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BODY SHAPE VARIATIONS OF TANK GOBY *Glossogobius giuris* (Hamilton 1822) IN THREE DISTINCT WATER BODIES OF CENTRAL VIETNAM

Le Thuy Lan Hoang[1], Van Giang Tran[1], Duc Thanh Nguyen[2], Van Loi Bui[3], Thi Kim Anh Tran[4,5], Ty Nguyen[1*]

[1] *University of Education, Hue University, Hue 530000, Vietnam*
[2] *Hue University of Agriculture and Forestry, Hue University, Hue 530000, Vietnam*
[3] *Hue University, Hue 530000, Vietnam*
[4] *School of Agriculture and Natural Resources, Vinh University, Vinh 460000, Vietnam*
[5] *School of Environmental and Life Sciences, The University of Newcastle, Callaghan, 2308, Australia*

*Corresponding Author: nguyenty@hueuni.edu.vn

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ABSTRACT

Tank goby *Glossogobius giuris* is widely distributed across Vietnamese rivers, estuaries, and lagoons, particularly in the central region where this species plays a pivotal role as a high commercial source for local communities. In this study, we employed landmark-based geometric morphometrics to compare the morphometric variations among three distinct populations of *G. giuris* inhabiting the Tam Giang Lagoon (Thua Thien Hue Province), Nhat Le Estuary (Quang Binh Province), and Truong Giang River (Quang Nam Province), Vietnam. The analysis, utilizing Permutational Multivariate Analysis of Variance (PERMANOVA) with Mahalanobis distances, revealed significant differences in the body shape among the three populations ($P < 0.001$). Specifically, with respect to the lateral side, the highest Mahalanobis distance was observed between specimens from the Tam Giang and Nhat Le, followed by the Tam Giang and Truong Giang River, with the lowest value found between the Nhat Le and Truong Giang. A similar pattern was observed for the dorsal side. Canonical variate analysis (CVA) illustrated three distinct groups with statistical significance in all cases ($P < 0.001$) and the confusion matrix showed a high corrected grouping rate of 88.5% for the lateral side and 82.8% for the dorsal side. These findings indicated notable variations in the body shape of *G. giuris* among the three studied areas. Fish sampled from the Tam Giang Lagoon exhibited a streamlined body shape, while those from the Truong Giang River and Nhat Le Estuary displayed a deeper body profile. The observed morphological differences among these fish populations are likely attributed to phenotypic adaptations driven by environmental factors and habitat distinctions. Importantly, this study marks the first attempt to compare the body shape variations of *G. giuris* in both freshwater and estuarine environments within central Vietnam, utilizing a landmark-based geometric approach. These findings provide crucial insights for further investigations into the ecological adaptations and evolutionary processes of this fish species.

Keywords:
Glossogobius giuris
Body shape
Landmark
Morphology

How to Cite

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INTRODUCTION

The morphology of fish is strongly influenced by environmental conditions (Echelle and Echelle, 1986; Hopper et al., 2012; Bell and Jacquemin, 2017; Gonzalez-Martinez et al., 2021), ecological characteristics of their habitats and their behavior (Kocovsky et al., 2013; Hooker et al., 2016; Styga et al., 2019; Amen et al., 2020). These environmental factors can induce variations in fish shape, either through natural selection or as a result of phenotypic plasticity. Body shape appears to be a key factor in morphological differences, with larger individuals from benthic habitats often displaying a more robust body shape (Bell and Jacquemin, 2017). These differences in body morphology reflect adaptations to diverse environmental conditions, allowing fish to optimize their swimming strategies and reduce energy expenditure (Pakkasmaa and Piironen, 2000).

Landmark-based geometric morphometrics is an advanced tool for assessing shape variations among individuals and understanding how these variations correlate with different factors (Webster and Sheets, 2010). Many researchers have applied this approach to analyze and quantify morphological differences among fish species, often utilizing canonical variate analysis (CVA) to provide graphical representations of body shape variations in different ecological environments (Zelditch et al., 2012; Barros et al., 2020).

