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RESEARCH PAPER

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Macrobrachium nipponense (De Haan, 1849) continues to spread in the Danube: first records in Germany and Hungary

Martin Bláha[1], Andreas Schrottenbaum[2,3], András Weiperth[4,5,6], Urban Hammerschmied[7], Wolfram Graf[8], Béla Csányi[9], Jiří Patoka[10,11,12] and Antonín Kouba[1,*]

[1] Faculty of Fisheries and Protection of Waters, South Bohemian Research Center of Aquaculture and Biodiversity of Hydrocenoses, University of South Bohemia in České Budějovice, Zátiší 728/II, CZ – 389 25, Vodňany, Czech Republic
[2] Nature Conservation Specialist at the Environmental Office of the City of Passau, Rathausplatz 2, D – 94032, Passau, Germany
[3] Water Warden at the Verein der Heiliggeist-Stift-Fischer "Apostelfischer" Passau e.V., Schießstattweg 85c, D – 94032, Passau, Germany
[4] HUN-REN National Laboratory for Water Science and Water Security, Institute of Aquatic Ecology, Centre for Ecological Research, 29 Karolina Road, Budapest, H – 1113, Hungary
[5] HUN-REN Institute of Aquatic Ecology, Centre for Ecological Research, 29 Karolina Road, Budapest, H – 1113, Hungary
[6] Department of Systematic Zoology and Ecology, Institute of Biology, ELTE Eötvös Loránd University, Pázmány Péter ave 1/C, H – 1117, Budapest, Hungary
[7] Technisches Büro Zauner GmbH, Marktstrasse 35, A – 4090, Engelhartszell, Austria
[8] BOKU, University of Natural Resources and Life Sciences, Vienna, Institute of Hydrobiology and Aquatic Ecosystem Management, Gregor Mendel Strasse 33, A – 1180, Vienna, Austria
[9] Independent Hydrobiologist, Budai Nagy Antal utca 14, HU – 2131, Göd, Hungary
[10] Department of Zoology and Fisheries, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, Kamýcká 129, CZ – 165 00, Prague, Czech Republic
[11] Department of Preschool & Primary Education, Faculty of Education, Jan Evangelista Purkyně University in Ústí nad Labem, Pasteurova 1, CZ – 400 96 Ústí nad Labem, Czech Republic
[12] Department of Biology, Faculty of Science, Humanities and Education, Technical University of Liberec, Studentská 1402/2, 461 17 Liberec, Czech Republic

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Abstract – This article presents the first records of the non-native Asian caridean shrimp *Macrobrachium nipponense* in Germany (Racklau Harbour, Passau) and Hungary (Lipót, Szigetköz floodplain), both discovered in 2023. Based on initial monitoring, both populations appear to be already established, and may serve as source populations for further spread, particularly downstream along the Danube River. The article explores the potential for upstream expansion from the lower Danube, where the species has been recently reported, as well as possible introduction pathways. We examined its ecological roles and potential impacts, which could be significant. Given the lack of effective eradication methods, efforts should prioritise minimising—and ideally preventing—further human-assisted spread. This should be underpinned by general environmental education and responsible pet ownership, potentially including a market ban, given the species' characteristics and its temperature tolerance across much of Europe. A deeper understanding of its interactions with both native and non-native species is needed. We call for intensified monitoring, particularly in suitable habitats such as harbours, using both conventional and eDNA methods to gain insights into its potential future distribution, and to reconstruct introduction pathways to inform management strategies.

Keywords: freshwater shrimps / invasive non-native species / Oriental river prawn / Palaemonidae / species introductions

*Corresponding author: akouba@frov.jcu.cz

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1 Introduction

Caridean shrimps (Crustacea: Decapoda: Caridea), commonly referred to as true shrimps, represent a highly diverse and species-rich group of aquatic invertebrates, comprising approximately 2,500 described species across more than 30 families (Bauer, 2023; De Grave *et al.*, 2015). Around three-quarters of these species inhabit marine ecosystems, while the remainder are found in diverse freshwater environments, eventually migrating to areas with elevated salinity for reproduction – diadromy (Bauer, 2013). Caridean shrimps are widely distributed, occurring on all continents except Antarctica. The Oriental region hosts the greatest diversity of species, but the Nearctic and western Palearctic regions are comparatively species-poor (Bauer, 2023; De Grave *et al.*, 2008).

