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Research Article

Expansion of the alien East Asian river prawn *Macrobrachium nipponense* (De Haan, 1849) in southwestern Ukraine and assessment of its commercial usage prospects

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Abstract

At this time East Asian river prawn *Macrobrachium nipponense* is present almost everywhere in the lower reaches of the Danube and Dniester basins, in the Danube-Dniester interfluves and water bodies to the east of the Dniester. Successful adaptation and favorable climatic conditions in recent years have provided a significant increase in the East Asian river prawn populations in the Danube and Dniester. High growth rates of *M. nipponense* have been observed in the Danube and Dniester. In these river basins, higher values of maximum body length of the prawn (males 115 mm, females 87 mm) than those recorded in the native range water bodies and the cooler water bodies of thermal power plants during introduction were recorded. In small shallow brackish-water reservoirs of the region (PSU 1.5–6.0) the growth rate of *M. nipponense* is significantly lower than in the freshwater Danube and Dniester deltaic zones. Female East Asian river prawn in such water bodies mature at a much smaller size. The egg-laying period of female *M. nipponense* in the Danube lasts from June to October. The peak of egg laying is observed in July and August. There have been reported cases of *M. nipponense* being affected by crustacean burn-spot disease. The prospect of organizing the fishing of *M. nipponense* in the Danube River has been determined. It is necessary to continue research to increase selectivity of fishing gears, determination of optimal terms of fishing, and places of installation of fishing gears.

Key words: palaemonids, Northern Black Sea region, Danube River basin, Dniester River basin, deltaic zones, commercial fishing, invasive species

Introduction

One of the greatest threats to biodiversity worldwide is the spread of non-indigenous species (Bij de Vaate et al. 2002; Leppäkoski et al. 2002). Within the European Union, the European Strategy on Invasive Alien Specie (IAS) was developed in 2003 to establish the main criteria of invasiveness for further control of biological invasions (Council of Europe 2003; Roy et al. 2015). Finally, the list of invasive alien species of the Union Concern is updated every two years (European Commission 2014). In

many cases, biological invasions result following intentional introductions, which is related mainly to commercially important species (Keller et al. 2011; Xu et al. 2014). In Ukraine, for example, the list of intentionally introduced fish consists of 32 species, which includes 17 successful cases (Kvach and Kutsokon 2017).

The East Asian river prawn (*Macrobrachium nipponense* [De Haan, 1849]) is a widespread Indo-Pacific species that inhabits estuarine and fresh waters (Yu and Miyake 1972; Cai and Ng 2002). In the far East Asian states, *M. nipponense* is an important commercial fisheries species, also used in aquaculture (Uno 1971; Ge 1980; New and Nair 2012). During the 2010–2018 period aquaculture provided 191–245 thousand tonnes of *M. nipponense* per year (FAO 2020).

This prawn species has been introduced into natural habitats and cooling reservoirs of thermal power stations in mainly Asian states, such as Singapore, the Philippines, Kazakhstan, Uzbekistan, Iraq, Iran, and Russia (Cai and Shokita 2006; De Grave and Ghane 2006; Salman et al. 2006). Outside Asia, the invasion is known in the US in North Carolina since 2014 in the White Oak River basin (Procopio and Daniel 2023). In Europe, cases of intentional introduction are known since the 1980s in Belarus, Moldova, and Ukraine (Vladimirov et al. 1989; Alekhnovich and Kulesh 2001). Recently, the range expansion of this species covered the southwestern part of Ukraine and northern Romania (Son et al. 2013, 2020; Surugiu 2022; Zhmud et al. 2022).

In recent years, two invasion centers have formed independently in the Ponto-Caspian basin. One covers the rivers of the Azov and Caspian Seas (Afanasyev et al. 2020; Zhivoglyadova et al. 2021a, 2021b), and the other covers the lower reaches of the Dniester and Danube, as well as small river basins of the North-Western Black Sea (Stepanok 2014; Son et al. 2020; Surugiu 2022; Zhmud et al. 2022). The presented study aimed to evaluate the perspectives of control of the East Asian river prawn invasion in Ukraine and its commercial use.

Materials and methods

The East Asian river prawns (*M. nipponense*) were sampled using the research sampling equipment (small-mesh nets of different types) in several water bodies in southwestern Ukraine (Fig. 1). In total, 18 sampling localities were studied in the Danube, Dniester, Baraboy and Akkazhanka rivers basins, also in Sukhyi Lyman and Dzhantshey Lagoon (Suppl. material 1). The information about the prawn finding in the Baraboy Reservoir (Baraboy River basin) was obtained from the iNaturalist site (https://www.inaturalist.org/observations/139907682). Salinity was measured using a handheld TDS meter (TDS-3) that was calibrated manually for a range of 0–9990 ppm.

In 2020–2022 the prawn was sampled mainly using a 5-mm mesh dipnet (1×0.5 m). In the Dzhantshey Lagoon, it was sampled in 2021 using commercial 6-mm mesh fyke-nets. Some samples were taken using a 1 mm mesh hand-net according to ISO 7828:1985 (Water quality – Methods of biological sampling; Guidance on hand-net sampling of aquatic benthic macro-invertebrates). Benthic samples were taken in all microhabitats, which occupied more than 5% of total habitats. The net was dragged along the shore at a distance of 5 m. The net was zig-zagged to cover depths from the water's edge to one meter with 4–5 replications. In the area of the village of Pivdenne, dredging was carried out at depths of 0.5–2.0 m using a naturalist's dredge (0.5 m width and 1 mm mesh size) according to ISO 10870:2012 (Water Quality — Guidelines for the selection of sampling methods and devices for benthic macroinvertebrates in fresh waters) with 15 replications. Since June 2022, the 5 mm and 10 mm mesh-size fyke-nets were used in the