Tank goby *Glossogobius giuris* (Hamilton 1822) is a member of the genus Glossogobius (Gill, 1859), belonging to the family Gobiidae and subfamily Gobiinae. This benthic species is widely distributed across diverse aquatic environments, including streams, rivers, wetlands, lakes, and estuaries throughout the Indo-Pacific region (Hammer et al., 2021). One distinctive feature of this species is its pelvic fins, which are fused to form an adhesive disc that allows them to cling to the substrate (Murdy and Hoese, 2002; Campang and Ocampo, 2015). In the ecological context, these fish play a crucial role in the food chain, occupying a position between small invertebrates and larger species (Engin et al., 2016).

In Vietnam, *G. giuris* has been documented in the Mekong Delta region where it plays a significant role in the local economy (Dinh et al., 2017; Tran et al., 2013). This species is also widely distributed across diverse environments (estuaries, lagoons and rivers) in the central region, playing a pivotal role as a high commercial source for local communities. Several studies have focused on the growth and reproductive patterns of this species in coastal and river areas in Can Tho and Ca Mau provinces (Nguyen and Dinh, 2021), the Ba Lat Estuary and Hong River (Ta et al., 2014), Con Tron River (Dinh and Ly, 2014), and Hau River (Pham and Tran, 2013). However, there is a lack of research on *G. giuris* in the unique lagoon and estuarine environments of the central region, as well as differences in morphology among various populations.

In this study, we utilize advanced geometric morphometric techniques to examine the variations in the body shape of *G. giuris* across three populations residing in rivers, estuaries, and lagoons. These locations are geographically distant and demonstrate significant variations in hydrological conditions, substrate composition, water temperature, flow, and salinity. The primary aim of the study is to assess the morphological variations of goby *G. giuris* in these three distinct environments. The findings from this research establish a valuable database for further exploration into the species' ecological adaptations, contributing to our comprehension of its biological characteristics.

MATERIALS AND METHODS

Study areas

Three distinct geographical locations including the Tam Giang Lagoon, Nhat Le Estuary and Truong Giang River in central Vietnam were selected for this study (Fig. 1).

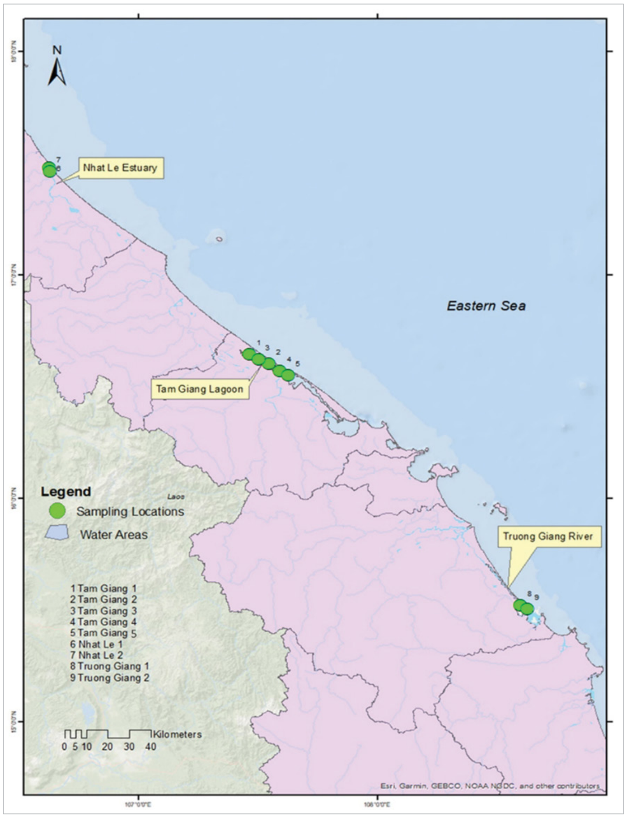

Fig 1. Map of sampling locations within three different water bodies of central Vietnam: Tam Giang Lagoon (1-5), Nhat Le Estuary (6-7) and Truong Giang River (8-9)

The Tam Giang Lagoon, situated in Thua Thien Hue province, holds the distinction of being the largest lagoon in Southeast Asia, spanning approximately 70 kilometers along the coast.

