (twice a year, if possible) travels up to Tokaj (Tokaj Shipping Service, North Hungarian Environment and Water Directorate, personal communication). If further travel is not possible, the ship usually ends its journey at Szolnok. However weak the traffic is, still, navigation is the only vector which can be reasonably related to the spread of the species. The correspondence between the most upstream occurrences of the species and the shipping hubs also gives support to this explanation. Of course, other factors, such as overland transport of fish or boats can not be excluded; however, to our present knowledge they are lacking any factual support. In the case of H. anomala, dispersal within the country via fish stocking is also a plausible, although not corroborated possibility (Borza et al., 2011).

The biology of P. lacustris – in part owing to its involvement in intentional introductions – is relatively well-studied. The body length of the species may attain 16-19 mm in the overwintering generation and 10.5-14 mm in the summer months in the lower Danube according to Băcescu (1954), while Khmeleva & Baichorov (1987) reported on 12.45-14.20 mm and 10.14-10.91 mm average female body length in the overwintering generation and in the first spring generation, respectively, in different native and introduced populations across the former Soviet Union. The average fecundity of the species varied within a wide range among these populations (between 10.5-24.6 eggs/female in the first spring generation and 19.6-42.5 eggs/female in the overwintering generation according to

Khmeleva & Baichorov (1987)), while Băcescu (1954) indicated a range of 10-20 eggs. Our results on both parameters fit well to these ranges, showing the closest affinity to the Lithuanian population (Khmeleva & Baichorov, 1987), but the factors determining the considerable intraspecific variation are poorly known. P. lacustris is a relatively stenohaline species, typically occurring at salinities between 0-3 PSU (Practical Salinity Unit) within its native range, but in the Baltic Sea it has been observed to form viable populations even at 5-6 PSU (Daneliya, 2002; Ovčarenko et al., 2006). It can tolerate a wide range of temperatures, well reflected in its wide distribution spanning between ~39-56º N latitude (approximate values based on Khmeleva & Baichorov (1987)), so its new environment represents no extremity in this regard.

P. lacustris is usually considered as a psammo-pelophilic species (i.e., preferring sandy-muddy substrata) (Băcescu, 1954; Dediu, 1966). Our results indicate that it can also be found on rip-raps, but the sampling was not systematic enough for a detailed appraisal of its substrate preference. It inhabits both lacustrine and riverine habitats within its native range (Băcescu, 1954), and it seems to be able to withstand the currents characteristic of the littoral region of the Hungarian section of the River Tisza, as our records at several free-flowing sites indicate. It shows a definite diel vertical migration; according to Băcescu (1954) it resides in depths > 2 m by day, while during the night it ascends to shallower waters (< 1 m deep). Similarly to H. anomala, this feature makes it hard to detect the species by conventional sampling procedures, which calls for increased attention in order to reveal its possible future range expansions. The habitat utilisation of P. lacustris also might change seasonally; Băcescu (1954) pointed out that in the winter the animals migrate to deep parts of the water, while Lesutienė et al. (2008) detected a migration to the shoreline during the autumn in the Curonian Lagoon. The authors attributed this to increased predation pressure and deteriorated feeding conditions in the open water, where most of the animals reside during the summer. In accordance with the habitat use the feeding of P. lacustris may also vary seasonally; in the Curonian Lagoon zooplankton was the main food source of the species in the open water in the summer, while in the autumn the animals shifted their diet to decaying submersed macrophytes and phytoplankton in the nearshore region (Lesutienė et al., 2007, 2008).

What are the possible consequences of the appearance of P. lacustris in the light of this knowledge? Due to its zooplanktivory it can be anticipated to have a considerable effect on the composition and abundance of the zooplankton assemblages (such as detected by Ketelaars et al. (1999) in the case of H. anomala), especially in the impounded reaches and in stagnant or slow-flowing backwaters, where the species itself can find hospitable environment and the conditions of the formation of an ample zooplankton stock are provided. It also may become an important food source of certain fish species (Băcescu, 1954; Rakauskas et al., 2010); however, Arbačiauskas et al. (2010) could not demonstrate positive effects on fish stocks in Lithuanian waters.