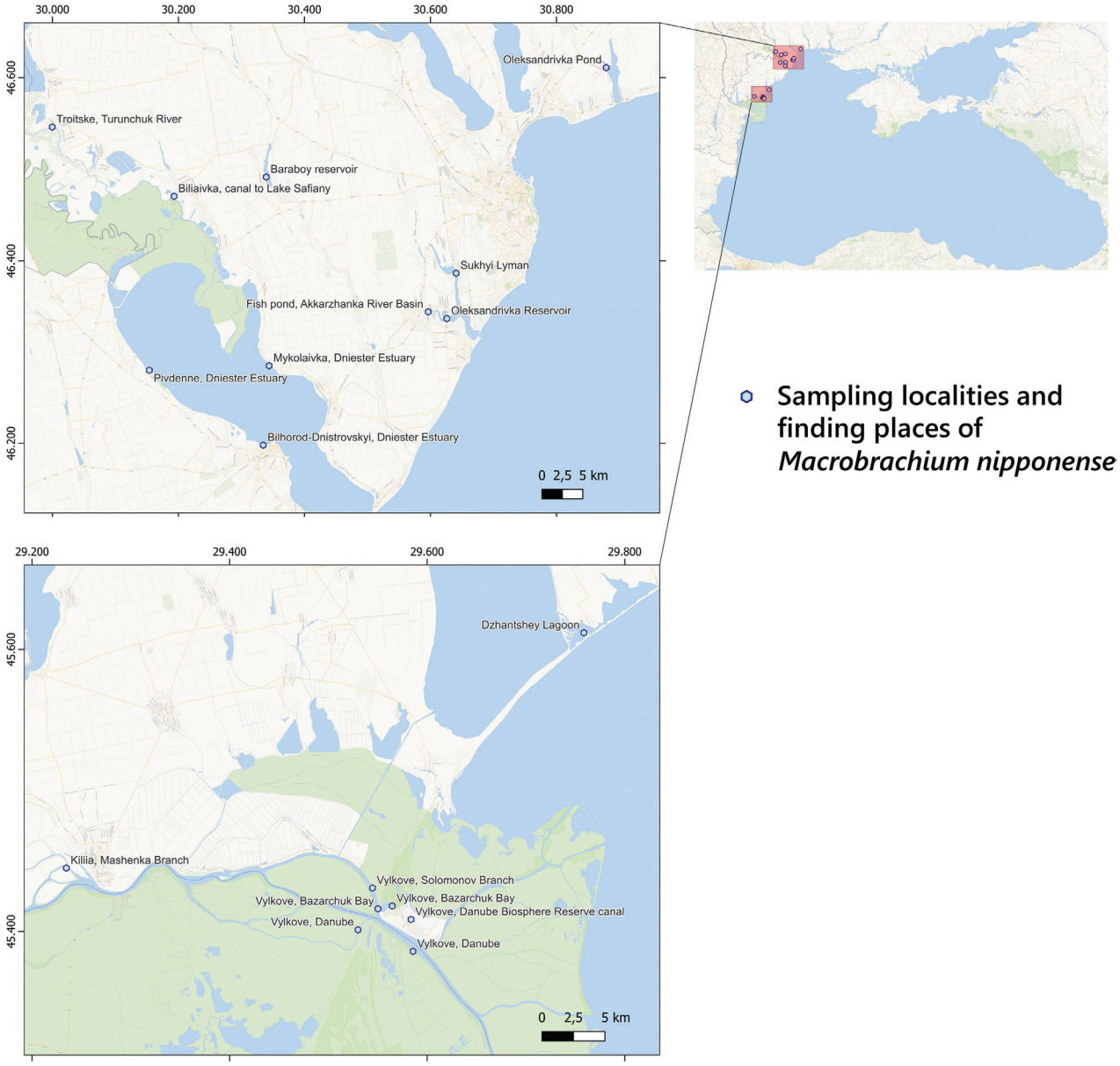

Figure 1. Map of sampling sites in the southwestern Ukraine.

Danube River and the Dniester Estuary. In a total of 21 fyke-net installations were deployed in the Mashenka Branch near the City of Kiliia and 2.5 km of the Solomonov Branch near the City of Vylkove: one to 9 nets were installed at the same time at the depth of 1–2 m for 12 to 168 hours. In August 2022 the sampling was provided in Priamyi and Kiliia branches of the Danube River using beam-trawl (1 m opening, 10 mm mesh) at the depth 4–20 m (6 trawling in total). In November 2022 the prawns were sampled using multimesh nets in the Bazarchuk Bay.

All the catch contents were identified, counted and some parts of the prawns were measured (L, length from the anterior rostrum end till the posterior telson end, mm) and weighed (W, g) alive. In addition, part of the catch was frozen or preserved in 96% ethanol for further laboratory study. Among the 769 sampled prawn individuals, 501 ind. were measured (300 males, 138 females, 63 juveniles) and 339 ind. were weighted (140 males, 136 females, 63 juveniles; Suppl. material 1, Table 4).

The species identification of the sampled individuals was provided based on the morphological items distinguishing this species from the local palaemonid

shrimps, such as *Palaemon adspersus* Rathke, 1837 and *Palaemon elegans* Rathke, 1837, i.e. double-row of seta on the rostrum ventral part, 10 or more dorsal teeth on the rostrum, while local species have only one row of seta and up to 9 dorsal teeth (González-Ortegón and Cuesta 2006).

The seasonal changes in size-weight parameters and sex composition of *M. nipponense* population were evaluated based on fyke-nets (June-December 2022) and beam-trawl (August 2022) samplings from the Danube River.

Results

The current range and new findings

The presence of *M. nipponense* is confirmed in all sampling localities (Suppl. material 1). In the Danube delta we confirm the numerous occurrences of this invasive species. The current range of the prawn captured comprise the deltaic zones of the Dniester and Danube rivers and their interfluvial water bodies, also the water bodies to the east of the Dniester River (Fig. 1).