The lagoon encompasses several smaller basins, including the Tam Giang-Cau Hai, Thanh Lam, Thuy Tu, and Cau Hai. For this study, our focus was on the Tam Giang, renowned for its vast and diverse aquatic populations (IMOLA, 2006; Truong et al., 2010; Nguyen and Nguyen, 2012). The Tam Giang Lagoon is characterized as a brackish water body with temperatures ranging from 27.0 °C to 31.6 °C, pH values between 6.31 and 8.16, and salinity levels ranging from less than 1 to 18 ppt (Cao et al., 2020; Nguyen et al., 2022; Thua Thien Hue portal, 2023).

The Nhat Le Estuary, located in Quang Binh province, stands as the largest estuary in this region. It marks the terminus of the Nhat Le River, originating from Truong Son Peak in the western part of Quang Binh and ultimately flowing into the sea. This area plays a pivotal role in aquaculture and fisheries activities (Nguyen, Vu et al., 2020). The Nhat Le Estuary exhibits specific environmental characteristics, including a water temperature ranging from 20 °C to 26 °C (Nguyen et al., 2019) and varying salinity levels between 11 and 25 ppt, as reported by the Quang Binh Hydrometeorological Station in 2021 and Phan and Hoang (1993).

The Truong Giang River, situated in Quang Nam province, ranks among the largest rivers in the region, boasting a length of 67 km. In the northern part, the river converges with the downstream of the Thu Bon River, ultimately flowing into the sea via the Dai Estuary. Conversely, in the southern section, it merges with the downstream of the Tam Ky River, leading to its outflow into the sea through the Lo and An Hoa estuaries. The Truong Giang River serves as a rich and diverse habitat for numerous aquatic species (Mai et al., 2020). This study area is characterized as a freshwater body (Hoang et al., 2011), with water temperature ranging from 28.0 to 32.5 °C (Ngo et al., 2019).

Sample collection

A total of 608 fish samples were randomly collected using gill nets and crab stake traps complying with fishing regulations in three locations, including 318 samples in the Tam Giang Lagoon, 155 samples in the Nhat Le Estuary, and 135 samples in the Truong Giang River, between October 2021 and September 2022. These specimens were collected in nine sites corresponding to three water bodies with different environmental characteristics in terms of flow regime, the type of water body and bottom substrate.

Landmark-based geometric morphometrics

For specimen preparation and digitization of landmarks, each fish sample was carefully positioned on a foam board and securely fastened in place. Subsequently, measurements and photographs were taken of the fish's dorsal (back) and left side using a Canon G16 digital camera. The images of the fish were then subjected to digitization to capture their body shape through the placement of waypoints. Landmarks (LMs) were precisely marked on the fish samples using TPSDig digitizing software version 2.12, as developed by Rohlf in 2015. A TPS file was generated to facilitate further analyses. In total, 18 points were marked on the left side of the fish's body, while 7 points were designated on the dorsal side (Fig. 2 and 3).

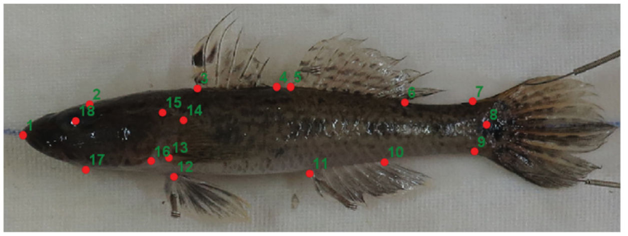

Fig 2. Selected landmarks to digitize the shape of *G. giuris* (side view): 1. Anterior maximum of snout; 2. Projection of landmark 17 on the dorsal outline; 3. Anterior origin of the first dorsal fin; 4. Posterior origin of the first dorsal fin; 5. Anterior origin of the second dorsal fin; 6. Posterior origin of the second dorsal fin; 7. Upper anterior origin of caudal fin on dorsal outline; 8. The endpoint of vertebra; 9. Posterior of landmark 7 on the ventral outline; 10. Posterior origin of the anal fin; 11. Anterior origin of the anal fin; 12. The end origin of the pelvic fin; 13. Under the origin of the pectoral fin; 14. Upper origin of the pectoral fin; 15. Upper anterior margin of the operculum; 16. Midpoint between landmarks 15 and 17 on the outline of operculum; 17. Juncture of the under margin of the operculum with the ventral outline; 18. Midpoint of eyes