There are over 45 freshwater species and subspecies known from the broader Mediterranean region that belong to 11 genera and three families–dominantly present Atyidae, followed by Palaemonidae and least numerous Typhlocarididae. They inhabit both subterranean (hypogean) and surface (epigean) habitats in equal measure with only a few also entering anchialine caves (Christodoulou *et al.*, 2016). Their distribution is typically very restricted. However, the eurytolerant west-Mediterranean atyid shrimp *Atyaephyra desmarestii* (Millet, 1831), for instance, successfully spread throughout the old navigable canals connecting major river basins in Western and later also Central Europe (Galil *et al.*, 2007; Straka and Špaček, 2009; Van der Velde *et al.*, 2000), including the Danube (Moog *et al.*, 1999).

Indeed, constructed canals have facilitated the spread of numerous aquatic species in both marine and freshwater realms. Examples include the migration of many Red Sea species to the Mediterranean Sea via the Suez Canal (Balzani *et al.*, 2022; Galil *et al.*, 2021), and the proliferation of numerous Ponto-Caspian species across Europe (Bij de Vaate *et al.*, 2002), a process well-known as faunal Ponto-Caspianisation (Soto *et al.*, 2023). Yet, a significant proportion of introductions in aquatic environments is driven by direct human actions when species are intentionally (e.g. stocking, pet dumping) or unintentionally (*e.g.* escapes) released for their use in fisheries and aquaculture. Others exploit the opportunity and spread together with the species of primary interest (*e.g.* as contaminants of consignments) (Nunes *et al.*, 2015; Patoka and Patoková, 2021; Savini *et al.*, 2010).

More recently, the aquarium trade has been recognised as an increasingly important introduction pathway (Bernery *et al.*, 2024; Padilla and Williams, 2004; Strecker *et al.*, 2011). Traded taxa are usually warm-water-adapted species, better suited to the conditions commonly seen in home aquaria (Novák *et al.*, 2020; Veselý *et al.*, 2015). It typically involves numerous fish species, but other vertebrates (e.g. amphibians and reptiles), invertebrates (gastropods, bivalves, and crustaceans), and plants are a significant component (Dickey *et al.*, 2023; Kopecký *et al.*, 2013; Patoka *et al.*, 2016a). Sadly, some of these organisms are released into the wild even in their non-native range, posing an environmental threat (Magalhães *et al.*, 2024; Patoka *et al.*, 2018). The motivations for releasing aquatic pets are diverse and often influenced by a combination of emotional, ecological, and logistical factors (intense proliferation resulting in surplus animals, owner fatigue or inability to care, ethical or emotional concerns, cultural or religious practices, or simply a lack of awareness and irresponsible behaviour (Banha *et al.*, 2019; Patoka *et al.*, 2017).

Especially naturally warm or thermally polluted waters have increasingly become important sites for the release of aquatic pets in Europe (Mojžišová *et al.*, 2024; Takács *et al.*, 2017). In the case of aquatic invertebrates, this trend is particularly evident with freshwater crayfish (Lipták *et al.*, 2024b; Weiperth *et al.*, 2017), following their growing popularity in the aquarium pet trade (Chucholl, 2013; Patoka *et al.*, 2014). More recently, a similar pattern has been observed in caridean shrimps. In Europe, *Neocaridina davidi* (Bouvier, 1904) is the most widespread species, already established in France, Germany, Hungary, Poland, and Slovakia (Jabłońska *et al.*, 2018; Jamonneau *et al.*, 2024; Klotz *et al.*, 2013; Prati *et al.*, 2024; Weiperth *et al.*, 2019a). *Caridina babaulti* (Bouvier, 1918) has been recorded in Poland and Hungary (Bláha *et al.*, 2022; Maciaszek *et al.*, 2021), while *Macrobrachium dayanum* (Henderson, 1893) has successfully established in Germany (Klotz *et al.*, 2013). The population status of other recorded species remains unclear. These occurrences are closely associated with locations featuring elevated water temperatures. However, there are concerns that such environments might foster local adaptations to regular temperature regimes, which, combined with climate warming, could facilitate a broader spread (Schneider *et al.*, 2022; Weiperth *et al.*, 2019a).

The freshwater prawn *Macrobrachium nipponense* (De Haan, 1849) is an emerging species of concern due to its high tolerance for lower temperatures and ability to reproduce exclusively in freshwater environments. Native to Southeast Asia, this species has expanded its range through introductions to the Far East and the Middle East. Of particular interest from a European perspective is its accidental introduction into the cooling reservoir at Elektrogorsk, Russia, together with juvenile grass carp *Ctenopharyngodon idella* (Valenciennes, 1844) from the Yangtze River in the early 1960s. This was followed by its introduction into the cooling ponds of the Berezovkaya Thermal Power Plant in Belarus in 1982 (see Surugiu (2022) and Nekrasova et al. (2024) for review). This introduction has enabled secondary dispersal and establishment in Ukraine and Moldova, including sites with natural temperature regimes (Bushuiev *et al.*, 2023; Munjiu *et al.*, 2023; Son *et al.*, 2020; Zhmud *et al.*, 2022). Its recent occurrence in Romania (Surugiu, 2022) and Bulgaria (Kutsarov *et al.*, 2023) has raised concerns about its further continental spread, including dispersal along the Danube River. Here, we report on the first records of *M. nipponense* in Germany and Hungary.