In 2022, in the Danube delta in the fyke-net catches we registered two decapod species and 19 species of fishes (Table 1). We did not register cases of fish and decapods' death in the fyke nets. The average number of prawns in the catches of one fyke-net per 1 inspection varied from 2.7 in the Dzhantshey Lagoon to

Table 1. Species composition of the small-mesh fyke-net catches in southwestern Ukraine.

Species	Danube River	Dzhantshey Lagoon	Dniester Estuary
Crustacea			
Astacus leptodactylus (Eschscholtz, 1823)	+		
Macrobrachium nipponense (De Haan, 1849)	++	+	+
Actinopterygii			
Alosa immaculata (Bennett, 1835)		+	
Clupeonella cultriventris (Nordmann, 1840)		+	
Silurus glanis (L., 1758)	+		
Blicca bjoerkna (L., 1758)	+		
Abramis brama (L., 1758)	+		
Carassius gibelio (Bloch, 1782)	+	++	+
Rutilus rutilus (L., 1758)	+		++
Rhodeus amarus (Bloch, 1782)			+
Pseudorasbora parva (Temminck & Schlegel, 1846)		+	+
Atherina boyeri (Risso, 1810)		+++	
Chelon auratus (Risso, 1810)		+	
Perca fluviatilis (L., 1758)	+		
Zingel zingel (L., 1766)	+		
Lepomis gibbosus (L., 1758)	+		
Neogobius fluviatilis (Pallas, 1814)		++	+
Neogobius melanostomus (Pallas, 1814)	+		
Ponticola kessleri (Günther, 1861)	+	+	+
Ponticola syrman (Nordmann, 1840)		+	
Platichthys flesus (Pallas, 1814)		+	

«+» – single individuals, «++» – dozens of individuals, «+++» – mass species.

9.6 in the Danube River (Table 2). In the Danube catches the average weight of a prawn individual in the 10-mm mesh fyke-nets comprised 7.16 g, but in 5-mm ones – 3.45 g. On the other hand, 5-mm mesh fyke-nets are more effective in the sampling of small-sized prawns, with the same total catch weight as in the 10-mm mesh fyke-nets. In general, the 10-mm mesh fyke-nets are more effective for possible *M. nipponense* fishing in the future because they allow to catch larger prawn individuals and they have less by-catch of other aquatic species (Table 2).

Table 2. Average numbers and weights of *Macrobrachium nipponense* and the other species in 10-mm and 5–6-mm fyke-net catches (a control per a net) in southwestern Ukraine.

Species	Catch	Danube River (mesh 10, 5 mm)	Dzhantshey Lagoon (mesh 6 mm)	Dniester Estuary (mesh 5 mm)
M. nipponense	n, ind.	9.6	2.7	7
	W, g	63.5	4.0	25.6
Other species	n, ind.	1.0	735	17
	W, g	44.6	1884.0	269.7

Morphology study

All found individuals of the prawn have typical for *M. nipponense* morphological features, e.g. long second pereopods with claws armoured by numerous setae (Fig. 2). In the Danube samples of *M. nipponense*, the variability of the following characters was studied: the length of the second pereopods (l = ischium+merus+-carpus+propodus); its relationship to the total body length (l/L); number of dorsal teeth on the rostrum (Table 3). In the Danube River, three females (2% of the total number of 154 examined individuals) had a non-standard shape of the rostrum with an increased number of dorsal teeth – rounded in two (17 teeth), large elongated in one (19 teeth) (Fig. 3). In some of the prawns sampled in the Danube River (2–3% depending of the sample) we observed the damages of carapaces and abdomens, caused by 'burn-spot' and 'black end' diseases (Fig. 4).

We registered the maximal length of second pereopods: 153 mm in males, 80 mm in females, 41 mm in juveniles. That is, the second pereopods are approximately two times longer in males than in females, and three times that of juveniles. The average second pereopod length was 110–111 mm in males, with a weight of pair of these limbs of 1.5–2 g in large males (about 20% of total body weight). The average length of the left and right pereiopods in representatives of different sexes does not differ significantly. The relation of the second pereopod length to total body length is 1.242–1.255 in males, 0.668–0.670 in females, and 0.573–0.575 in juveniles (Table 3).

Table 3. Morphometric data of *Macrobrachium nipponense* from the Danube River.

Characteristic	Sex	Mean value	Range	σ	l/L ratio	n
length of 2nd pereiopod, right, l_{right}, mm	Males	109.96	50–148	18.48	1.242	254
	Females	48.60	23–80	9.14	0.670	110
	Juv.	31.09	17–40	3.11	0.575	33
length of 2nd pereiopod, left, l_{left}, mm	Males	111.12	20–153	19.21	1.255	257
	Females	48.46	32–70	8.41	0.668	109
	Juv.	30.97	17–41	3.65	0.573	32
number of teeth on the dorsal side of the rostrum	Males	12.73	11–15	0.939	–	45
	Females	13.12	11–19	1.24	–	92
	Juv.	12.29	11–13	0.588	–	17

Figure 2. Adult individuals of *Macrobrachium nipponense* from the Danube Delta. Photographs by M. Son (upper) and S. Bushuiev (lower).

The number of dorsal teeth on the rostrum varied from 11 to 19, with modal parameters of 12–13. Females have a higher variation of this parameter (Table 3). The maximal number of dorsal teeth was registered in a female with an atypically large elongated rostrum (Fig. 3).