The biology and possible impacts of H. anomala have been widely discussed in relation to its recent range expansions (e.g., Ketelaars et al., 1999; Borcherding et al., 2006; Ricciardi et al., 2012). In the River Tisza it is likely to remain rather scattered, reaching higher densities only on rip-raps. However, if it continues to spread, the impounded reaches at Kisköre and Tiszalök may provide hospitable conditions for the species, where it can exert a considerable impact on the biota.

With P. lacustris a fourth Ponto-Caspian mysid species began to spread spontaneously in the Danube river basin, as indicated by the Serbian and Hungarian records. It can be anticipated that the spread of P. lacustris will continue, similarly to the other species. Although the River Tisza itself is dead-end street in a hydrological sense (i.e., it is not connected directly to other river basins via canals), it may potentially contribute to the further spread of the species. The Tisza region in Hungary has a strong fishing industry; fish are stocked from the river and connected fish farms into several fishing ponds throughout the country. *P. lacustris* is well-adapted to lacustrine conditions, and therefore can be anticipated to be able to colonize fishing ponds, similarly to *L. benedeni*, which has appeared in several such waters presumably via fish stocking (Borza et al., 2011). Consequently, this species may become by and by an important and commonly occurring member of the aquatic communities in the invaded regions.

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Captions of figures and tables

Fig. 1. Ovigerous female of Paramysis lacustris (Czerniavsky, 1882) from the River Tisza. Scale bar: 2 mm.

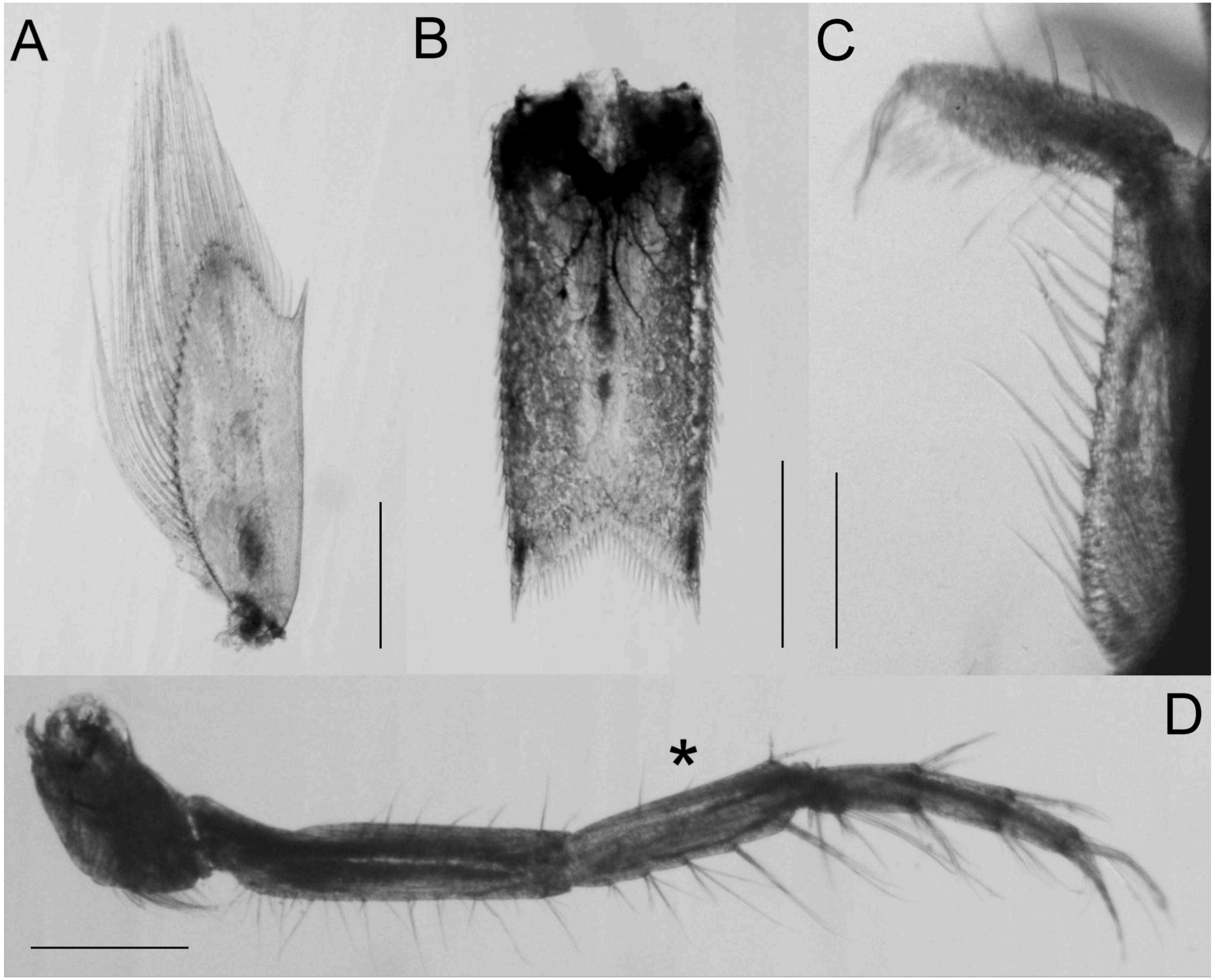
Fig. 2. Paramysis lacustris (Czerniavsky, 1882) from the River Tisza. A, antennal scale; B, telson; C, mandibular palp; D, endopod of first pereiopod (second thoracopod). Asterisk: carpal segment. Scale bars: A, B, D, 0.5 mm; C, 0.2 mm.