Fig 3. The landmarks selected to digitize the shape of *G. giuris* captured in the Tam Giang Lagoon (back side): 1. Midpoint of snout; 2. Anterior maximum of the eye; 3. Depression in the pectoral fin on the ventral outline; 4. Projection of landmark 3 on the ventral outline; 5. Posterior maximum of eys; 6. Midpoint of under eye; 7. Midpoint of the upper eye

To perform the morphological analysis, any information which is not shape-related, including position, orientation, and size, was systematically eliminated from the landmark dataset. This was achieved by applying a generalized "Procrustes" analysis (GPA) and generating partial warps, uniform components using the software tpsRelw 1.75, as developed by Rohlf in 2015. The variation in shape among the population samples was subsequently described using a wireframe graph in MorphoJ software, as provided by Tabatabaei in 2011.

Data analysis

Analysis of variance (ANOVA) of Procustes was conducted using MorphoJ version 1.06d software (Klingenberg,

2011) to assess the potential impact of digitization-related measurement errors on observed variability, in line with established practices (Klingenberg and McIntyre, 1998; Savriama and Klingenberg, 2011).
The multivariate normality test for partial warps, uniform components of the lateral and dorsal data revealed they were not normally distributed; thus, PERMANOVA (10000 permutations) with Bonferroni-corrected p values were applied with similarity index of Mahalanobis distances to calculate possible divergence among the three stocks of *G. giuris*. A canonical variate analysis (CVA) was examined to evaluate the types of body shape variation among groups. PAST software is used to analyze all statistical analyses.

RESULTS

The ANOVA results for Procustes showed that the main effect of fish body shape is highly significant. Thus, the difference among samples highly exceeds the measurement error caused by digitizing, which means this measurement error is insignificant in this present study (Table 1). Therefore, all subsequent analyses were conducted utilizing a singular set of measurements, obviating the need to iterate through each image twice for the remaining samples.

Body shape variation

Significant variations have been observed among the three populations when evaluating the consensus body shapes on both the lateral and dorsal sides. In the Tam Giang Lagoon, the fish exhibit a tendency for their heads to widen, their snouts to elongate forward, and their operculums to broaden backward (Fig. 4A). Conversely, in the Nhat Le Estuary, there is a contrasting trend characterized by a reduction in the length of the fish's head, along with a shortening of the snout and a narrowing of the operculum to the extent that it aligns with the length of the body (Fig. 4B). In contrast, the body shape of fish in the Truong Giang River closely aligns with the shape consensus observed across all samples (Fig. 4C). It is worth noting that the fish sampled from the Tam Giang Lagoon exhibit a more streamlined body shape, whereas those from the Truong Giang River and Nhat Le Estuary display a deeper body profile, accentuating the marked differences in their morphology.

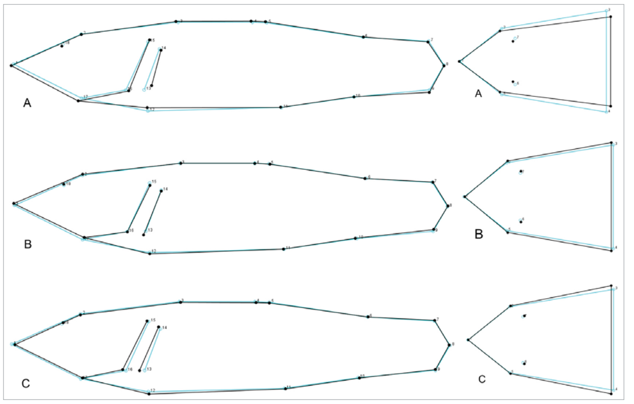

Fig 4. The wireframe graph illustrates the body shape of fish in three distinct water bodies. The cyan line represents the consensus of body shape across all populations. The black lines depict the body shape of fish in the three populations: A. Tam Giang Lagoon; B. Truong Giang River and C. Nhat Le Estuary.