3 Materials and Methods

The oriental river prawn, *Macrobrachium nipponense* (De Haan, 1849), was inadvertently recorded during monitoring activities using electrofishing at two distinct locations along the Danube River in Germany and Hungary. The first detection occurred at Racklau Harbour, Passau, Germany, situated at river kilometre 2228 on 25 July 2023 (Fig. 1). The species was

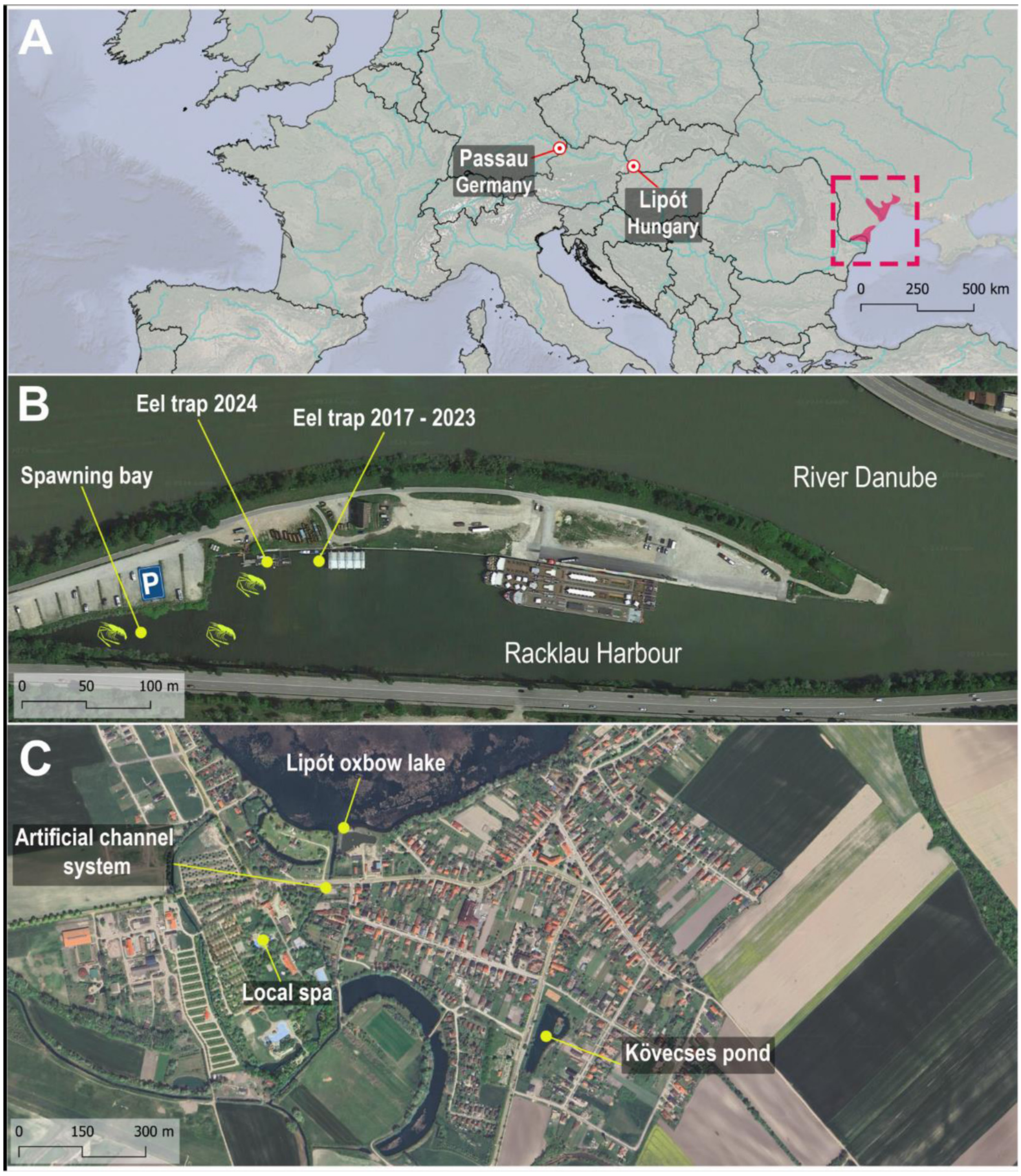

Fig. 1. A situation map of sites with recorded presence of *Macrobrachium nipponense* in Central Europe, and the red area in the Danube and Dniester River delta outlined with dashed lines, indicate the known occurrence of the *M. nipponense* to date (Surugiu, 2022; Bushuiev *et al.*, 2023) – A. Detailed view of the monitored locality: Racklau Harbour in Passau, Germany, with depicted position of eel traps during two different time periods; Prawn pictograms indicate the area where the species was first detected in July 2023 – B, and Lipót region, Hungary, where *M. nipponense* was first spotted in August 2023 in Kövecses pond, and then found in January and July 2024 in artificial channel system and Lipót oxbow lake, respectively – C.