Fig. 3. Records of mysids in the River Tisza catchment and in the Serbian Danube. White trangle: Paramysis lacustris (Czerniavsky, 1882) (Hungarian records), black triangle: P. lacustris (Serbian records by Paunović et al. (2007) and Marković et al. (2012)), black star: Hemimysis anomala G. O. Sars, 1907, grey circle: Limnomysis benedeni Czerniavsky, 1882.

Table I. Records of mysids in the River Tisza and some of its tributaries during 2011-2012 (leg. Borza, Boda; det. Borza). Sampling was not quantitative; therefore, the numbers of specimens collected do not reflect the actual abundance of the species

Fig. 1.

Fig. 2.



384 Fig. 3.

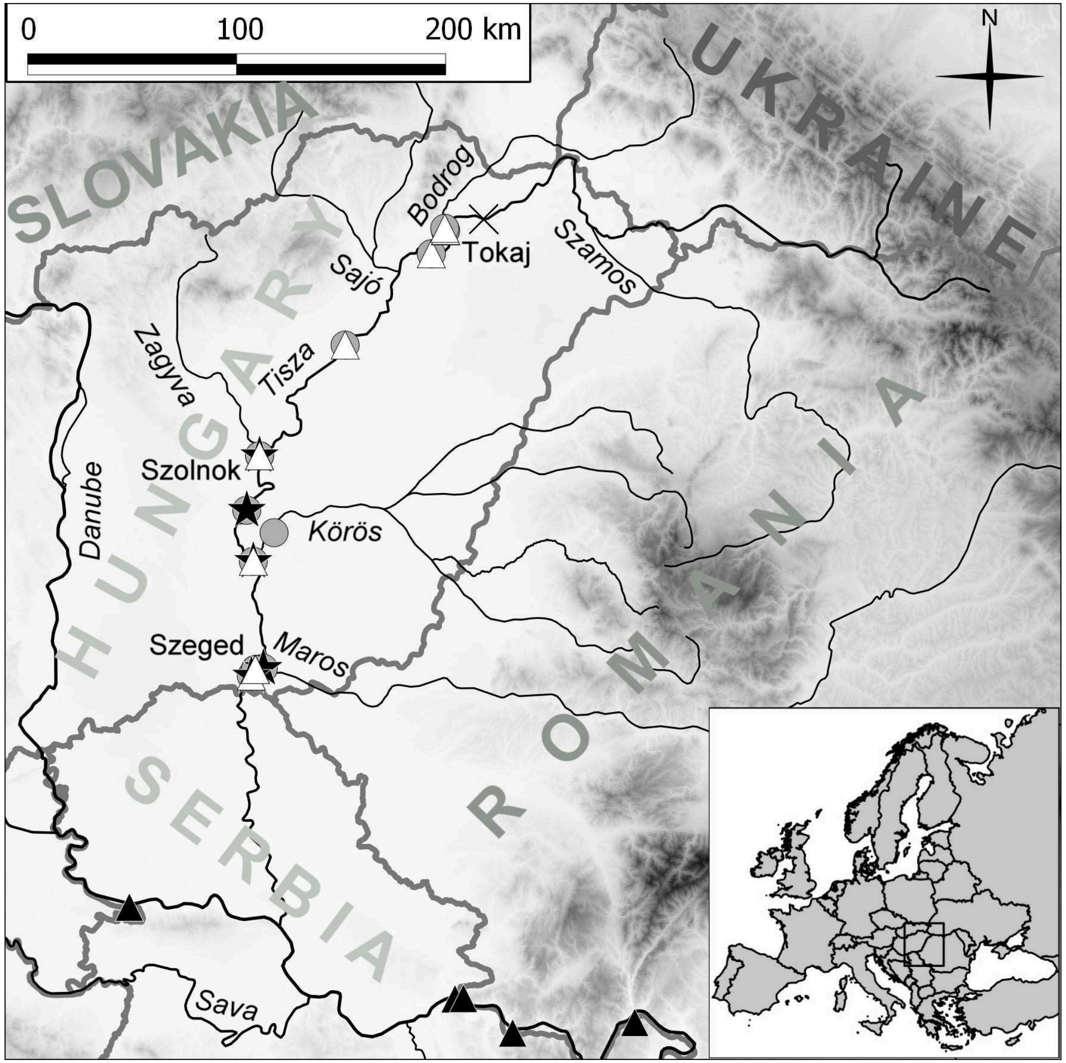
385 
0
100
200 km
N
SLOVAKIA
UKRAINE
HUNGARY
ROMANIA
SERBIA
Bodrog
Tokaj
Szamos
Sajó
Zagyva
Tisza
Szolnok
Danube
Körös
Szeged
Maros
Sava