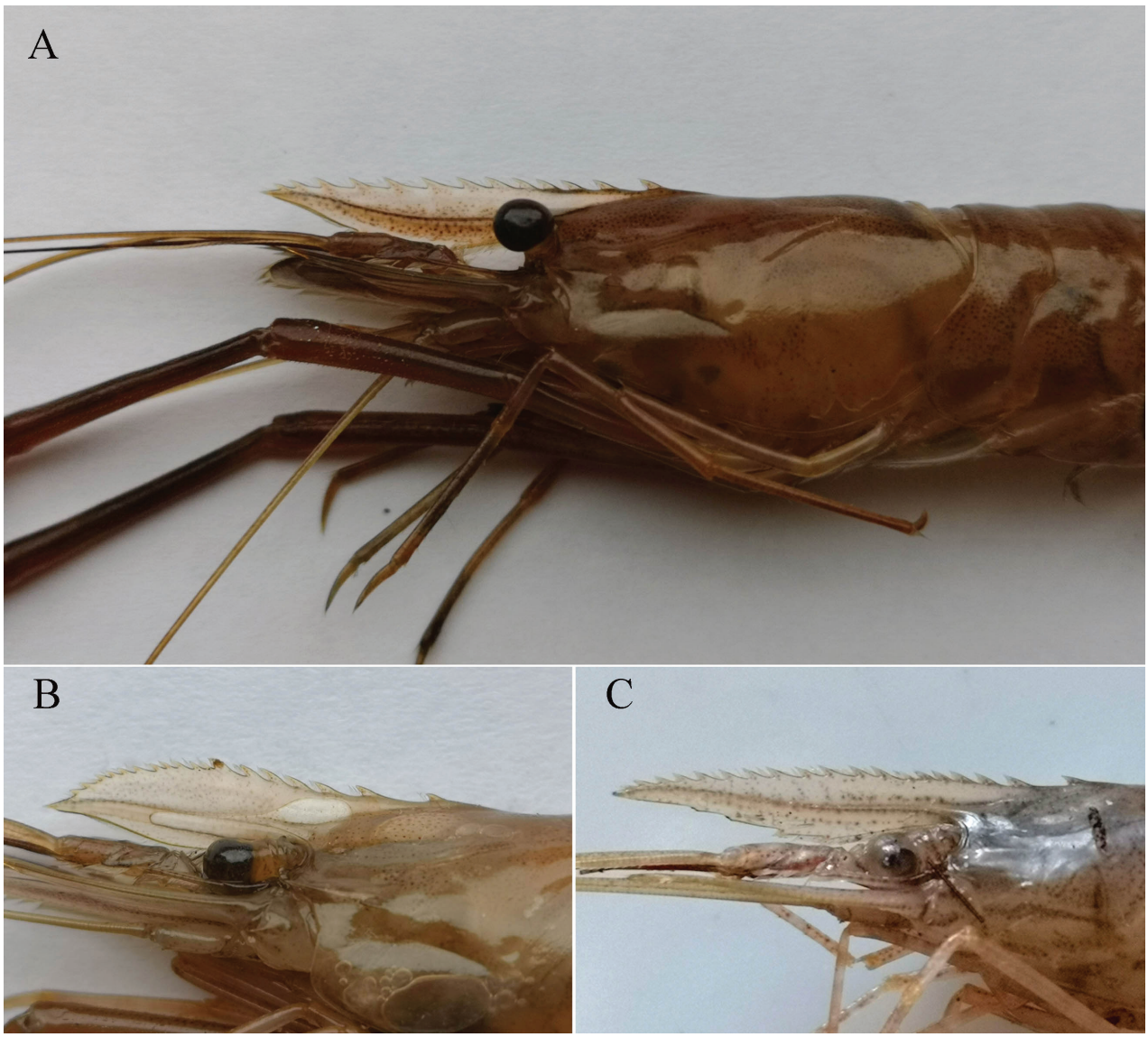

Figure 3. Rostrum variations in *Macrobrachium nipponense* from southwestern Ukraine, Solomonov Branch, Danube. **A** typical form with 13 dorsal rostrum teeth, male, L = 81 mm; **B** atypical forms with 17 dorsal rostrum teeth and rounded rostrum, female, L =71 mm; **C** elongated rostrum of typical shape with 19 dorsal rostrum teeth, female, L = 68 mm. Photographs by S. Bushuiev.

Size-weight data

The growth rate of the East Asian river prawns significantly depends on the type of their habitat. They reach the largest sizes in large freshwater or oligohaline water bodies, such as the Danube River or the Dniester Estuary. In the small shallow mineralized ponds and estuaries, the size and mass parameters of prawns were much lower (Table 4).

The total length of the prawn males from the fyke-net catches in the Danube (biggest samples) varied between 70–115 mm, with an average of 83.4 mm. The female's lengths in the same samples were 58–86 mm, averaging 59.9 mm. The male's weight in the same samples in the Danube was 5.2–13.0 g (average 8.51 g), and females – 1.92–7.71 g (4.16 g). Thus, the females' weights were half that of the males (Table 4).

The juveniles of the smallest sizes (9–26 mm in length) were registered in the Oleksandrivka Reservoir (Akkarzhanka River basin), but in the Danube samples, they varied from 42 to 65 mm in length (Table 4).

Table 4. Size and weight parameters of *Macrobrachium nipponense* from southwestern Ukraine.

Sex	Average body length, mm	Range, mm	n	Average weight, g	Range, g	n
Oleksandrivka Reservoir (Akkarzhanka River Basin), 26.08.2020						
Juv.	16.91±6.33	9–26	11	0.04	<0.01–0.18	11
Dzhantshey Lagoon, 01.11.2021						
Females	53.58±1.92	51–57	8	1.40±0.26	1.07–1.91	8
Dniester Estuary, July – September 2022						
Males	83.63±6.00	75–90	8	6.63±1.62	4.23–8.94	8
Females (total)	78.00±8.38	63–87	8	5.56±1.46	3.23 – 8.00	8
Ovigerous females	76.50±9.31	63–87	6	5.59±1.72	3.23–8.00	6
Juv.	50.13±7.06	38–56	8	1.26±0.40	0.45–1.62	8
Danube River, Bazarchuk Bay 21.10.2021						
Juv.	37.1±12.01	25–57	9	0.46	0.15–1.44	9
Danube River, Kiliia Branch, June – October 2022						
Males	88.55±8.34	70–115	292	8.51±1.81	5.2–13.0	132
Females (total)	72.40±5.99	58–86	122	4.16±1.19	1.92–7.71	120
Ovigerous females	74.67±5.29	63–86	42	4.94±0.99	3.08–7.71	42
Juv.	54.03±7.93	42–65	35	1.44±0.48	0.37–2.17	35