observed during ichthyological and malacological monitoring of the site conducted by TB Zauner GmbH, Engelhartszell, Austria (TB Zauner GmbH, 2023) and two co-authors (AS and UH) were involved. This 4.4-hectare harbour serves primarily as a winter and flood sanctuary and mooring location for boats, capable of withstanding even 100-year flood events. Racklau Harbour is the only downstream oxbow connected to this stretch of the Danube River, serving as a significant refuge and winter habitat for various fish species. Fish spawning habitats also occur in its shallower western part, supporting their populations. Fishing is generally prohibited in the harbour during the peak of fish reproduction (February 15–May 31) and a year-round ban is applied to the zone with spawning substrates. Overall, fishing activity is minimal in the Racklau Harbour and historically restricted to 12 persons only as regulated by the Heiliggeist-Stift-Fischer "Apostelfischer" Passau e.V., an association established in 1445. The adjacent river stretch is part of a Natura 2000 protected area, with numerous valuable species present.

The local fish community is relatively diverse. In 2023, a total of 29 fish species were observed, 22 of which were native. Four fish species — *Leuciscus aspius* (Linnaeus, 1758), *Barbus barbus* (Linnaeus, 1758), *Rhodeus amarus* (Bloch, 1782), and *Rutilus virgo* (Heckel, 1852) and one gastropod (*Viviparus acerosus* (Bourguignat, 1862)) are of elevated conservation status (TB Zauner GmbH, 2023).

In addition to these surveys, the locality has occasionally been monitored by a single unbaited eel trap (Apollo II model) placed on the bottom of the harbour near the boat pontoon on the northern shore (location slightly changed between 2017-2023 and 2024 onwards; see Fig. 1). Out of 12 individuals historically holding fishing rights, only two are actively fishing using eel traps in the Racklau Harbour. Additionally, one unbaited trap was deployed directly in the Danube River both upstream (48.5778°N, 13.4084E) and downstream (48.5754 °N, 13.4695E) of the harbour, and remained in place continuously from July to November 2024.

In the second case, a suspicious shrimp individual was collected in an artificial gravel pond (Kövecses-tó/Kövecses pond) in Lipót, Hungary (47.8593 °N, 17.465E) on August 11, 2023 by two co-authors (AW, and BC). It was electrofished during the monitoring programme documenting the occurrence of non-native pet-traded aquatic species (shrimp, crayfish, fish, amphibians, and aquatic reptiles) in Hungarian open waters. The individual occurred in dense emergent aquatic macrophytes and was captured together with *Faxonius limosus* (Rafinesque, 1817), *Carassius auratus* (Linnaeus, 1758), *L. gibbosus*, *Pseudorasbora parva* Temnick et Schlegel, 1846, *Rutilus rutilus* (Linnaeus, 1758), *Carassius gibelio* (Bloch, 1782), and turtles *Trachemys scripta* (Schepff, 1792) of different sizes. This pond is located in an urbanised, recreational area and is utilised for angling. The Kövecses pond has no direct connection with other surface waters, and its water level is defined by groundwater levels in the vicinity.

Following this initial observation, a survey programme was initiated to determine the distribution of the shrimp species in the area. Besides the Kövecses pond, the next monitored sites were the artificial channel system (47.8618 °N, 17.4576E), and the Lipót oxbow lake (47.8631 °N, 17.4583E). In all cases, a 150 m section was monitored. The two-day surveys were repeated every season, *i.e.* three months, starting in January 2024, and combined the use of the macroinvertebrate hand net (kick-netting and sweeping), electrofishing, and five baited Pirate crayfish traps exposed overnight. The artificial channel system has two main functions. It interconnects the different artificial and natural standing and running waters, including the Lipót oxbow system, with the main arm of the Danube River, and drives the used thermal water from a local spa (47.8607N, 17.4557E) to the floodplain region. The outflow from the spa is located in the middle of the monitored section in the artificial channel system.

