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MORPHOLOGICAL AND MERISTIC ANALYSIS OF *Macrobrachium nipponense* POPULATIONS: IMPLICATIONS FOR ECOLOGICAL STABILITY IN LENTIC HABITATS OF THE DANUBE DELTA

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Abstract

This paper analyzes the morphometric and morphological characteristics of the alien species Macrobrachium nipponense (De Haan, 1849) in the Danube Delta ecosystem. The study was conducted on a representative sample of specimens collected from Matița-Merhei lake complex of the Danube Delta Biosphere Reserve, aiming to assess phenotypic variability in the context of acclimatization to local hydro-climatic conditions. The methodology involved measuring 15 morphometric parameters, including total length, carapace length, and claw dimensions, as well as examining the qualitative characteristics of the rostrum The meristic analysis focused on the variability of the rostral formula and pereiopod segmentation, confirming a high adaptive plasticity of the species in lentic habitats. The analysis of morphometric correlations indicates a plastic adaptation of populations to the thermal and hydrological regime of the Danube Delta, confirming the high competitive potential of the species compared to native crustaceans. The data obtained provide essential information for monitoring the population dynamics of this oriental shrimp, contributing to the understanding of the ecological impact of allochthonous species on benthic biodiversity in the region.

Key words*: freshwater, interspecific competition, Matița-Merhei, meristic traits, shrimp.*

INTRODUCTION

Macrobrachium nipponense (De Haan, 1849), commonly known as the oriental river prawn, is a freshwater decapod native to the subtropical and temperate regions of East Asia, including China, Japan, Korea, and Taiwan, where it inhabits a variety of environments ranging from rivers and lakes to low-salinity estuaries (Chen et al., 2015a; Jin et al., 2023). In its native range, the species is characterized by its significant role in benthic food webs and its high commercial value for aquaculture, being well-adapted to fluctuating seasonal temperatures and varying dissolved oxygen levels (Wang et al., 2022).

However, the expansion of non-native species in aquatic ecosystems represents one of the most significant challenges to global biodiversity, carrying the potential to alter the structure of benthic communities and local trophic interactions. In this context, decapod crustaceans, particularly those within the Palaemonidae family, have gained attention for their remarkable invasive capabilities, facilitated by high ecological tolerance and significant dispersal capacity (Ashelby et al., 2013; De Carvalho-Souza et al., 2025).

As a globally successful invader, *M. nipponense* has expanded its range into numerous aquatic systems across Iran (De Grave & Ghane, 2006) and, more recently, Europe, where it continues to spread upstream into countries like Germany and Hungary (Bláha et al., 2025). Recent studies indicate that in newly colonized habitats, such as the Danube Delta, individuals can even exceed the sizes recorded in their native range,

suggesting a high adaptive plasticity (Lepekha et al., 2025). Its success is attributed to a strategic combination of structural stability in its body plan and pronounced phenotypic plasticity—traits that enable it to cope with environmental variability (Ashelby et al., 2013; Chen et al., 2015b).

In the Danube basin, the presence of *M. nipponense* has shifted from isolated reports to a widespread phenomenon, becoming a common element of the local benthic fauna (Zhmud et al., 2021). The species has demonstrated high invasive potential by establishing viable populations in freshwater systems across the lower Danube and Dniester (Nekrasova et al., 2024; Bushuiev et al., 2023). This expansion, which includes the first official record in Romania (Surugiu, 2022) and recent confirmations in the Bulgarian sector (Kutsarov et al., 2025), transforms the Danube River into a critical invasion corridor where the species may directly compete with native fauna.

Morphometric analysis and allometric growth models are essential tools for understanding the adaptation of this species to new ecosystems (Chen et al., 2015b). Differentiating between size-related (structurally integrated) and shape-related (functionally flexible) traits provides valuable insights into energy allocation strategies and sexual maturation (Jin et al., 2023). Furthermore, pronounced sexual dimorphism influences population dynamics and the capacity for persistence in non-native habitats (Jin et al., 2023; Wang et al., 2022).

The present study aims to characterize the morphological structure of an *M. nipponense* population collected from the Matița-Merhei complex (Danube Delta), evaluating the stability of biometric correlations and the variability of functional traits as indicators of adaptive success in this specific deltaic environment.

MATERIALS AND METHODS

Sampling and data collection. A total of 45 individuals of *Macrobrachium nipponense* were collected from lentic habitats within the Danube Delta- Matița Merhei Lake Complex, Miazăzi lake (Figure 1). Surface area estimates were derived using geospatial analysis based on publicly available cartographic data.