Table I

Date	River	Rkm	Location	Geographic coordinates	Habitat	P. lacustris	H. anomala	L. benedeni
17.vii.2011	Tisza	178	Szeged, Tápé ferry	46°15'18.71"N 20°12'8.23"E	rip-rap		3	not counted
19.viii.2011	Tisza	286	Tiszakécske	46°56'11.26"N 20°6'44.99"E	rip-rap		1	not counted
06.viii.2012	Tisza (inlet)	168	Szeged, winter harbour	46°13'21.51"N 20°7'36.52"E	rip-rap	2	8	100
06.viii.2012	Tisza	173	Szeged, city center 1	46°15'3.72"N 20°9'8.73"E	rip-rap, mud	3		20
06.viii.2012	Tisza	173	Szeged, city center 2	46°15'1.36"N 20°9'7.85"E	rip-rap, mud	2		12
06.viii.2012	Tisza	246	Csongrád	46°42'58.34"N 20°8'56.88"E	rip-rap	2	139	48
07.viii.2012	Hármas-Körös	21	Kunszentmárton	46°50'16.84"N 20°16'54.41"E	clay, mud			4
07.viii.2012	Tisza	334	Szolnok 1	47°10'13.59"N 20°11'52.30"E	rip-rap	29	2	114
07.viii.2012	Tisza	334	Szolnok 2	47°10'13.84"N 20°11'52.27"E	clay, stones	46		3
07.viii.2012	Tisza (impoundment)	430	Tiszafüred	47°38'22.90"N 20°45'10.73"E	clay, mud	20		174
10.ix.2012	Tisza (impoundment)	518	Tiszalök	48°1'23.26"N 21°19'7.17"E	mud, stones	17		24
10.ix.2012	Tisza	543	Tokaj 1	48°7'11.67"N 21°24'48.41"E	rip-rap	11		402
10.ix.2012	Tisza	543	Tokaj 2	48°7'18.06"N 21°24'53.01"E	mud	136		22
10.ix.2012	Bodrog	1	Tokaj	48°7'51.18"N 21°24'34.38"E	mud, stones	10		21

10.09.2012	Tisza	568	Tiszabercel	48°9'53.80"N 21°39'40.79"E	rip-rap, mud	no mysid