PERMANOVA with Mahalanobis distances revealed significant variability among the three populations ($P < 0.001$; Table 3). The Mahalanobis distances exhibited a range from 2.05 to 5.17 for the lateral side and from 1.46 to 3.34 for the dorsal side. Regarding the lateral side, the highest Mahalanobis distance was observed between specimens from the Tam Giang and Nhat Le, with a value of 5.17, followed by the Tam Giang and Truong Giang River, with a distance of 5.16. In contrast, the lowest Mahalanobis distance of 2.05 was observed between specimens from the Nhat Le and Truong Giang. Similarly, when considering the dorsal side, the highest Mahalanobis distances were recorded between specimens from the Tam Giang and Nhat Le (3.34), followed by the Tam Giang and Truong Giang (3.00). The lowest Mahalanobis distance of 1.46 was observed between specimens from the Nhat Le and Truong Giang.
These findings highlight the substantial morphological distinctions among the fish populations across the studied regions, with the greatest dissimilarities consistently observed between specimens from the Tam Giang and the other two locations.
CVA has been a useful tool to determine variables that are responsible for the differences among and within populations. The results in Fig. 5 and Table 2 show that the proportion of the group in the Tam Giang Lagoon was the highest compared to other populations, reflecting evident separation among stocks.

Table 1. Procrustes ANOVA for digitizing error for *G. giuris* in three major water bodies of central Vietnam. *F*: *F*-value; p: *P*-value; ***: $P < 0.001$.

Effect	Sum of squares	Mean square	degrees of free-dom	F
Individual	2.5438297	0.00012989	19.584	37.86***
Digitizing error	0.0671829	0.00000343	19.584	0.08

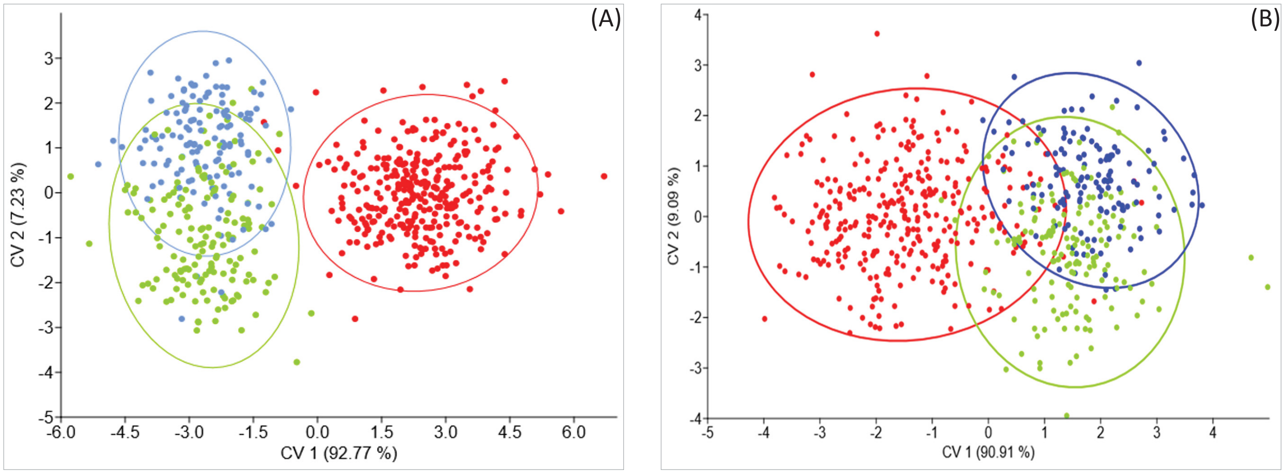

Fig 5. CVA of landmarks left-side (A) and back-side (B) between populations. Red: Tam Giang Lagoon; Blue: Truong Giang River; Lime: Nhat Le Estuary.

Table 2. Mahalanobis distances and PERMANOVA results for *G. giuris* specimens from three collection areas in central Vietnam. Pairwise comparison of fish shape among the three areas.