All sampling sites are located in Szigetköz region, the largest floodplain area of the Danube River in Hungary. The Szigetköz floodplain is in the upper part of the Hungarian-Slovak section of the Danube River, within the Kisalföld region (*i.e.* Little Danube Plain). It is situated on the right side of the extensive alluvial cone stretching from Rajka to Gönyű (between river kilometres 1850 and 1794). However, this floodplain was hardly affected by the flood-controlling dyke construction at the end of the 19^{th} century (Farkas-Iványi and Guti, 2014). Additionally, the construction of the Gabčíkovo hydropower dam in the late 20th century led to further alterations (Guti, 2002). Several rehabilitation projects have been carried out over the past two decades to restore the connection between various habitats of the floodplain (e.g. wetlands, side-arm systems, oxbows) and the main channel of the Danube River. These efforts have ensured a continuous water supply to the floodplain area, even during the driest years, such as 2022.

The whole Szigetköz floodplain is a part of the Fertő-Hanság National Park, which is known for its stunning natural beauty, diverse wildlife, and unique wetland ecosystem, being a prime destination for eco-tourism (Csabai and Nosek, 2006; Farkas-Iványi and Guti, 2014; Guti *et al.*, 2010). The region's rich soil, shaped by the Danube's sediment deposits, supports diverse crops, but also boasts several public thermal spas and wellness centres. Located in the municipality of Lipót is one of the most popular spas in the area. The presence of thermal waters in the region motivated hydrobiological biomonitoring in the area, which yielded diverse non-native aquatic and semi-aquatic species detected (Guti and Pekarik, 2016; Takács *et al.*, 2017; Weiperth, 2022a).

4 Molecular methods

In addition to morphological identification, according to Rogers and Thorpe (2019), molecular markers amplified by polymerase chain reaction (PCR) were applied. Tissue samples from three individuals was used for DNA analysis. Genomic DNA extraction and PCR amplification of the mitochondrial cytochrome c oxidase subunit I (COI) gene was performed according to Bláha *et al.* (2016). LCO1490 and HCO2198 (Folmer *et al.*, 1994) primers were used to amplify COI gene fragment. The obtained sequences were manually inspected in GENEIOUS 8.0.5 (Kearse *et al.*, 2012). The standard nucleotide BLAST (https://blast.ncbi.nlm.nih.gov) was used by comparing the sequences with those available in the NCBI database and confirm the species status. Newly obtained haplotypes were uploaded to NCBI database under accession numbers PQ883994 and PQ883995. All molecularly analysed individuals were preserved in ethanol and are available in the collection of the first author (MB), housed at the Faculty of Fisheries and Protection of Waters in Vodňany, Czech Republic.

5 Results

Four adult shrimp ranging from 5 to 7 cm in total body length were captured by electrofishing in Racklau Harbour in July 2023. The species was reconfirmed in September 2023, when five individuals measuring 3–7 cm were caught. The initial morphological examination, further supported by molecular methods, identified the specimens as *M. nipponense* (Fig. 2). Genetic analysis proved the species status inferred using morphology as *M. nipponense*. Each individual had a different haplotype (accession numbers PQ883994 and PQ883995) differing by a single base. Both haplotypes were found unique to other uploaded haplotypes in the NCBI database. The most similar sequences were PP747062, PP747057, and KY977505 (99.55% identity). To our knowledge, this is the first report of the species in Central Europe. Using a single eel trap, the species was not noted in the

Fig. 2. Two captured individuals of *Macrobrachium nipponense* from Racklau Harbour Passau, Germany in September 2024. The scale bar in the lower image represents 2.5 cm.

harbour before (2017 to 2023). Despite this relatively restricted trapping, several individuals of different sizes were noticed from July to September 2024, suggesting successful overwintering of the species. Specifically, 17 individuals were caught on three occasions in September. Six animals were adults, of which three females were ovigerous. In October, 30 individuals, of which half were medium-sized adults or bigger, were captured on two occasions. In November, eight individuals (seven adults) were seen during two visits. The maximum size recorded was a male measuring 8.5 cm in total body length (measured from the tip of the rostrum to the outermost margin of the telson). Combined electrofishing and trapping data showed that all captured individuals were restricted to the westernmost section of the harbour, largely overlapping with the fish spawning bay. No shrimps were trapped in the river's main channel both upstream and downstream from July to November 2024. The water rarely exceeds 25 °C and can drop below 2 °C in the measuring profile of the Danube River in Passau (Fig. 3). The lowest daily average observed in winter 2023–2024 was 2.4 °C. So far, temperatures have not been systematically measured in the harbour itself but are expected to be slightly higher.