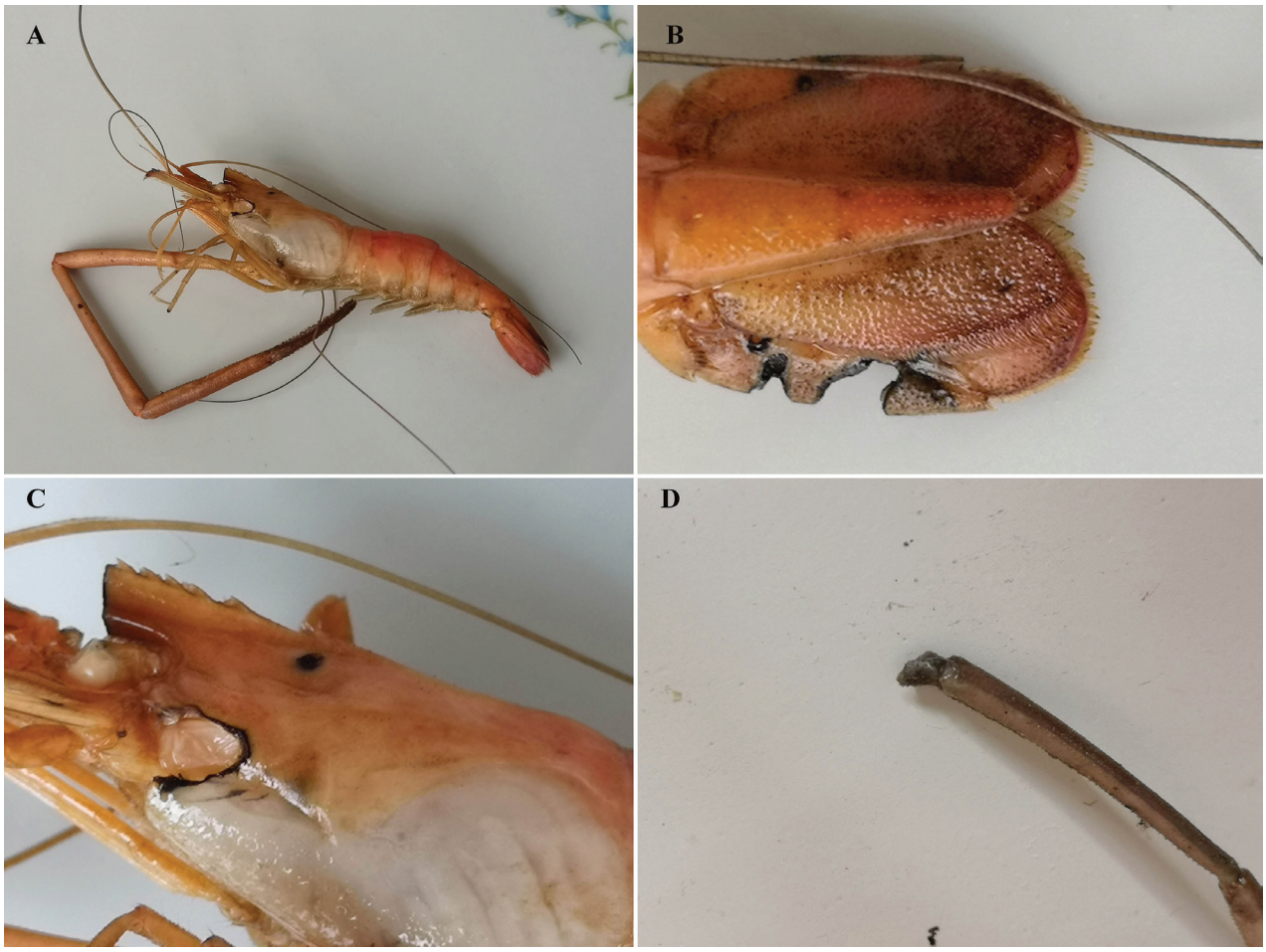

Figure 4. Diseases of *Macrobrachium nipponense* from the Danube River. **A.** Total view of a male infected with 'burn-spot' disease, L = 83 mm, Solomonov Branch; **B.** 'Burn-spot' infection of uropod, male, L = 89 mm, Solomonov Branch; **C.** 'Burn-spot' infection of carapace and rostrum, male, L = 83 mm, Solomonov Branch; **D.** 'Black end' disease of left second pereopod, male, L = 89 mm, Mashenka Branch. Photographs by S. Bushuiev.

The smallest ovigerous females on pleopods in the Danube River and the Dniester Estuary had a length of 63 mm (weight 3.08 and 3.23 g, respectively). In the shallow brackish water bodies, the fertile ovigerous females on pleopods have smaller sizes. Thus, in the Dzhantshey Lagoon the smallest ovigerous females had a length of 52.0 mm (1.34 g), but in Oleksandrivka Reservoir (Akkarzhanka River basin) just 34.0 mm total length and 0.48 g weight (Fig. 5). Typical fertile males with long second pereopods (longer than the total body length) do not occur in the small and shallow brackish water bodies.

