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Research article

Morphometrics allometry changes and sexual dimorphism in *Caragobius urolepis* (Gobiiformes: Gobiidae)

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Abstract

The present study reported an alternative way of sex-determining for scaleless worm goby Caragobius urolepis based on the regression relationship of some morphological parameters. A total of 328 samples were collected at the trawl nets in two coastal regions in Bac Lieu and Ca Mau from April to August 2022. After collection, the samples were transported to the laboratory in order to measure the total length *(TL)*, body height *(BD)*, head length *(HL)*, the distance of eye *(DE)*, and mouth width *(MD)* before surgery for accurate sex determination based on gonads. Regression analysis results of *TL-BD* (growth pattern A+ in females and I in males), *TL-HL* (growth pattern A+ in females and A- in males), and *TL- MD* (growth pattern A- in females and A+ in males) could be used to determine the sex of this fish. Moreover, *TL-DE* and *TL-BD* could be used to estimate when the samples were collected, e.g., in the dry or wet season, because *DE* and *BD* displayed A+ in the wet season but A- in the dry one. The findings could be used as an alternative way to determine fish sex and catching season for this species and others in the Mekong Delta.

Keywords: *Caragobius urolepis*, Mekong Delta, Regression relationship, Sex discrimination

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INTRODUCTION

The Mekong Delta is formed mainly from the river deposit of the Mekong River. The Mekong River basin is up to 795,000 km2 and is divided into two main basins: the upper Mekong rises from China, and the lower passes through countries such as Myanmar, Laos, Cambodia, Thailand, and Vietnam (Tran et al., 2012). Besides, the Mekong Delta has a long coastline of about 700 km with many species of dense mangrove trees such as Mangroves (*Rhizophora* sp.), Crabapple mangrove (*Sonneratia caseolaris*), or Avicennia (*Avicennia* sp.). Therefore, the number of aquaculture products supplied by the Mekong River and East Sea accounts for an enormous amount (Tran et al., 2013). With geographical benefits, people in these coastal areas also exploit and catch fish as a career with a high annual income (Trinh and Tran, 2012). Among them, gobies cannot be ignored, especially scaleless worm goby.

The scaleless worm goby *Caragobius urolepis* is firstly described by Bleeker (1852) and is distributed from the Indian Ocean to the Philippines and can develop in fresh to brackish water (Kottelat et al., 1993). Their favorite habitat is in the bottom layers of estuaries and extends inland (Talwar and Jhingran, 1991). In Vietnam, scaleless worm goby is widely distributed in Southern provinces from Ben Tre, Bac Lieu, and Soc Trang to Ca Mau, concentrated in rivers, estuaries, and tidal flats where there is a lot of humus (Tran et al., 2013). Murdy and Shibukawa (2003) described *C. urolepis* as having a pale pink body, small scales covering all head and anterior half of the body, with the posterior part of the body devoid of scales. The food source of this fish is crustaceans and small invertebrates distributed in the bottom layer (Rainboth, 1996). This fish is caught and sold by some localities along the coast of Bac Lieu to Ca Mau with high value. However, the information about this species is still scarce. Current studies only record their existence (Murdy and Shibukawa, 2003; Jayaneththi, 2017), but no studies have been carried out about the morphological and biological characteristics of this fish. This study aims to provide information on how to determine the sex of fish based on morphological changes. This is an alternative method of determining the sex of fish without killing the sample. These data will be the basis for future studies on this fish.

MATERIALS AND METHODS

Sample collection and analysis

Caragobius urolepis samples for this study were collected monthly from April to August 2022. Fish samples were collected directly and indirectly through local fishermen's trawl nets at Dong Hai, Bac Lieu, and Dam Doi, Ca Mau (Figure 1). Animal ethics approval was not required due to dead fish use. After that, the analysis process was helped when the samples arrived at the laboratory. In order to accurately identify the species, the external morphological features as described in Tran et al. (2013) were used to identify the fish. In the laboratory, fish specimens were sex determined through morphological characteristics of gonads (Dinh et al., 2016), and measured morphological parameters included total length *(TL)*, standard length *(SL)*, body height *(BD)*, and head length *(HL)*.