Mahalanobis	Tam Giang Lagoon	Truong Giang River	Nhat Le Estuary
Tam Giang Lagoon	---	3.00*	3.34*
Truong giang River	5.16*	---	1.46*
Nhat Le Estuary	5.17*	2.05*	---

Above "---'' denotes the dorsal side; below "---" represents the lateral side; * significant difference ($P < 0.001$)

The variations in body shape among the three morphotypes were scattered over two canonical variate axes (CV1 and CV2). The CVA results show that the division of landmark data set by ecological regions is fairly concentrated. CV1 presented the clear division of the lateral and dorsal landmark datasets in the overall morphology (92.77 % and 90.91 %, respectively). The CVA plot clearly shows the division of the populations by habitats (Fig. 4). According to Mahalanobis distances, the rates of the group were correctly divided, ranging from 74.2 - 98.1% and 73.2 - 88.2% for lateral and dorsal of all samples (Table 3). The proportion of the correctly grouped Tam Giang Lagoon population in its original group was the highest (98.1% for the left side, 88.2% for the dorsal side), showing a clear separation from the other populations. Correctly grouped specimens in the Truong Giang River were 74.2% and 73.2% of the total samples, while 25.8% of the left side were incorrectly grouped as specimens in the Nhat Le Estuary. Moreover, 2.0% of the lateral side and 24.8% of the dorsal side were incorrectly grouped as specimens in the Tam Giang Lagoon and Nhat Le Estuary, respectively. Besides, 82.2% and 80.6% of the two sides of specimens were correctly grouped in the Nhat Le Estuary, and the incorrectly grouped samples obtained 0.7% and 18.7% in the Truong Giang River and Tam Giang Lagoon, respectively.

Table 3. Proportion group (%) for the lateral and dorsal sides of all specimens of *G. giuris* from three collection areas in central Vietnam. Bolded numbers represent correctly grouped rates, while unbolded numbers indicate incorrectly grouped rates.

Corrected Cross Group (%)	Lateral side			Dorsal side		
	Tam Giang Lagoon	Truong Giang River	Nhat Le Estuary	Tam Giang Lagoon	Truong Giang River	Nhat Le Estuary
Tam Giang Lagoon	**98.1**	0.3	1.6	**88.2**	7.1	4.6
Nhat Le Es-tuary	0	**74.2**	25.8	2.0	**73.2**	24.8
Truong Giang River	0	17.8	**82.2**	0.7	18.7	**80.6**

DISCUSSION

Morphological characteristics of fish often exhibit significant variations both within and between populations, as well as across different geographic areas (Tajbakhsh et al., 2018). The fish samples in our study were collected from three distinct types of aquatic environments, each displaying characteristic features. For example, the Tam Giang Lagoon, with its soft, muddy bottom and shallow, low-salinity waters, provides an ideal habitat for marine and brackish fish, fostering the growth of freshwater grass and seagrass beds (Tran and Do, 2002; Truong et al., 2010; Le, 2012). On the other hand, the Nhat Le estuarine area features high sandy terrain and tidal shallow waters (Nguyen et al., 2020), while the Truong Giang River has a substrate composed of both mud and sand (Dinh et al., 2021).

The different bottom substrates may influence the morphology of goby species (Tajbakhsh et al., 2018). For example, African weakly electric fish (genus Campylomormyrus) exhibits environmental plasticity in response to the divergence of the substrate where they forage the food. The snout morphology of Campylomormyrus species changes in accordance with the substrate structure in which *C. tamandua* with a short snout prefers a sandy substrate, while the long-snouted *C. rhynchophorus* prefers a stone substrate (Amen et al., 2020). The variations in shape may be due to the adaptation to the feeding habits in their habitats. Given that tank gobies are bottom-dwelling fish with suitable morphology for clinging to the substrate, particularly while feeding on the bottom, it is plausible that the properties of the substrate itself may indeed influence the body shape of this fish species.

The flow velocity of aquatic environments can significantly impact fish body shape, with rivers typically having higher flow levels compared to estuaries and salt marshes (Styga et al., 2019). The currents in the three study areas exhibit notable differences. For instance, in the Tam Giang-Cau Hai Lagoon, where specimens were collected, water flow is generally slow (Le, 2018). Tidal fluctuations, especially during intense floods, result in the regular exchange of water currents both within and among areas in the lagoon, contributing to its ecological diversity. However, the introduction of aquacultural activities and net enclosures has led to a significant reduction in current flow, particularly in the Cau Hai area (Cao et al., 2014).

In contrast, the water regimes in the Truong Giang River and Nhat Le Estuary are characterized by stronger currents. The Nhat Le Estuary features tidal shallow-water areas highly influenced by changes in river discharge throughout the local seasons, resulting in complex flow patterns (Nguyen et al., 2019; Nguyen et al., 2021). Similarly, the Truong Giang River experiences complex flow dynamics influenced by tidal forces from both northern and southern ends, creating strong currents, especially in the northern and southern areas, with continuously changing flow directions (Nguyen, Mai et al., 2019, Mai et al., 2020).

