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Research article

Morphometric and Meristic Variations of *Mystus albolineatus* Roberts, 1994 in the Mekong Delta, Vietnam

Ton Huu Duc Nguyen, Quang Minh Dinh *

Department of Biology, School of Education, Can Tho University, Xuan Khanh ward, Ninh Kieu district, Can Tho 900000, Vietnam

Abstract

This study contributed to investigating the changes in morphometric and meristic variations in *Mystus albolineatus* at two different sites in the Mekong Delta (VMD). This is a high economic-value fish species in the region. The study was conducted for 12 months (03/2022 - 02/2023) at two sites along the Hau River (a branch of the Mekong River) with different environmental characteristics, including a freshwater site year-round at Cai Rang (Can Tho City) and a site affected by saltwater intrusion during the dry season at Long Phu (Soc Trang province). Fish samples were collected using different fishing gear of various sizes. The results obtained 825 individuals (443 females and 382 males) at both sites (408 at Cai Rang and 417 at Long Phu). Through the analysis process, it was found that the total length (*TL*) and weight (*W*) of this fish species were significantly influenced by gender and season. Both parameters were significantly higher in females (*TL*: 11.13±0.09 SE cm; *W*: 10.17±0.06 SE g) than in males (*TL*: 10.68±0.10 SE cm; *W*: 9.95±0.07 SE g). Meanwhile, during the dry season (*TL*: 10.15±0.10 SE cm; *W*: 9.58±0.08 SE g), the fish had lower length and weight compared to the wet season (*TL*: 11.42±0.08 SE cm; *W*: 10.39±0.05 SE g). The interaction between gender and season also significantly affected the *TL* of *Mystus albolineatus*. In addition, eye diameter (*ED*), eye distance (*DE*), body height (*BH*), head length (*HL*), *ED*/*HL*, *DE*/*HL*, *BH*/*TL*, and *HL*/*TL* all showed significant differences by gender and season. The results of this study on the morphological characteristics of this fish species indicate that it adapts well to the environment at both research sites. The findings of this study provide basic data on the variation in morphological characteristics of *Mystus albolineatus* in the VMD region.

Keywords: Catfish, Fish body weight, Fish total length, Meristic, Morphometrics

Corresponding author: Quang Minh Dinh, Department of Biology, School of Education, Can Tho University, Xuan Khanh ward, Ninh Kieu district, Can Tho 900000, Vietnam. Email: dmquang@ctu.edu.vn

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INTRODUCTION

The Mekong Delta in Vietnam (VMD) has an area of approximately 40,922 km², making it one of the largest deltas in Southeast Asia (General Statistics Office, 2021). With a dense network of rivers, mainly sourced from the Mekong River, the area has abundant freshwater resources and diverse ecosystems. The two major river systems, the Tien and the Hau have a total length of 14,826 km. According to the survey results of Tran et al. (2013), there are about 186 fish species in VMD, many of which have high economic value and are exploited to meet human needs. However, overfishing has led to a sharp decline in some fish species, and they are at risk of being unable to recover (Nguyen et al., 2018). Bagridae is one of the families with high economic value. Most species in this family are heavily exploited. Some species have been artificially raised to meet market demand in the region, such as *Mystus gulio* (Nguyen et al., 2012), *Hemibagrus wyckioides* (Phan and Phan, 2015), *Hemibagrus guttatus* (Le and Le, 2017), *Pseudomystus siamensis* (Vo et al., 2020). *Mystus* is a small to medium-sized fish belonging to the Bagridae family. Approximately 33 species of this fish are worldwide (Ferraris, 2007). In VMD, only seven species were recorded in 2013, the most common being *Mystus mysticetus*, *Mystus albolineatus*, and *Mystus atrifasciatus* (Tran et al., 2013). *Mystus albolineatus* is a fish species with high economic value and is heavily exploited in VMD (Nguyen et al., 2018).