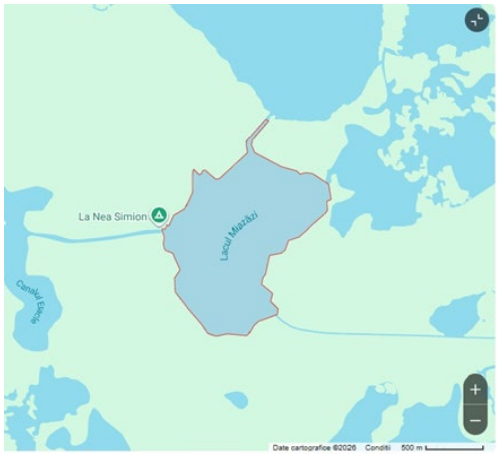

Figure 1. Map with a description of the research area (https://maps.app.goo.gl/5MEdZbMeHJwAD84y5)

Sampling was conducted during the pre-reproductive period (March-April), when individuals undergo gonadal development but prior to active spawning. In temperate regions, the reproductive period of the species typically extends from May to September (Jin et al., 2022). During the pre-reproductive stage, body weight may increase due to energy allocation toward gonadal development, while lacking the additional variability associated with ovigerous females (Hartnoll, 1982; Sastry, 1983).

Sampling was performed using baited crayfish traps (length: 0.40-3.00 m; diameter: 30-50 cm; mesh size: 10 mm; wire thickness: 1.5 mm), ensuring minimal selectivity bias across size classes. All specimens were preserved and transported to the laboratory for subsequent analyses. Sampling and handling procedures followed standard practices for invertebrate research.

Morphological measurements. Each specimen was photographed using a stereomicroscope (OZP 558, KERN & SOHN GmbH, Balingen, Germany) at 40× magnification, equipped with a digital imaging system (ODC 832, KERN & SOHN GmbH, Balingen, Germany). Images were processed and measured using MicroscopeVIS 2.0 PRO software (x64 version), compatible with the imaging system (Figure 2).

The following variables were recorded: Total length (TL, mm), Carapace length (CL, mm), Rostrum length (RL, mm), Carapace width (CW, mm), Body weight (W, g) (Kawamata &

Taino, 2018). Additionally, proportional indices were calculated to describe body shape: CL/TL, RL/CL, CW/CL.



Figure 2. Morphometric measurements of *Macrobrachium nipponense* based on digital image analysis (Source: original)

All measurements were performed using a digital caliper (precision ±0.01 mm) and an electronic balance (precision ±0.01 g). Measurements were performed on calibrated images using integrated measurement software. Values displayed in the figure are expressed in pixels (px) and were subsequently converted to millimeters (mm) based on image calibration (1 mm ≈ 44 px).

Sample size was constrained by field conditions but considered sufficient for multivariate statistical analysis.

Ethical approval. All sampling and handling procedures were conducted in accordance with standard ethical practices for invertebrate research and in line with the general principles of Directive 2010/63/EU. The measurement activities were supervised by the Bioethics Commission of the Research and Development Institute for Aquatic Ecology, Fishing and Aquaculture, Galați (Decision no. 52/16.03.2023).

Descriptive statistics. Descriptive statistics were calculated for all variables, including mean, standard deviation (SD), standard error of the mean (SEM), minimum and maximum values, and coefficient of variation (CV). These parameters were used to characterize the variability and structural organization of the population.

Data distribution and quality assessment. The presence of outliers was assessed using the Grubbs test, while the normality of data distribution was evaluated using the Shapiro-Wilk test ($\alpha = 0.05$). These analyses ensured the reliability of subsequent statistical procedures and informed the selection of appropriate analytical methods.

Frequency distribution analysis. Frequency distributions for total length (TL), carapace length (CL), and body weight (W) were constructed using grouped class intervals to evaluate the size structure and population homogeneity.

Sex-related analysis. Sex was determined for each individual, and the sex ratio (F:M) was calculated. A chi-square (χ^2) test was applied to assess deviations from the expected 1:1 ratio. Differences between sexes in morphological variables were tested using the Mann-Whitney U test. The analysis focused on both size-related variables (TL, CL, W) and proportional indices (CL/TL, RL/CL, CW/CL), allowing the identification of potential sexual dimorphism.

Length-weight and allometric relationships. The relationship between total length and body weight was described using a power function: $W = a \cdot TL^b$, where a is the intercept and b is the allometric coefficient (Ricker, 1975; Froese, 2006; Ko, 2025).