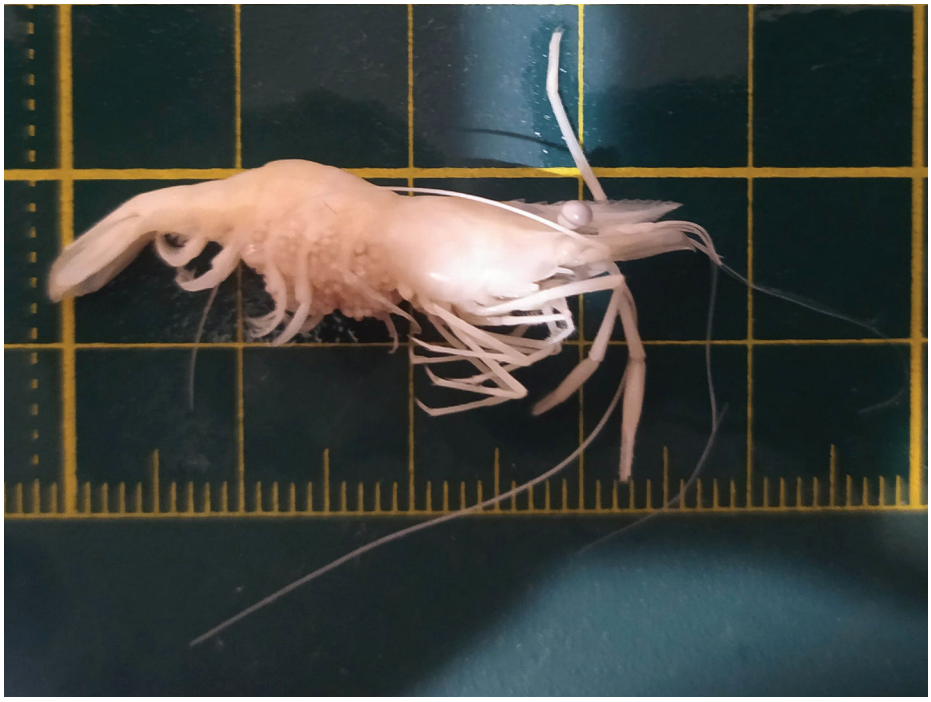

Figure 5. *M. nipponense* female less than 40 mm long with eggs, Oleksandrivka Reservoir (Akkarzhanka River Basin), 02.09.2018, PSU 1.555. Photograph by M. Son.

Seasonal changes

The size-weight parameters of *M. nipponense* of both sexes changed similarly seasonally (Table 5, Fig. 6). Average parameters of the total body length and weight of males and females increased from summer, then decreased during autumn.

The average body length in August is characterised by large parameters (93.2 mm in males, 76.5 mm in females), but decreased at the beginning of December to 78 mm in males and 73.2 mm in females. During the fall period, the average weight of males decreased from 9.50 g in August to 7.00 g in December, but that of the females decreased from 5.42 g to 4.53 g (Fig. 6).

Table 5. Seasonal changes of sex ratio in *Macrobrachium nipponense* catches in the Danube River in June-December 2022, %.

Sex	June	July	August	September	October	November–December
Males	100.0	84.9	61.8	100.0	3.3	29.9
Females (total)	–	14.2	23.6	–	78.3	66.2
Ovigerous females	–	73.1	90.5	–	6.2	0
Juveniles	–	0.9	14.6	–	18.5	3.9
n	30	212	89	22	92	77