In the case of Hungary, the first individual captured (Fig. 4) shared the same haplotype as one analysed individual (PQ883994) from Racklau Harbour, Passau, Germany. During the monitoring, another seven individuals were captured at the locality over two years. The channel system yielded the highest counts (19) and the species was also present in the Lipót oxbow lake (two individuals; Tab. 1). In all cases, both small and adult individuals, including three ovigerous females, were observed over the monitoring period – two in the Kövecses Pond in the summer of 2024 and one in the channel system in the autumn of the same year. Monitoring of the thermal habitats of the spa and its outflow entering the artificial channel system additionally resulted in the capture of South American catfish *Microglanis iheringi* Gomes, 1946, and viviparous fish

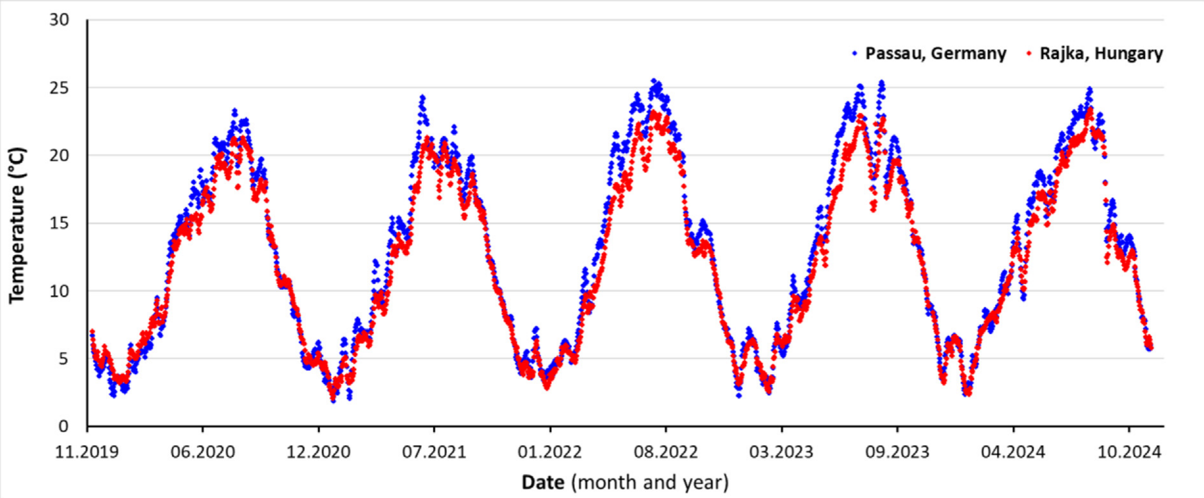

Fig. 3. The course of mean daily water temperatures in the Danube River, measuring site number 10091008, Passau, Germany (above the confluence with Inn, river kilometre 2,226.7), and Rajka, Hungary (river kilometre 1,848.3) from October 2019 to November 2024. Data from the Bavarian State Office for the Environment, and the Hungarian General Directorate of Water Management.

Fig. 4. The first adult individual of *Macrobrachium nipponense* captured in the Kövecses pond, Lipót, Hungary in August 2023.

Poecilia reticulata Peters, 1859 and *Xiphophorus* sp. Heckel, 1848. Besides, turtle individuals of *Trachemys scripta* and *Graptemys pseudogeographica* (Gray 1831) were repeatedly noticed.

6 Discussion

Macrobrachium nipponense is already well established in Eastern Europe, including the lower sections of the Dniester and Danube basins (Bushuiev *et al.*, 2023). Its recent confirmations in Romanian (Surugiu, 2022) and the Bulgarian parts of the Danube (Kutsarov *et al.*, 2023) raised concerns about its further spread across the continent. Given that the current and especially future climates are expected to support the species establishment in large parts of Europe (Nekrasova *et al.*, 2024; Šindler *et al.*, 2024), its natural expansion could have been expected. However, the occurrences reported here are beyond any expectations as the overcome distances from its previously known distribution are overwhelming.

Considering the multiple individuals of different size classes, including reproductive females observed over two seasons, we expect that both populations are well established. The Racklau Harbour likely serves as a suitable refuge from lower temperatures seen in the Danube River main channel, especially after its confluence with the Inn flowing from the Alps. The water temperature of the Danube in the Hungarian section is only slightly lower (Fig. 3), primarily due to its confluence with cold alpine rivers in Austria (Pekárová *et al.*, 2023). Still, it should be kept in mind that the species tolerates temperatures as low as 1 °C (Shekk and Astafurov, 2023). The complex freshwater habitats in the Szigetköz floodplain provide numerous opportunities, including areas with much-reduced water currents and higher temperatures, including thermal spots. The species has been recorded at all three monitored places of which one is isolated (Kövecses pond). It suggests that both the spread of the species in the water network and human-assisted translocations are taking place in the area. As a consequence, both the German and Hungarian sites will serve as places from where the shrimps can further spread, especially in a downstream direction (Lipták *et al.*, 2017; Weiperth, 2022b; Weiperth *et al.*, 2019a).