Allometric relationships between morphological traits (e.g., TL–CL, CL–CW, CL–RL) were analyzed using log-transformed linear regressions (Wang et al., 2022). The value of b was used to determine growth patterns (isometric, positive or negative allometry).

Correlation analysis. Relationships between morphological variables were assessed using Pearson correlation coefficients. This approach was selected based on the approximate normal distribution of the data and the expected linear relationships among variables.

Principal component analysis (PCA). Principal component analysis (PCA) was performed on standardized variables using a correlation matrix (Maćkiewicz & Ratajczak, 1993). The aim was to reduce data dimensionality and identify the main axes of morphological variation.

Only the first two principal components (PC1 and PC2) were retained for interpretation, based on their high cumulative explained variance. Factor loadings were used to interpret the contribution of each variable, while individual scores were used to visualize population structure through a PCA biplot.

All statistical analyses were performed using XLSTAT Essentials (Addinsoft, 2026.1.0 version), integrated within Microsoft Excel.

RESULTS AND DISCUSSIONS

A total of 45 individuals of *Macrobrachium nipponense* were collected during the study period, with a cumulative biomass of 167.27 g. Descriptive statistics of the analyzed morphological variables are presented in Table 1.

Table 1. Descriptive statistics of morphological variables of Macrobrachium nipponense populations

Variable	N	Mean ± SEM	Min.–Max.	CV (%)
TL (mm)	45	77.80±1.61	59.56-99.14	13.88
CL (mm)	45	32.01±0.61	22.67-40.09	12.76
RL (mm)	45	21.97±0.68	11.22-30.11	20.77
CW (mm)	45	3.67±0.10	1.79-4.95	17.99
W (g)	45	3.72±0.24	1.19-7.86	43.37
CL/TL	45	0.41±0.004	0.38-0.48	6.01
RL/CL	45	0.69±0.02	0.31-0.96	18.41
CW/CL	45	0.11±0.002	0.08-0.14	13.99

Values are presented as mean ± standard error of the mean (SEM), with minimum and maximum values and coefficient of variation (CV).

The absence of significant outliers (Grubbs test, $p > 0.05$) indicates a homogeneous dataset, supporting the reliability of subsequent analyses. Similarly, the Shapiro–Wilk test confirmed that all variables did not significantly deviate from normality ($p > 0.05$), justifying the use of parametric approaches for further analyses, although the value observed for TL ($p = 0.058$) suggests slight heterogeneity in size distribution.

The population exhibits a heterogeneous pattern of variability across traits, reflecting differences in biological control and functional significance. Body weight (W) showed the highest variability (CV = 43.37%), a result that is biologically expected, as this parameter is strongly influenced by short-term physiological processes such as feeding intensity, energy reserves, and reproductive status. In crustaceans, fluctuations in gonadal development can significantly affect body mass independently of structural dimensions, contributing to the observed dispersion. In *M. nipponense*, rapid gonadal development and early sexual maturation can significantly influence growth dynamics and energy allocation, contributing to variability in body weight and condition (Jin et al., 2022).

Rostrum length (RL) also displayed relatively high variability (CV = 20.77%), suggesting a degree of phenotypic plasticity in this trait. Given its functional role in feeding, defense, and environmental interaction, variability in RL may reflect adaptive flexibility, potentially allowing individuals to exploit a wider range of ecological niches. In invasive species, increased variability in functionally relevant structures is often associated with enhanced ecological performance in novel environments.

In contrast, the CL/TL ratio exhibited very low variability (CV ≈ 5%), indicating a high level of morphological stability in body proportions. This suggests strong developmental or genetic control over the relative growth of the cephalothorax and total body length. Such stability in core structural proportions is essential for maintaining biomechanical efficiency and overall organismal functionality.

The coexistence of highly variable traits (e.g., weight, rostrum length) and highly stable proportions (e.g., CL/TL) highlights a dual pattern of morphological organization: structural stability combined with functional flexibility. This pattern is particularly relevant in the context of invasive species, where the maintenance of a stable body plan, coupled with variability in ecologically relevant traits, may contribute to successful establishment and persistence in new environments.

The successful establishment of *M. nipponense* in non-native habitats has been attributed to its combination of structural stability and phenotypic plasticity, traits that enhance its ability to cope with environmental variability (Ashelby et al., 2013). The recent expansion of *M. nipponense* in the Lower Danube, including its first record in Romania, provides a relevant ecological context for interpreting the morphological patterns observed in this study, as such traits may facilitate its successful establishment and persistence in newly colonized environments (Surugiu, 2022). This pattern is consistent with the global spread of

Macrobrachium nipponense, which has been increasingly reported as a non-native species in various aquatic systems, facilitated by its high ecological tolerance and dispersal capacity (De Carvalho-Souza et al., 2025).