Studies have shown that water flow can induce morphological variations in fish due to their adaptive phenotypic plasticity. For instance, salmon living in fast-flowing waters tend to have more robust and slightly streamlined body shapes compared to those inhabiting slower-flowing areas (Pakkasmaa and Piironen, 2000). Catostomus platyrhynchus, a benthic stream species, exhibits a streamlined body shape in low-flow habitats, favoring steady swimming, whereas individuals in high-flow environments develop deeper body shapes to enhance their unsteady swimming abilities. Fish are known to adapt their body shape to match the flow levels of their habitats, optimizing their swimming performance in each environment (Meyers and Belk, 2014). The observed variations in the body shape of *G. giuris* across the three different locations can thus be attributed to the distinct flow regimes in these aquatic environments.

Salinity is a well-documented factor known to influence the external morphology of fish (Georgakopoulou et al., 2007), and this phenomenon has been observed in various fish species. For instance, the body shape of Fundulus species, which frequently transition between freshwater/brackish and saltwater habitats, tends to adapt to different salinity conditions (Styga et al., 2019). In the case of stickleback *Gasterosteus aculeatus* populations, those residing in saltwater environments typically exhibit a more streamlined body shape compared to their freshwater counterparts (Aguirre and Bell, 2012). This species is widely distributed in bodies of water with varying salinity levels. In the specific study locations, salinity levels vary significantly. The Tam Giang-Cau Hai Lagoon, for example, exhibits salinity levels ranging from less than 1 ppt (parts per thousand) (Cao et al., 2020). In contrast, the Nhat Le Estuary experiences salinity levels ranging from 23-25 ppt during the dry season and 11-18 ppt during the rainy season (Quang Binh Hydrometeorological Station, 2023; Phan and Hoang, 1993), while the Truong Giang River is characterized by freshwater conditions (Hoang et al., 2011). Although *G. giuris* is considered a euryhaline benthophiline gobiid species adapted to tolerate varying salinity levels, they inhabit regions with distinct habitat salinity. As a result, salinity can indeed influence the body shape of this fish species.

Besides the factors mentioned above, the increase in temperature in the environment also impacts fish. It is known that morphology and body shape exhibit phenotypic plasticity in response to various environmental conditions (Lema et al., 2019; Sfakianakis et al., 2011). For example, temperature has been shown to impact the body shape of fish larvae, with different developmental temperatures resulting in distinct body shapes. In one study, *Sparus* *aurata* L. larvae reared at different thermal conditions (17, 20, and 23 °C) exhibited a slender body shape at 17 °C (Kourkouta et al., 2021). During ontogenetic stages, it has been shown that water temperature also induces body shape differences in the European sea bass *Dicentrarchus labrax* (L.), with individuals exposed to 15 °C becoming slenderer than those at 20 °C. These shape differences were attributed to developmental shape variations in sea bass larvae, leading to differences in juvenile shape in later stages (Georgakopoulou et al., 2007).

In the study area, there is a gradual increase in water temperature from north to south. The Nhat Le Estuary experiences temperatures of 20-26 °C (Nguyen et al., 2019), the Tam Giang-Cau Hai Lagoon has higher temperatures ranging from 27.0 °C to 31.6 °C (Cao et al., 2020), and the Truong Giang River has temperatures of 28.0-32.5 °C (Hoang et al., 2011; Ngo et al., 2019). Temperature is a crucial environmental factor impacting the existence, reproduction, growth, and metabolic abilities of fish (Michie et al., 2020). Tank gobies inhabit these different water bodies that are geographically distant and experience gradually warmer water temperatures. The observed variations in body shape could be attributed to metabolic processes during the developmental stages of the species.

Similar studies have also noted variations in the morphology of *G. giuris* in different regions, such as ponds, haors, and estuaries in Bangladesh (Mollah et al., 2012). Landmark-based morphometrics was applied to identify significant variations ($P < 0.001$) among three populations, aligning with the findings of our study. Morphological differentiation has been observed in other fish populations as well, such as Brycon dentex in rivers, where body weight, standard length, total length, and eye diameter exhibited significant differences among three rivers due to environmental factors (Gonzalez-Martinez et al., 2021). Similarly, in the Colombian Andes, the body shape of reared red and Nile tilapia in three farms varied, with environmental influences contributing to these variations (Montoya-López et al., 2019).