A natural upstream spread of the species from its previously known distribution in the lower Danube without being detected **seems** unlikely, given the distances and strong water currents in the Danube. The species possesses certain swimming abilities, but these are more pronounced in standing or slow-moving waters. For instance, the critical swimming speed of bigger species *Macrobrachium rosenbergii* (De Man, 1879) (Upadhyay et al., 2014) appears to be lower than that of the water currents occurring in the middle and upper sections of the Danube (0.9–3.0 ms^{-1}; Gâstescu, 1998). Considering the bigger size of this congeneric species compared to *M. nipponense*, the capabilities of the upstream migration of the latter species might be even lower. Instead, one might assume that walking and climbing on the structures close to the shore would be more effective at sections with elevated water velocity. Yet, the long-term regular international Joint Danube

Table 1. Results of the monitoring campaign for *Macrobrachium nipponense* in the Lipót area, Hungary. The data are presented as the number of juveniles/number of adults. Adults were identified as individuals with enlarged claws in males and/or those with visibly developed oocytes or attached eggs in females.

Date/locality	Kövecses pond	Artificial channel system	Lipót oxbow lake
August 11, 2023	0/1	NA	N/A
January 16-17, 2024	–	2/0	–
April 18-19, 2024	2/1	3/2	–
July 6-7, 2024	0/3	2/3	0/1
October 9-10, 2024	1/0	4/1	0/1
January 8-9, 2025	–	0/2	–
Total number	3/5	11/8	0/2

Survey (Liška et al., 2021) managed to track the spread of other non-native species (e.g. *Dresissena rostiformis bugensis*), but not *M. nipponense*. Thus, the absence of previous detection further questions natural upstream spread as a prime mode of dispersal.

The introduction pathway is, however, not obvious and might vary between the two sites. The first possibility could be the release (or less likely escape) of aquatic pets and ornamentals, which are commonly introduced in urban areas, especially when thermal habitats are present (Patoka *et al.*, 2016b, and this study). *Macrobrachium* species are pet-traded much less often than other caridean shrimps (De Grave *et al.*, 2008; Lipták and Vitázková, 2015). If involved, other species, such as *M. lanchesteri* (De Man, 1911) and *M. dayanum* (Henderson, 1893), are rather marketed (Klotz *et al.*, 2013; Weiperth *et al.*, 2019b), unless already established in the country (Uderbayev *et al.*, 2017). The species was not detected in the Hungarian pet trade in the past (Weiperth *et al.*, 2019b), but it is currently available. The species is relatively attainable, priced at 2 500-3 500 Ft, 6-8 EUR per individual. Besides, regular imports from Slovakia were also noticed, suggesting a broader availability in the region (Gábor Lázár, Márk Liziczai, András Weiperth, personal observation). However, we have no direct evidence of its presence in the pet trade in Germany and Austria. It should be noted that intentional release of non-native species is forbidden in both countries – the Federal Nature Conservation Act § 40 a-f (BNatSchG) in Germany, and Act No. LIII of 1996 on Nature Conservation (Articles 13–15) in Hungary.

Another possibility involves ballast water as documented for numerous taxa (Bij de Vaate *et al.*, 2002; Gallardo and Aldridge, 2015), such as Ponto-Caspian species (Holdich and Pöckl, 2007; Nehring, 2005). This pathway increased in its importance especially after opening the Rhine-Main-Danube Canal in 1992 (Soto *et al.*, 2023). When compared with marine transportation, the ballasting and deballasting operations are much reduced in inland channels. Yet, this possibility cannot be entirely ruled out. The zoeal larvae of the species are small and pelagic, so their pumping into the ballasting tanks is possible.

The species is not intensively fished or aquacultured in Central Europe; therefore, intentional introduction aiming at this utilisation is unlikely. The fishery of established stocks (Bushuiev *et al.*, 2023) and aquaculture are currently under consideration in Eastern Europe (Bushuiev *et al.*, 2023; Kulesh and Alekhnovych, 2018; Shekk and Astafurov, 2023), where the species has a longer introduction history. One may consider possible contamination of fish stocking material. However, we do not expect it to be our case, given the species has not been known in the broader region previously, and it is unlikely it would remain unnoticed by the personnel involved. Due to diverse reasons (e.g. logistical, economical, veterinary, conservational), fish stockings are conducted rather regionally and rarely involve long-range transportation (e.g. from the lower Danube). The species may have been translocated as fishing bait (De Grave and Ghane, 2006), more likely originating in the pet trade. Their origin from the lower Danube is much less probable, considering the distances and the need to cross several borders if physically transported. This, again, rather points to the pet trade origin of such a bait. It should also be noted that such a fishing method is illegal both in Hungary and Germany. Lipót is a part of a well-known spa region extensively visited by guests from many countries. So, one can even imagine a situation when the species, once established there, was taken by visitors, transported, and later released in the Racklau Harbour or nearby. On the bank of its westernmost tip, a relatively big parking place for caravans is located.