The size structure of the population further supports this interpretation. Total length (TL) and carapace length (CL) exhibited approximately symmetrical distributions, as indicated by low skewness values (TL: 0.18; CL: −0.19) and slightly negative kurtosis. This suggests a relatively homogeneous population structure, without the dominance of a single cohort. In contrast, body weight (W) showed moderate positive skewness (0.63), reflecting a higher frequency of individuals with lower mass and fewer high-weight specimens. This divergence between length-based and weight-based distributions indicates a partial decoupling between structural growth and energetic condition.

The frequency distributions of total length (TL), carapace length (CL), and body weight (W) confirm the observed structural patterns (Figure 3). Both TL and CL exhibit unimodal distributions, with most individuals concentrated in intermediate size classes (approximately 73-80 mm for TL and 31-34 mm for CL), indicating a relatively homogeneous and structurally coherent population.

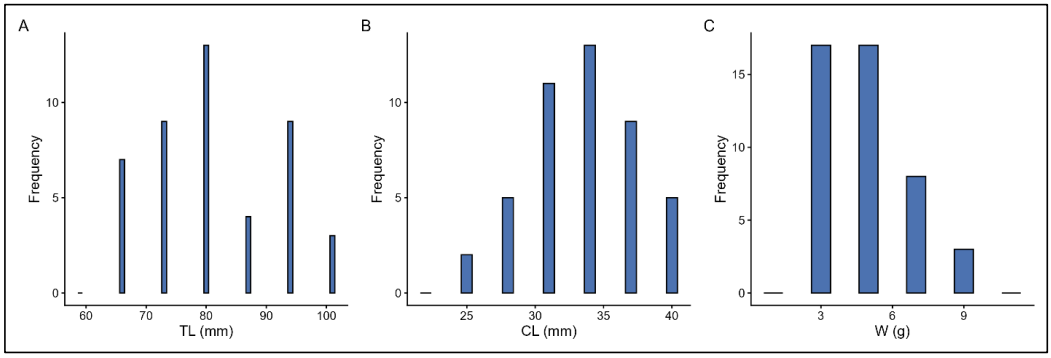

Figure 3. Frequency distributions based on grouped class intervals

In contrast, body weight (W) shows a more uneven distribution, with a concentration in lower and intermediate classes (3-6 g) and a gradual decline toward higher values, suggesting variability in physiological condition. This pattern is consistent with flexible energy allocation among individuals.

The divergence between the relatively compact length distributions and the broader, skewed weight distribution indicates a decoupling between structural growth and energetic status. While body dimensions (TL and CL) appear tightly regulated, body mass varies more substantially, likely reflecting differences in feeding efficiency, metabolic reserves, or reproductive stage. Such a pattern is characteristic of populations with flexible energy allocation strategies and may be particularly advantageous in invasive species, allowing individuals to maintain structural integrity while adjusting physiological condition in response to environmental variability.

Morphometric variability observed in this study is consistent with previous findings showing that *Macrobrachium nipponense* exhibits significant morphological differentiation among populations, likely driven by environmental conditions and local adaptation (Chen et al., 2015b).

Sex-related analyses revealed a balanced sex ratio (F:M = 1.25:1), which did not differ significantly from the expected 1:1 distribution (χ^2 test, $p > 0.05$). However, significant differences were observed between sexes in size-related traits. Males exhibited significantly higher values of total length (84.22 ± 10.27 mm vs. 72.67 ± 8.29 mm; $p = 0.001$) and body weight (4.59 ± 1.72 g vs. 3.02 ± 1.14 g; $p = 0.001$), indicating a pronounced sexual dimorphism. The absence of differences in sex ratio, coupled with significant size differences, suggests that this dimorphism reflects intrinsic biological patterns rather than sampling bias.

These results indicate a clear sexual dimorphism in overall body size, with males exhibiting significantly larger size and higher weight compared to females. The absence of deviation in sex ratio suggests that this pattern is not related to sampling bias but reflects intrinsic biological differences between sexes. This finding is consistent with previous studies reporting faster growth rates and larger body size in male *Macrobrachium nipponense*, driven by differences in reproductive physiology and hormonal regulation (Jin et al., 2022; Chen et al., 2015b).