In this paper, our study investigated the body shape differentiation of three *G. giuris* populations using geographic morphological landmarks. Environmental factors, including temperature, salinity, substrate, and water flow in their habitats were also analyzed. Given the bottom-dwelling lifestyle of this species with limited mobility, as well as their distribution across separate geographical distances and different environments, we concluded that the body shape of *G. giuris* inhabiting rivers, estuaries, and lagoons varies significantly. This variation likely results from high phenotypic adaptation in response to environmental conditions and habitat types. To further assess ecological diversity among localities, genetic analysis should be conducted in conjunction with the phenotypic expression of this species.

CONCLUSIONS

Through the landmark-based geometric morphometrics method to investigate the body shape variation of *G. giuris* across three prominent water bodies in central Vietnam, the results indicate a concentrated division of the landmark dataset by ecological regions. Specifically, the body shape of *G. giuris* differs significantly among the three areas; individuals from the Tam Giang Lagoon exhibit a streamlined shape, while those from the Truong Giang River and Nhat Le Estuary display a deeper body shape. Notably, this study represents the first attempt to compare body shape differences in *G. giuris* within the freshwater and estuarine environments of central Vietnam.

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VARIJACIJE OBLIKA TIJELA GOBIJA (*Glossogobius giuris*, Hamilton 1822) IZ TRI RAZLIČITE VODE SREDIŠNJEG VIJETNAMA

SAŽETAK

Gobi (*Glossogobius giuris*) je široko rasprostranjen po vijetnamskim rijekama, estuarijima i lagunama, posebno u središnjoj regiji, gdje ova vrsta igra ključnu ulogu kao komercijalna vrsta za lokalne zajednice. U ovoj je studiji upotrijebljena geometrijska morfometrija temeljena na orijentirima kako bismo usporedili morfometrijske varijacije među trima različitim populacijama *G. giuris* koje nastanjuju lagunu Tam Giang (provincija Thua Thien Hue), estuarij Nhat Le (provincija Quang Binh) i rijeku Truong Giang (Quang Provincija Nam) u Vijetnamu. Analiza, primjenom permutacijske multivarijantne analize varijance (PERMANOVA) s Mahalanobisovim udaljenostima, otkrila je značajne razlike u obliku tijela između triju populacija ($P < 0{,}001$). Konkretno, s obzirom na bočnu stranu, najveća Mahalanobisova udaljenost uočena je između uzoraka iz Tam Gianga i Nhat Lea, zatim Tam Gianga i rijeke Truong Giang, s najnižom vrijednošću između Nhat Lea i Truong Gianga. Sličan je uzorak uočen na dorzalnoj strani. Kanonička varijabilna analiza (CVA) ilustrirala je tri različite skupine sa statističkom značajnošću u svim slučajevima ($P < 0{,}001$), a matrica zabune pokazala je visoku ispravljenu stopu grupiranja od 88,5% za lateralnu stranu, 82,8% za dorzalnu stranu. Ovi nalazi ukazuju na značajne varijacije u obliku tijela *G. giuris* među tri proučavana područja. Ribe uzorkovane iz lagune Tam Giang imale su aerodinamični oblik tijela, dok su one iz rijeke Truong Giang i estuarija Nhat Le imale dublji profil tijela. Uočene morfološke razlike među tim ribljim populacijama vjerojatno se pripisuju fenotipskim prilagodbama potaknutim okolišnim čimbenicima i razlikama u staništima. Važno je da ova studija označava prvi pokušaj usporedbe varijacija oblika tijela *G. giuris* u slatkovodnim i estuarinskim sredinama u središnjem Vijetnamu, koristeći geometrijski pristup temeljen na oznakama. Ova otkrića daju ključne uvide za daljnja istraživanja ekoloških prilagodbi i evolucijskih procesa ove riblje vrste.

Ključne riječi: *Glossogobius giuris*, oblik tijela, orijentir, morfologija

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