The main distribution area of *Mystus albolineatus* includes three river basins, which are the Chao Phraya River (Thailand), the Bangpakong River (Thailand), and the Mekong River (Vietnam) (Froese and Pauly, 2023). This fish species is described and distinguished from other species in the same genus by prominent features such as a long-based adipose fin and a silvery gray body with a narrow pale mid-lateral stripe (Tran et al., 2013). It is a freshwater fish species that primarily inhabits the bottom layer of rivers and lakes. The maximum body length of *Mystus albolineatus* can reach up to 35 cm *SL* (Baird et al., 1999). The species is known to have a diet consisting of larvae, invertebrates, and small fish (Rainboth, 1996). According to Breder and Rosen (1966), this species has a spawning season during the wet season, from July to August. The fish can mate and lay eggs during the spawning season. Despite being of economic value and heavily exploited, there is currently very little information about them in the VMD region. The preliminary data on this fish species in the area focuses on some morphological characteristics to differentiate it from other fish species. However, this information is still incomplete and may lead to misclassification.

Morphological characteristics are an essential classification factor widely used (Strauss and Bond, 1990). They can also distinguish between freshwater and saltwater fish species (Mai et al., 1992). In addition, these characteristics are essential factors in determining the characteristics of fish populations and their relationships with the environment (Cadrin and Silva, 2005; Siddik et al., 2016). Although *Mystus albolineatus* was only recorded in freshwater areas in previous studies, substantial saltwater intrusion has occurred in the VMD in recent years. Therefore, saltwater may intrude into deep freshwater areas of the river during the dry season. The presence of *Mystus albolineatus* has been observed in areas invaded by saltwater. This may

affect the morphological characteristics of the fish. According to Langerhans et al. (2003), the environment in different ecological regions can change the morphological characteristics of fish species. Many studies in the area also show this change, such as *Butis koilomatodon* (Lam and Dinh, 2020), *Butis humeralis* (Dinh et al., 2021a), *Periophthalmus gracilis* (Dinh et al., 2021b), which have size changes in their morphological characteristics according to salinity; *Glossogobius aureus* (Phan et al., 2021), *Glossogobius giuris* (Nguyen and Dinh, 2021) have changes in their morphological characteristics from freshwater to saltwater environments. This shows that the different environmental characteristics between areas with year-round freshwater and areas invaded by saltwater during the wet season may affect the morphological characteristics of *Mystus albolineatus*. Therefore, this study aims to clarify the differences and redefine the classification criteria for this fish being used for its ecological adaptation understanding.

MATERIALS AND METHODS

Study site, fish collection, and analysis

This study was conducted for 12 months, from March 2022 to February 2023. Fish samples were collected at two study sites with different environmental characteristics in the VMD. One place was located in Cai Rang District, Can Tho City (CRCT), with a relatively stable environment and a source of freshwater all year round. The second site was located in Long Phu District, Soc Trang Province (LPST), with an environment affected by saltwater intrusion during the dry season (from January to May). Both study sites were located in the Hau River Basin of the Mekong River system (Figure 1). Environmental data were recorded using a pH meter (HI98107) to measure pH and temperature and a refractometer to measure salinity (Model: 950.0100 PPT-ATC) at sampling sites.