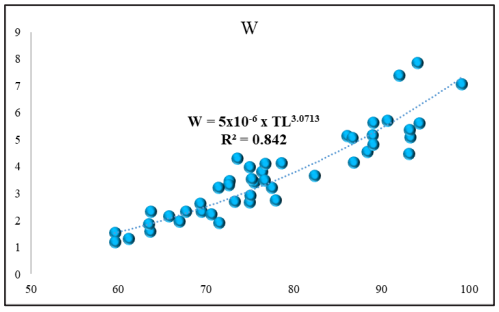

Figure 4. Length–weight relationship for *M. nipponense*

The length–weight relationship was best described by a power function ($W = 5 \times 10^{-6} \cdot TL^{3.0713}$; $R^2 = 0.842$), indicating a strong positive association between size and mass. The allometric coefficient (b = 3.07) suggests slightly positive allometric growth, where weight increases at a marginally higher rate than length (Figure 4).

This pattern reflects efficient energy accumulation and may be associated with favorable environmental conditions or adaptive life-history strategies.

Further analysis of allometric relationships revealed that the TL–CL relationship (Figure 5) follows a negative allometric pattern (b = 0.856; $R^2 = 0.817$), indicating that total length increases faster than carapace length, resulting in body elongation with growth. The CL–CW relationship showed moderate association ($R^2 = 0.416$) and negative allometry (b = 0.447), supporting a consistent elongation trend within a relatively stable structural framework. In contrast, the CL–RL relationship was weak ($R^2 = 0.174$) and characterized by a low allometric exponent (b = 0.226), indicating high variability and reduced structural constraint.

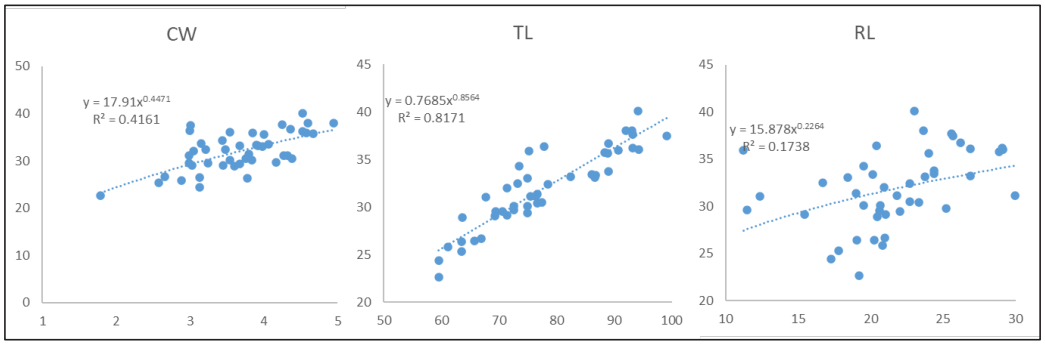

Figure 5. Patterns of Morphological Allometry and Structural Variability in *Macrobrachium nipponense*

Such differences in growth patterns and body proportions are in agreement with studies demonstrating that allometric relationships and morphometric traits in *M. nipponense* vary across populations and environmental contexts (Chen et al., 2015b).

The Pearson correlation matrix supports these findings (Figure 6), revealing strong positive correlations among total length (TL), carapace length (CL), and body weight (W), with TL–CL (r = 0.903), TL–W (r = 0.919), and CL–W (r = 0.850), indicating that these variables define the core structural framework of the organism. Moderate correlations were observed between TL and carapace width (CW) (r = 0.596), as well as between CW and CL (r = 0.644), suggesting that width increases with size but with greater variability compared to longitudinal growth. In contrast, rostrum length (RL) exhibited weaker correlations with structural variables, particularly with CL (r = 0.461) and CW (r = 0.493), while its association with TL was

moderate (r = 0.657), confirming a lower degree of structural integration and higher variability of this trait.

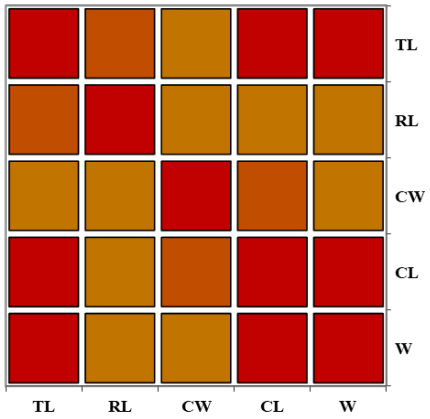

Figure 6. Correlation Matrix of Morphological Variables in *Macrobrachium nipponense*

Overall, these results highlight a clear distinction between tightly integrated morphological traits (TL, CL, W), which define the core body structure, and more variable traits such as RL, which may reflect higher phenotypic plasticity. This combination of strong structural coherence and localized variability may contribute to the adaptive capacity of *Macrobrachium nipponense* in heterogeneous or novel environments.