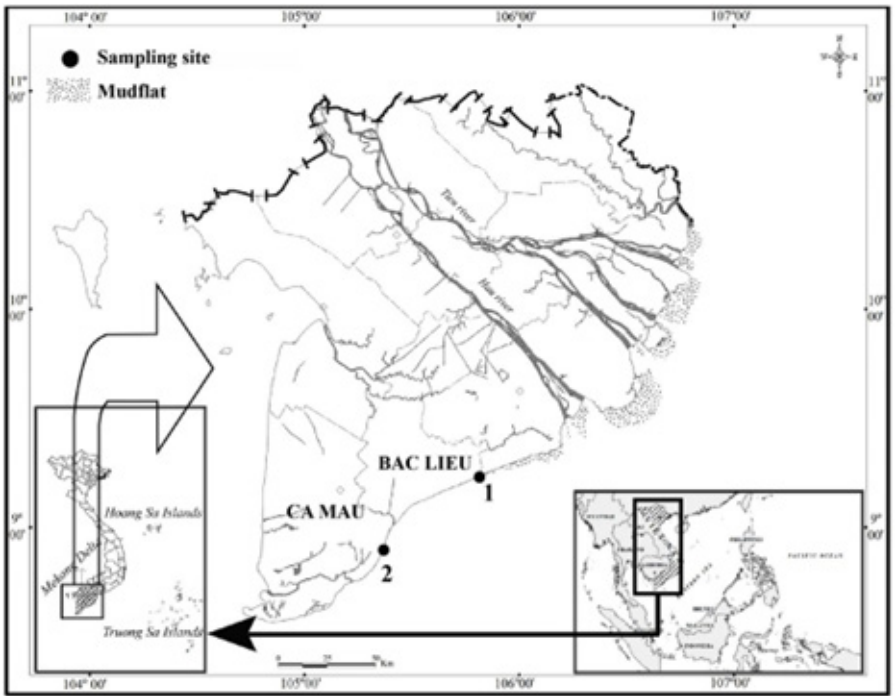

Figure 1 Map of sampling location (1: Dong Hai, Bac Lieu; 2: Dam Doi, Ca Mau) modified from Dinh (2018)).

Data analysis

According to Minos et al. (2008), the relationship between total length *(TL)* and morphological parameters of fish was determined based on the formula $Y=a\times Log_{10}TL + b$, in which Y was body height *(BD)* or head length *(HL)* or eye distance *(DE)* or mouth width *(MD)*. The letters *a* and *b* in the formula were the regression coefficients, a was the intercept, and *b* was the slope. A T-test was used to verify if b was close to one−isometric threshold. Morphological variables were classified as dominant (A+) if the gradient was significantly higher than one, less dominant (A-) if *b* was less than one, and isotropic (I) if the slope was equal to one. In addition, the t-test was also used to see if coefficient *b* varies with gender and season. SPSS v21 software was used for data analysis. All comparisons were determined at the 5% significance level.

RESULTS

The analysis results of morphological measurements of 328 samples (168 males and 160 females) showed that the fish sex could be estimated from *BD*, *HL*, and *MD*, but not *DE*. Indeed, males and females showed isometry for this parameter as the fish grew (Table 1), suggesting that the development of *DE* in this fish was relatively equal for the two sexes. However, the regression relationship of *TL* and *BD* of females and males were classified into two groups. Specifically, the regression relationship of *TL-BD* in males was classified as I, proving that the body height of the males in this species grew to be equivalent to the total length. Meanwhile, the *TL-BD* regression relationship in females was classified into A+, indicating that the increase in female body height was

relatively faster than the total length of fish (Table 1). Changes between females and males were found in the regression relationship between *TL* and *HL*. The *TL-HL* of females fell into A+, revealing that the head length grew faster during the development process than the total length. In contrast, head length in males grew less than the total length because they had a regression relationship of A-. Compared with head length, the relationship between mouth width and total length had completely different results. The *MD* displayed an A+ in males but A- in females, showing that MD developed faster than *TL* in males but slightly slower in females (Table 1).

Table 1 Regression relationship of total length *(TL)* and body height *(BD)*, head length *(HL)*, eye distance (DE), and mouth width *(MD)* of scaleless worm goby based on sex.