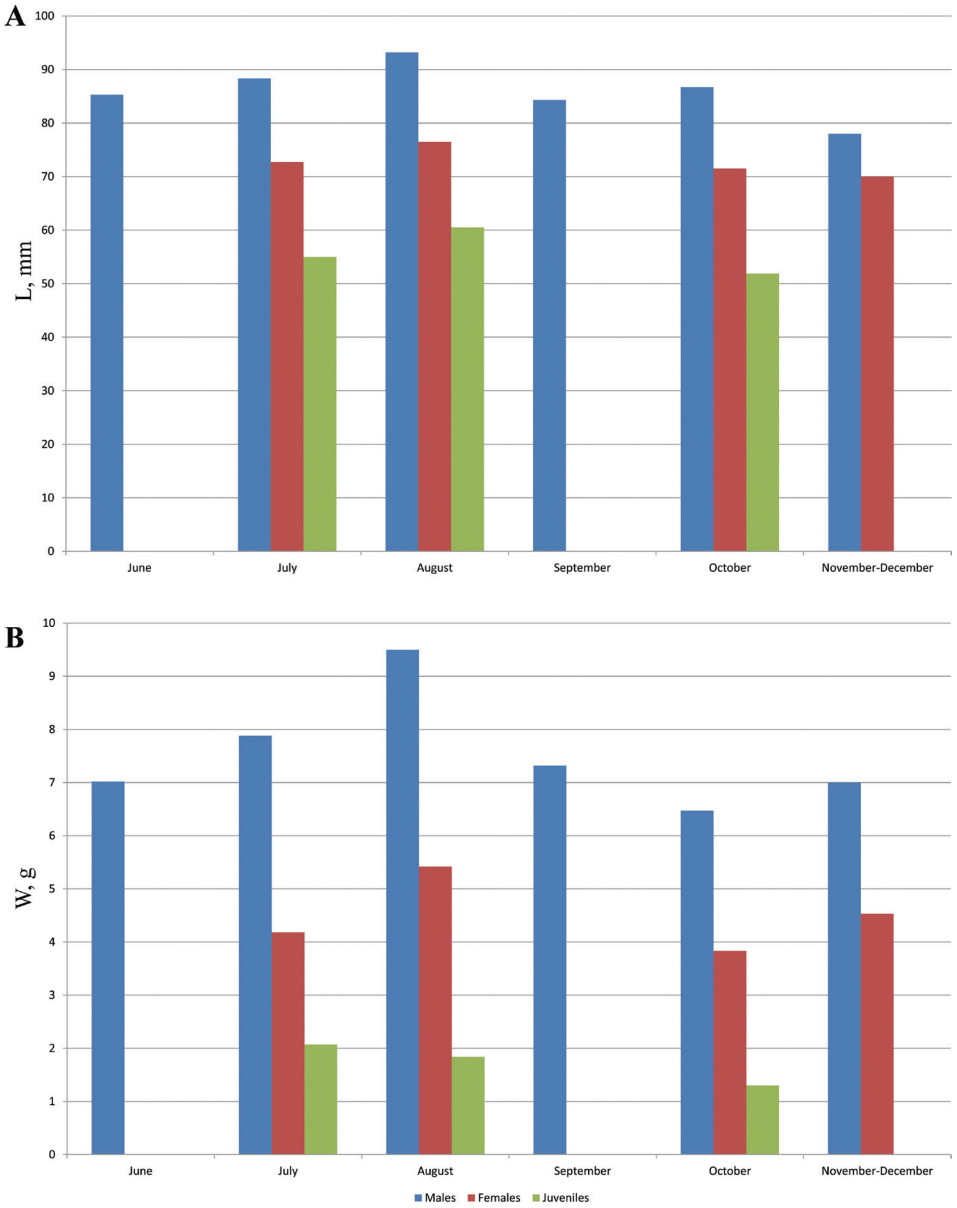

Figure 6. Seasonal changes in the size-weight parameters of *Macrobrachium nipponense* in the Danube River in June-December 2022. **A.** L, mm; **B.** W, g.

Sex-ratio

In June-September, males dominated the catches (Table 5). Their proportion in the samples varied from 62% to 100% by month. Since October, the proportion of males decreased significantly. In contrast, the proportion of females increased from 14% in July to 78% in October and only decreased slightly by early December. The dynamics of changes in the proportion of juveniles was the same as for females (Table 5).

In addition, during different periods, males, females, and juveniles of the Asian prawn may concentrate in different locations using different types of habitats in the river. Females and juveniles appear to be able to remain isolated from males during certain periods. To illustrate this phenomenon, we can compare the composition of fyke-nets (10 mm mesh) and beam-trawl (10 mm mesh) catches in the first decade of August in the same river section. In the catches of fyke-nets, which were exposed near the water's edge at a depth of about 1–1.5 m, the proportion of males was 84%, that of females was 16%, and juveniles were absent.

In beam-trawl catches (in the river channel with depths of 5–20 m, at a distance of 70–100 m from the shore) the sex composition of the sample was significantly different: the proportion of males was only 4%, females — 44%, and juveniles — 52%. A female prawn with a soft carapace after a recent molt was recorded in the catch. Remains of the chitinous cover of *M. nipponense* overmoulting individuals were also noted in the trawl among debris collected from the bottom.

According to our data in the Danube in 2022, the reproduction of *M. nipponense* was very successful, peaking in August. In July, 73% of adult females had eggs on the pleopods, and by August, the proportion of ovigerous females had increased to 90.5%. In autumn, there was a significant decrease in this indicator. Nevertheless, in October at a water temperature of 12–14 °C, over 6% of females were carrying eggs (Table 5). In the Dniester estuary in July, the proportion of ovigerous females was 67%, and at the very beginning of September, it was 100% (with an overall small sample size of 8 adult females).

Discussion

With this study, we confirm the post-invasional range-expansion of the East Asian river prawn (*Macrobrachium nipponense*) in southwestern Ukraine, which harbored the Danube and Dniester basins, their interfluvial zone and east from the Dniester delta till the Great Adzhalyk Estuary. In 2022 we registered a high number of adult individuals, probably from the 2019 generation. We confirm the growth of the population compared to the previous years (Son et al. 2020; Zhmud et al. 2022).

One of the methods to control the invasive species population growth is their commercial use (Giakoumi et al. 2019; Frommelt 2020). In the Mediterranean region, the cases of commercial perspectives are known for non-indigenous crustaceans, such as Northern brown shrimp (*Penaeus aztecus* Ives, 1891) (Kampouris et al. 2021). For the invasive *M. nipponense* the potential of commercial use is known in Iran (Lavajoo et al. 2018). In Ukraine, because of frequent cases of catches of adult prawns in commercial fisheries nets, this species has become well known in the last couple of years to fishermen and local people, which has shown high perspectives of its further commercial use.

Growth rates

We found that the maximal sizes of the prawn are in large water bodies, such as the Danube River and the Dniester Estuary, but in small brackish reservoirs, the sizes were much smaller (Table 4). Thus, the growth rates of *M. nipponense* tend to be higher in large water bodies, than in small brackish ones. The decrease in weight of both sexes during the fall period is probably related to the increase in the natural mortality of large individuals of the older age category. Similarly, the maximal lengths of the prawn in Ukraine are larger than in the native range. Thus, we registered a maximal length of 115 mm in males (in the Danube River) and 87 mm in females (in the Dniester Estuary; see Table 4), but in some places of the native range they were 86 mm in males, and 75 mm in females in natural water bodies and 88 mm in males and 80 mm in females in cooling reservoirs of thermal power plants in places of introduction (Ogawa et al. 1994; Nguyen et al. 2002; Kulesh 2009; Aye 2020).

Higher growth rates are already registered for *M. nipponense* in the acquired range, as well as earlier maturity, higher reproductive intensity with 6–8 spawnings per season (Vladimirov et al. 1989; Giginyak et al. 2006). In the Hiroshima region, Japan, spawning is recorded in June-September, with a maxima in July (Ogawa et al. 1994). The high percentage of ovigerous females in the Danube River (see Table 5) points to the successful adaptation of the prawn to the local climatic con-

ditions. In Ukraine, the period when the ovigerous females were registered was in June-October (even in October more than 6% of females had eggs), with a maximum in July-August. We registered a much higher percentage of ovigerous females in the Dniester Estuary than in 2016–2019, when only 13.6–20.6% were found (Shekk 2021). At the same time, the average length of females was higher twice in 2022 than in 2016–2019. This may indicate a qualitative increase in the intensity of reproduction of *M. nipponense* in this water body in recent years.