Principal component analysis (PCA) revealed that the first two components explained 86.04% of the total variance (Figure 7). PC1 (74.16%) was strongly associated with total length (TL), carapace length (CL), and body weight (W), representing an overall body size gradient. PC2 (11.88%) was primarily driven by rostrum length (RL), reflecting variation in body proportions rather than size.

These results indicate that morphological variation in the analyzed population is structured along two main axes: a size-related component characterized by strong integration of core body traits, and a shape-related component associated with increased variability in specific functional structures.

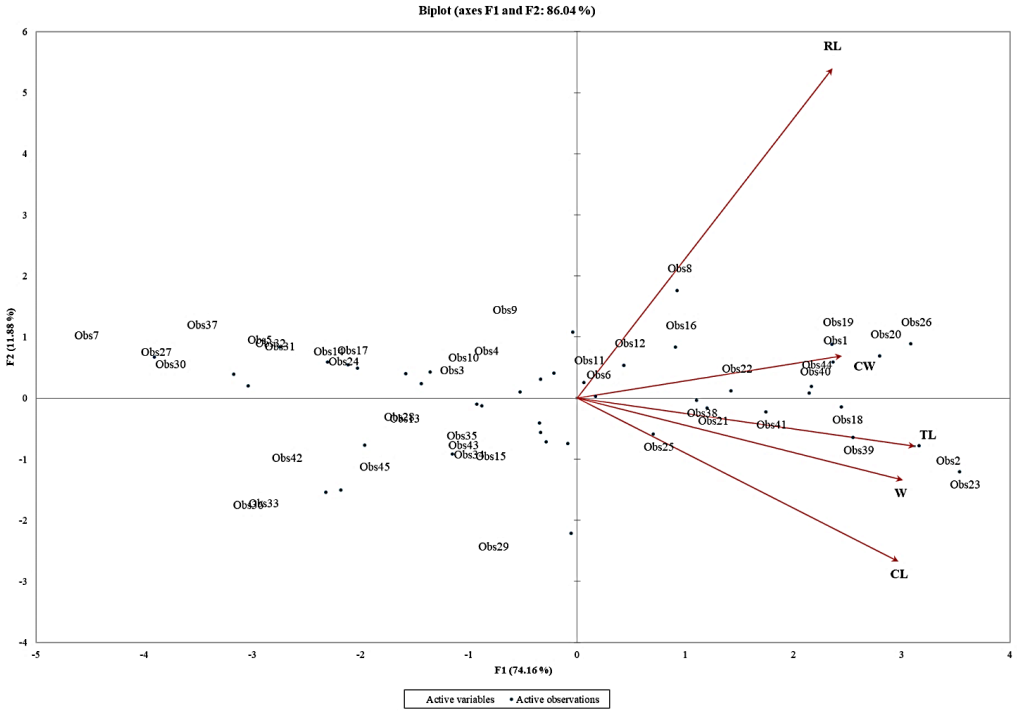

Figure 7. Principal component analysis (PCA) biplot based on standardized morphological variables. Arrows indicate the direction and magnitude of variable contributions, while points represent individual observations (i.e., measured specimens), positioned according to their scores on the first two principal components (PC1 and PC2)

This combination of structural stability and phenotypic plasticity is consistent with patterns reported for invasive populations of *Macrobrachium nipponense*, which exhibit high ecological tolerance and capacity to establish in non-native freshwater systems (Nekrasova et al., 2024).

The differentiation between size-related and shape-related traits identified in this study is consistent with multivariate analyses showing that morphological variation in *M. nipponense* reflects both structural integration and environmental adaptation (Chen et al., 2015b).

From an ecological perspective, this pattern is highly relevant, as it indicates that the species maintains a stable body structure, essential for movement, growth, and survival, while allowing flexibility in specific traits that interact directly with the environment. For instance, variability in rostrum length may reflect differences in feeding strategies or habitat use. This combination of structural stability (size-related traits) and phenotypic flexibility (shape-related traits) is characteristic of species capable of adapting to a wide range of environmental conditions and may partly explain the ability of *Macrobrachium nipponense* to establish and persist in non-native habitats.