Morphometrics	b	SE	a	SE	n	Type	ts	P
Female								
DE	1.029	0.022	2.530	0.75	160	I	1.32	0.19
BD	1.049	0.022	0.895	0.264	160	A+	2.23	0.03
HL	0.956	0.010	0.908	0.138	160	A+	-4.40	0.00
MD	0.932	0.005	0.962	0.067	160	A-	-13.60	0.00
Male								
DE	0.995	0.017	4.417	1.054	168	I	-0.29	0.77
BD	1.017	0.016	1.524	0.333	168	I	1.06	0.29
HL	0.950	0.009	1.107	0.14	168	A-	-5.56	0.00
MD	0.953	0.003	0.676	0.032	168	A+	-15.67	0.00

Additionally, since they showed different growth patterns, some morphological metrics could be used to estimate when scaleless worm goby was caught, e.g., during the dry or wet season. Specifically, two relationships with differences between the dry and wet seasons were *TL-DE* and *TL-BD*. In the *TL-DE* relationship, A- and A+ resulted from this relationship in fish during the dry and wet seasons. Thereby, it could be seen that the eye distance of the fish was dominant in the wet season but less prevalent in the dry season compared to the total length of the fish. The analysis results of the *TL-BD* relationship in this fish showed that the body height of the growing fish was less dominant than the total length in the dry season (A-) but dominated in the wet season (A+). Meanwhile, in the two relationships *TL-HL* and TL-MD, there was no change between the dry and wet seasons. Both of these relationships indicated type A- in the dry and wet seasons. Changes in environmental conditions between the two seasons thus influenced the growth of the morphological parameter of this fish (Table 2).

Table 2 Regression relationship of total length *(TL)* and body height *(BD)*, head length *(HL)*, eye distance *(DE)*, and mouth width *(MD)* of scaleless worm goby based on the season.

Morphometrics	b	SE	a	SE	n	Type	ts	P
Dry season								
DE	0.958	0.006	8.826	0.786	139	A-	-7.00	0.00
BD	0.984	0.006	2.866	0.242	139	A-	-2.67	0.01
HL	0.918	0.005	1.819	0.126	139	A-	-16.40	0.00
MD	0.939	0.003	0.851	0.039	139	A-	-20.33	0.00
Wet season								
DE	1.061	0.022	1.454	0.417	189	A+	2.77	0.01
BD	1.080	0.021	0.531	0.146	189	A+	3.81	0.00
HL	0.978	0.010	0.639	0.095	189	A-	-2.20	0.03
MD	0.947	0.004	0.747	0.049	189	A-	-13.25	0.00

Research results at two sites, including Dong Hai, Bac Lieu (DHBL) and Dam Doi, Ca Mau (DDCM), showed that there was a difference in the regression relationship between morphological parameters. This difference was found in two regression relationships, *TL-DE* and *TL-BD*. Specifically, in the regression relationship *TL-DE* was classified as A- in DHBL and I in DDCM. Through this relationship at the two sites, it showed that DE in DDCM has a stronger development than in DHBL. The next difference was found in the *TL-BD* relationship. A- and A+ were the regression results of this relationship in DHBL and DDCM, respectively. As this result can be seen in DHBL, BD has less development than TL and the opposite is found in DDCM. In addition to the two relationships *TL-DE* and *TL-BD*, the relationship *TL-HL* and TL-MD were also studied at these two sites. However, the research results at these two sites showed that the two relationships *TL-HL* and TL-MD have similar results. Specifically, both of these relationships represent an A- relationship in DHBL and DDCM. Thereby, it can be seen that the HL and MD in this fish are quite stable according to the study site (Table 3).

Table 3 Regression relationship of total length *(TL)* and body height *(BD)*, head length *(HL)*, eye distance *(DE)*, and mouth width *(MD)* of scaleless worm goby based on the sites.

Morphometrics	b	SE	a	SE	n	Type	ts	P
Dong Hai, Bac Lieu								
DE	0.956	0.007	9.143	0.878	118	A-	-6.29	0.00
BD	0.975	0.007	3.231	0.299	118	A-	-3.57	0.00
HL	0.924	0.005	1.699	0.121	118	A-	-15.20	0.00
MD	0.939	0.003	0.845	0.042	118	A-	-20.33	0.00
Dam Doi, Ca Mau								
DE	1.037	0.020	2.141	0.579	210	I	1.85	0.07
BD	1.059	0.020	0.744	0.193	210	A+	2.95	0.00
HL	0.964	0.010	0.803	0.113	210	A-	-3.60	0.00
MD	0.946	0.004	0.768	0.046	210	A-	-13.50	0.00