In small brackish water bodies in southwestern Ukraine (PSU 1.5–6.0) the growth rates of *M. nipponense* were lower than in the freshwater Danube waters and slightly oligohaline Dniester Estuary, and the life cycle probably shorter. The females in such water bodies mature earlier, with smaller sizes. For example, in Oleksandrivka Reservoir the minimal length of the ovigerous females was 34 mm, but in the Danube River, it was 63 mm (see Table 4). We registered an interesting fact, in the absence of fertile males with long second pereopods in the small brackish water bodies. Apparently, the advanced growth of second pereopods appears in males only after maturation. In the Danube, this happens when males reach a body length of about 70 mm. This could be caused by the less favourable conditions for the prawn species in such kinds of waters. The early maturation of *M. nipponense* upon reaching a small size and the formation of peculiar "slow-growing" populations is obviously an adaptation to unfavourable habitat conditions in shallow mineralized water bodies during wintering.

Place of *M. nipponense* in the ecosystem

The East Asian river prawn (*M. nipponense*) is an almost omnivorous species (Leontyev 2015; Mirzajani et al. 2020). At this time, we have no confirmation of any threat to local crustaceans due to food competition. Even more, the juveniles of this prawn are a good dietary item for many fish and invertebrates. In theory, the adult prawns could be consumed by predatory fish, such as catfishes, pickerels, pike-perches, and large perches. In southwestern Ukraine, only Wels catfish (*Silurus glanis* L., 1758) is regularly found in fyke-net catches together with the East Asian river prawn (see Table 1; also unpublished data). Fishermen claim that catfish, caught in fyke-nets, sometime eructate dead prawns; however, it is just as likely that the prawns were captured at the same time as the catfish, and that the fish ate the prawns while in the net, i.e. they were not predated upon as such but taken opportunistically.

The invasion of *M. nipponense* could harm the local crayfish populations because of the distribution of specific pathogens. The cases of *M. nipponense* infestation with 'burn-spot' disease are already confirmed (see Fig. 4). The prawns could also spread the diseases of the local Danube crayfish (*Pontastacus leptodactylus* [Eschscholtz, 1823]), i.e. 'black-end' and 'burn-spot' diseases, which caused by several species of pathogenic fungi.

Commercial use perspectives

In the last two years, when the density of large individuals of older age groups of *M. nipponense* in the Danube increased significantly, it began to be considered by local fishermen as a new potential commercial fishery species. Fishermen quickly began to master fishing with small-mesh fyke nets of various types. To date, the catch for own consumption prevails, but there are also cases of the sale of *M. nipponense* in the markets.

The fishing of the Asian prawn in Ukraine is currently carried out illegally, since the use of small-mesh nets in the Danube and Dniester basins is not provided for

by the Official Ukrainian Fishing Rules (State Fisheries Committee of Ukraine 1998). The legal crayfish traps with 16 mm mesh are almost unsuccessful for prawn fishing. In the Dzhantshey Lagoon, as well as in the other lagoons and estuaries in Ukraine connected to the sea, the 6-mm mesh fyke-nets are used for the fishing of the sand-smelts (*Atherina* spp.). Fishermen from the Dniester Estuary confirm the presence of about 10–15 ind. of *M. nipponense* per fyke net, with maximal catches of 40 prawns per fyke net (unpublished data). In the Danube River near Kiliia in July the average catch was about 25 ind. (~170 g) per a fyke-net. It is noteworthy that the average catches using the same research equipment near Vylkove were almost three times lower (Table 2). The most effective type of nets for *M. nipponense* fishing was 10–15-m length and 10-mm mesh size fyke-nets with many vents. This kind of trap catches mainly large individuals of the prawn. Taking into account the usage of more than 20 fyke nets per fisherman, as well as low labour and fuel costs, the commercial fisheries of the East Asian river prawn could be very cost-effective. In this regard, the issue of legalizing fishing becomes relevant.

An important point in organizing an ecosystem-friendly fishery for *M. nipponense* is to minimize the by-catch of non-target objects. Due to our data, the non-target species in fyke-net catches were two invasive species, i.e. *Pseudorasbora parva* and *Lepomis gibbosus*, and one protected species, *Zingel zingel* (Red Data Book 2009). The last one was caught only in one case. Because no cases of fish death in the fyke-nets were recorded, the threatened species could be released alive. However, considering possible damage to released fish, unwanted by-catch (discard) should be minimized. According to this parameter, the situation in the Danube looks the most promising.

Currently, the percentage of prawn in catches in the Dniester Estuary and the Dzhatshey Lagoon is small. The perspectives of the commercial fisheries of the prawn are only in the Danube River. However, if the growth of *M. nipponense* density in the region continues, commercial fisheries may become feasible in other water bodies.

It is also necessary to consider what gear could be used to fish prawns. The fyke-nets with 10-mm mesh selectively catch the largest individuals, among which adult males predominate since adult males reach a significantly larger size and weight than females. A significant part of small adult females and almost all juveniles do not stay in such vents. In 5–6 mm mesh fyke-net catches, the percentage of females noticeably increases, and the percentage of juveniles also increases, although small juveniles are also not caught by them. So, we determined the prospect of organizing the fishery for *M. nipponense* in the Danube River. Since fishing of the prawn with 10-mm mesh fyke-nets threatens to be unsafe for a large number of fish species, further research is needed to find solutions to increase the selectivity of fishing gear, including the construction of nets and the importance of bait. It is also necessary to determine the best methods for fishing for prawn and locations for fishing gear.

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Authors' contribution

SB, MOS, YK research conceptualization; SB, SS, MOS, GK, YK sampling; SB, MOS, GK laboratory proceeding; SB, SS writing original draft; IS graphics preparation, geoinformatics support; YK funding administration

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Supplementary material 1

Sampling localities and finding places of *Macrobrachium nipponense* in southwestern Ukraine

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