Such adaptive capacity has been associated with traits including rapid reproductive development and flexible energy allocation, which enhance population growth and persistence under favorable conditions (Chen et al., 2015a; Jin et al., 2022). In addition, morphometric variation in this species has been linked to environmental conditions and habitat type, suggesting a strong relationship between morphology and ecological adaptation (Chen et al., 2015b).

At a broader scale, the increasing number of records of *M. nipponense* outside its native range indicates an ongoing expansion process, driven by its high ecological tolerance and dispersal capacity (De Carvalho-Souza et al., 2025). In the Danube basin, this trend is already evident (Kutsarov et al., 2025), as the species has shown a high invasive potential, being able to establish viable populations in freshwater systems (Surugiu, 2022). Eastern Europe has been identified as a suitable region for further expansion, particularly under future climate scenarios (Nekrasova et al., 2024).

The establishment of this species may have ecological consequences, including potential impacts on benthic communities and trophic interactions, thereby posing a risk to local biodiversity in the Danube Delta ecosystem. In this context, the Danube River represents an important invasion corridor, and the increasing presence of *M. nipponense* highlights the need for continuous monitoring and assessment of its ecological impact.

In this context, further research is needed to integrate morphological data with environmental variables to better understand the drivers of population variability and expansion. In particular, the relationships between morphological traits and key abiotic factors, such as temperature, dissolved oxygen, and trophic conditions, should be investigated across different habitats in the Danube Delta.

Given the invasive nature of *Macrobrachium nipponense*, priority should be given to assessing its ecological impact, including trophic interactions and potential competition with native species. Complementary approaches, such as stable isotope analysis and eDNA monitoring, may provide valuable insights into its ecological niche and spatial distribution.

From a management perspective, the increasing occurrence of this species highlights the need for early detection and continuous monitoring programs, particularly in ecologically sensitive areas of the Danube Delta. Management efforts should focus on limiting further spread, identifying potential ecological impacts on native communities, and integrating the species into existing biodiversity monitoring frameworks.

CONCLUSIONS

The analyzed population of *Macrobrachium nipponense* exhibits a dual morphological structure, characterized by strong integration of size-related traits and increased variability in functionally relevant features. Significant sexual dimorphism was identified, with males displaying larger body size and higher weight. Allometric relationships indicate differential growth among body components, while PCA confirms the separation between size and shape variation. These characteristics support the species' adaptive capacity and its potential to

establish in non-native environments. Given its increasing occurrence in the Danube Delta, continued monitoring and management strategies are required to assess and mitigate its ecological impact.

These findings support the need for targeted monitoring and management strategies to limit the spread and ecological impact of this invasive species in the Danube Delta.

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REFERENCES

Ashelby, C. W., De Grave, S., & Johnson, M. L. (2013). The global invader *Palaemon macrodactylus* (Decapoda, Palaemonidae): An interrogation of records and a synthesis of data. *Crustaceana*, *86*(5), 594–624.

Bláha, M., Schrottenbaum, A., Weiperth, A., Hammerschmied, U., Graf, W., Csányi, B., Patoka, J., & Kouba, A. (2025). *Macrobrachium nipponense* (De Haan, 1849) continues to spread in the Danube: First records in Germany and Hungary. *Knowledge & Management of Aquatic Ecosystems, 426*, 9. https://doi.org/10.1051/kmae/2025004.

Bushuiev, S., Snigirov, S., Son, M. O., Sokolov, I., Kharlov, G., & Kvach, Y. (2023). Expansion of the alien East Asian river prawn *Macrobrachium nipponense* (De Haan, 1849) in southwestern Ukraine and assessment of its commercial usage prospects. *Aquatic Invasions, 18*(2), 231–246. https://doi.org/10.3391/ai.2023.18.2.104092.

Chen, P. C., Shih, C. H., Chu, T. J., Wang, D., & Lee, Y. C. (2015a). Population structure and historical demography of the oriental river prawn (*Macrobrachium nipponense*) in Taiwan. *PLOS ONE, 10*(12), e0145927. https://doi.org/10.1371/journal.pone.0145927.

Chen, P. C., Tzeng, T. D., Shih, C. H., Chu, T. J., & Lee, Y. C. (2015b). Morphometric variation of the oriental river prawn (*Macrobrachium nipponense*) in Taiwan. *Limnologica, 52,* 51–58. https://doi.org/10.1016/j.limno.2015.03.002.