DISCUSSION

Results showed that the relationships between morphological characteristics in scaleless worm goby were different between males and females. It was a potential and effective sex discrimination measure in this fish. The *TL-BD*, *TL-HL*, and TL-MD could be used to determine the sex of the fish. The relationship between TL and some other morphological metrics was used in sex determination for some specific fish species in Vietnam and worldwide. Minos et al. (2008) studied the morphological characteristics of *Pagrus pagrus* from Greece and showed that the sex of this fish could be determined based on these regression relationships. Similarly, Obi (2010) also studied *Heterotis niloticus* distributed in Nigeria, showing that TL and SL can be used to distinguish between males and females. Meanwhile, the species *Zacco koreanus* distributed in Korea also gave similar results (Kim et al., 2008). *Glossogobius sparsipapillus* in the Mekong Delta was sexed from the *TL-SL* relationship (Dinh et al., 2021a). Another species from the same genus Glossogobius, e.g., Glossogobius giuris, also showed a distinct *TL-HL* relationship between males and females. The *TL-SL*, *TL-DE*, and TL-MD relationships could be to differentiate the sex of *Mystus mysticetus*–a freshwater catfish in the Mekong Delta (Phan et al., 2022). In saltwater fish such as *Ellochelon vaigiensis*, the *TL-BD* relationship can also be used to distinguish fish by sex (Dinh et al., 2021b). This showed that this method of sex discrimination was effective for fish because the behavior of males and females was different. However, the use of regression relationship of morphological indices depends on the characteristics of each fish species.

The difference in the *TL-BD* relationship between the two seasons might be due to favorable environmental conditions (heavy rainfall) during the wet season that makes it easier for fish to find food, leading to solid growth in body height. These results demonstrated that from the *TL*, *DE*, and *BD* measurements, it was possible to determine which season this fish was caught in the Mekong Delta. The change in the regression relationship between fish in the dry season and fish in the wet season was also found in Glossogobius giuris distributed in freshwater and coastal estuaries in the Mekong Delta (Dinh et al., 2021b).

Although the two sampling sites in this study were not too far apart (about 20 km), there was a difference in the regression relationship of the morphological values of the fish. This difference was due to the characteristics of each sampling site. With DHBL, fish samples were collected at the estuary dug by humans, so the width of the estuary was not too large, and the terrain on both sides was mainly alluvium mixed with sand. Meanwhile, fish samples from DDCM were collected from natural estuaries. The two sides of the river were mainly mudflats deposited by alluvium. These differences have affected the development process of this fish. This fish tends to develop a larger *BD* than a TL for a more domesticated environment due to the fish accumulating energy better. Meanwhile, fish mainly develop body length in DHBL with a non-natural environment. Thereby, it can be seen that the regression relationship between morphological values can not only help to distinguish the sex and fishing season of fish but also help consider whether the fish species was suitable for that environment or not. Another study that showed a significant difference between these regression relationships was the Glossogobius giuris (Dinh et al., 2021b). In Glossogobius giuris, it was shown that the environment impacts the *TL-SL*,

TL-BD, and *TL-HL* regression relationships. Like *Caragobius urolepis*, Glossogobius giuris developed better BD in a suitable environment (freshwater versus saline intrusion). Likewise, according to Phan et al. (2022), HL could be used to estimate the distribution environment of M. mysticetus.

CONCLUSIONS

The *BD*, *HL*, and *MD* could be used to distinguish the sex of *Caragobius urolepis*. In addition, *DE* and *BD* could be used to determine the fishing season for this species. The results from this study presented that sex discrimination based on morphological changes in *Caragobius urolepis* was practical and could be applied to many other fish species.

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AUTHOR CONTRIBUTIONS

Phuc Le Hoang Nguyen; Investigation, methodology, formal analysis, manuscript preparation
Ly Thi Cam Tran; Investigation, methodology, formal analysis, manuscript preparation
Thu Thi Anh Phan; Investigation, methodology, formal analysis, manuscript preparation
Thoai Kim Nguyen; Investigation, methodology, formal analysis, manuscript preparation
Lam Thi Thao Vo; Investigation, methodology, formal analysis, manuscript preparation
Quang Minh Dinh; Conceptualization and design the experiment, investigation, supervision, editing, and finalization

CONFLICT OF INTEREST

We have no conflict of interest.

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