Despite some potential benefits that might arise from fishery and aquaculture utilisation of the species, potential negative impacts prevail. These are mainly ecological, but they can translate into socioeconomic dimensions as well (e.g., a newly fished resource at the expanse of decline in previously fished species, cf. Haubrock *et al.*, 2021). *Macrobrachium nipponense* is a relatively large-bodied and long-lived (over 10 cm body length, 3 years) omnivorous species with rapid growth, early maturation, high fecundity, and frequent spawning (Abbas *et al.*, 2021; Alekhnovich and Kulesh, 2001; Surugiu, 2022 and references therein) that can utilise a broad range of food resources, exhibiting a density-dependent trophic pressure. It feeds on decomposing plant material and carcasses, periphyton, soft plants, filamentous algae, aquatic insects, mollusks, crustaceans (mysids, ostracods, cladocerans, copepods, amphipods, small crayfish), and annelids (Mirzajani *et al.*, 2020 and references therein; Surugiu, 2022). There is no doubt that extended antennae and elongated claws are successfully employed in detection and predation on fish eggs and fry, which is very concerning taking the spatial overlap with the fish spawning areas in the Racklau Harbour into account. As in many other decapod crustaceans (Veselý et al., 2021), predation on conspecifics (cannibalism) is also known (Mirzajani et al., 2020). On the other hand, predation from locally occurring omnivorous and predatory fish, as well as larger crayfish, surely occurs (albeit direct evidence is missing – no information indicating the presence of shrimp in the stomach contents of the captured fish was noticed, but keep in mind that the fishing activity in the Racklau Harbour is low and shrimp exoskeleton is much thinner, and hence less detectable than in other preyed organisms, such as crayfish *F. limosus* in large predatory fish or shell of bivalve *C. fluminea* in *N. melanostomus* (Brandner et al., 2013)).

Besides predation and competition for food sources, interspecific competition for habitats, such as hiding places is expected (Bushuiev et al., 2023; Wang et al., 2021). Additionally, it also appears that at least some shrimp species (including *Macrobrachium*) can contribute to the dynamic of the crayfish plague pathogen as an alternative host (Mrugała et al., 2019; Putra et al., 2018; Svoboda et al., 2014) or spread an array of other diseases, including the white spot syndrome virus (Ding et al., 2016; Yu et al., 2024; Yun et al., 2014). While little is currently known about interactions with local native species, the capability of *M. nipponense* to deal with other species seems substantial, considering the co-occurrence with several predatory fish and abundant *N. melanostomus* in Racklou Harbour as well as *F. limosus* occurring at both sites, species considered highly invasive in Europe (EU, 2016). Similarly, it can be kept in polyculture with a number of species that are considered prominent invaders out of their native ranges, such as the crab *Eriocheir sinensis* H. Milne Edwards, 1853 (Hongtuo and Jin, 2018; Kouba et al., 2022). Therefore, we presume the species has the potential to alter local biodiversities and ecosystem functioning.

Considering the nature of occupied habitats both in Germany and Hungary, no existing methods currently allow for successful eradication of the species once established (Lidova et al., 2019). Thus, the main focus should target the prevention of further human-assisted spread via environmental education, responsible pet ownership, and fishing (Lipták et al., 2024a; Patoka et al., 2018). It particularly applies to places where the *M. nipponense* is already established, as these sites might serve as a source for the animals for translocation – both the Racklau Harbour and Szigetköz floodplain are exposed to elevated tourism. Among caridean shrimp, this species is comparatively high risk (Uderbayev et al., 2017) and its ban in the pet market should be considered (e.g. via the inclusion of the species on the list of invasive species of Union concern), especially as the temperature appears to be a weak barrier preventing successful settlement in the continent (Nekrasova et al., 2024, and this study). In addition, we call for continuous and intensified monitoring efforts along the Danube River, especially in suitable habitats such as Harbours that often serve as introduction hotspots. Besides traditional methods, the approaches should include eDNA monitoring to strengthen the efforts in biomonitoring of non-native species. A deeper understanding of interspecific relationships between *M. nipponense* and both native and non-native species is also necessary. Additionally, more detailed genetic analyses (e.g. microsatellites or single nucleotide polymorphisms) of European populations and animals available in the pet trade could clarify introduction pathways and invasion history, aiding future management efforts.

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