De Carvalho-Souza, G. F., Cuesta, J. A., & González-Ortegón, E. (2025). A new non-native species detected through citizen science: The presence of a *Macrobrachium* species (Decapoda, Palaemonidae) in the Guadalquivir River estuary (SW Spain), with an overview of its global spread. *Estuarine Management and Technologies, 2,* 71–86. https://doi.org/10.3897/emt.2.165887.

De Grave, S., & Ghane, A. (2006). The establishment of the oriental river prawn, *Macrobrachium nipponense* (De Haan, 1849) in Anzali Lagoon, Iran. *Aquatic Invasions, 1*(4), 204–208.

Froese, R. (2006). Cube law, condition factor and weight–length relationships. *Journal of Applied Ichthyology, 22*(4), 241–253.

Hartnoll, R. G. (1982). Growth. In D. E. Bliss (Ed.), *The Biology of Crustacea, Vol. 2* (pp. 111–196). San Diego, USA: Academic Press.

Jin, S., Zhang, W., Xiong, Y., & Fu, H. (2023). Recent progress of male sexual differentiation and development in the oriental river prawn (Macrobrachium nipponense): A review. *Reviews in Aquaculture, 15*(1), 305–317. https://doi.org/10.1111/raq.12718.

Ko, Z. K. (2025). Carapace length-weight and width-weight relationships of mud crab *Scylla serrata* (Forsskål, 1775) from Ye Estuary, Mon coastal area. *International Journal of Earth Sciences Knowledge and Applications, 7*(2), 248–254. https://doi.org/10.5281/zenodo.17021602.

Kutsarov, Y., Ivanova, P., Dzhembekova, N., Raykov, V., Hineva, E., Valkova, E., & Yakimov, K. (2025). First record of the alien oriental river prawn *Macrobrachium nipponense* (De Haan, 1849) (Decapoda, Palaemonidae) in the lower Danube (Bulgarian sector), confirmed by DNA barcoding. *Nature Conservation, 58*, 153–163. https://doi.org/10.3897/natureconservation.58.142047

Lepekha, A., Bushuiev, S., Hulak, B., Leonchyk, Y., & Kvach, Y. (2025). Morphological features of the oriental river prawn (*Macrobrachium nipponense* (De Haan, 1849)) at different localities in Ukraine. *BioInvasions Records, 14*(1), 93–106. https://doi.org/10.3391/bir.2025.14.1.09.

Maćkiewicz, A., & Ratajczak, W. (1993). Principal components analysis (PCA). *Computers & Geosciences, 19*(3), 303–342. https://doi.org/10.1016/0098-3004(93)90090-R.

Nekrasova, O., Lepekha, A., Pupins, M., Škute, A., Čeirāns, A., Theissinger, K., Georges, J.-Y., & Kvach, Y. (2024). Prospects for the spread of the invasive oriental river prawn *Macrobrachium nipponense*: Potentials and risks for aquaculture in Europe. *Water, 16*(19), 2760. https://doi.org/10.3390/w16192760.

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada, 191*, 1–382.

Sastry, A. N. (1983). Ecological aspects of reproduction. In F. J. Vernberg & W. B. Vernberg (Eds.), *The Biology of Crustacea, Vol. 8* (pp. 179–270). San Diego, USA: Academic Press.

Shigeru, K., & Seiya, T. (2018). A novel *in situ* method for estimation of the carapace length of sheltering spiny lobsters, *Panulirus japonicus*, via stereo photography. *Fisheries Research, 201,* 56–67. https://doi.org/10.1016/j.fishres.2018.01.008.

Surugiu, V. (2022). The spread of the alien oriental river prawn *Macrobrachium nipponense* (De Haan, 1849) (Decapoda: Palaemonidae) in the lower Danube, with the first record from Romania. *BioInvasions Records,*

11(4), 1056-1066. https://doi.org/10.3391/bir. 2022. 11.4.23.

Wang, H., Zhang, Y., Wang, L., Guan, T., Chang, G., Zhao, H., & Wu, N. (2022). Modeling the relationships of growth and morphometrics to dress-out traits in the oriental river prawn, *Macrobrachium nipponense*. *Aquaculture Reports, 26*, 101295. https://doi.org/10.1016/j.aqrep.2022.101295.

Zhmud, M., Yuryshynets, V., Liashenko, A., Zorina-Sakharova, K., & Abramiuk, I. (2022). The first record of the oriental river prawn *Macrobrachium nipponense* (De Haan, 1849) (Decapoda: Palaemonidae) in the Ukrainian part of the Danube Delta. *BioInvasions Records, 11*(1), 192–198. https://doi.org/10.3391/bir.2022.11.1.19.