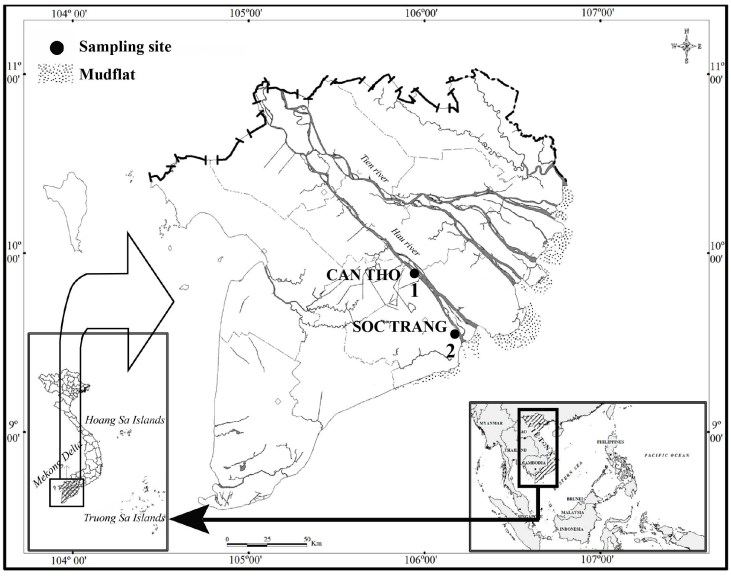

Figure 1 The two sampling sites in Mekong Delta (1: Cai Rang, Can Tho; 2: Long Phu, Soc Trang; modified from Dinh (2018)).

Each month at each research site, fish samples of various sizes were collected by local fishermen, ensuring an adequate sample size and comprising several length groups. The dead fish samples were preserved in a 4% formalin and transported to the laboratory for morphological characteristics determination. No animal ethics approval was required since we used dead fish in the present study. Fish were sexed by genital spines based on the description of Vo et al. (2022). The morphological characteristics determined included total weight (*W*), total length (*TL*), eye distance (*DE*), eye diameter (*ED*), body height (*BH*), and head length (*HL*) (Figure 2). *W* was measured with an accuracy of 0.01 g, while *TL*, *ED*, *DE*, *BH*, and *HL* were measured with an accuracy of 0.1 cm, 0.01 cm, 0.01 cm, 0.01 cm, and 0.01 cm, respectively.

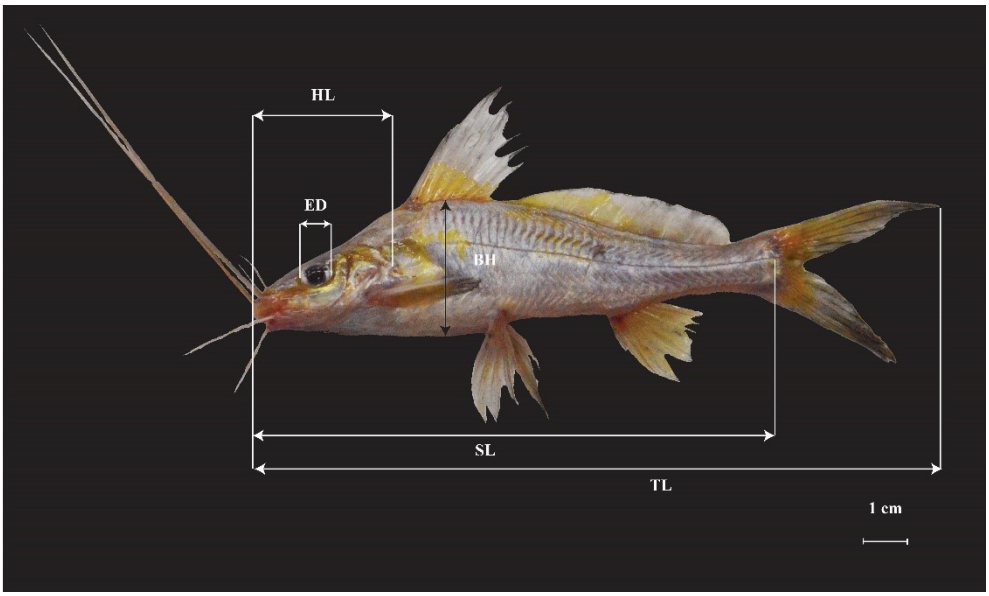

Figure 2 *Mystus albolineatus* collected in Long Phu, Soc Trang (HL: head length; ED: eye diameter; BH: body height; TL: total length)

Data analysis

The differences in pH, salinity, and temperature by site and season were determined using the t-test. The differences in the parameters (*W*, *TL*, *ED*, *DE*, *BH*, *HL*) and morphometric ratios (*ED*/*HL*, *DE*/*HL*, *BH*/*TL*, *HL*/*TL*) by gender, season, sites, and their interaction were determined using the PERMANOVA test. These tests were performed using PRIMER v.6.

RESULTS

Environmental characteristics in the two study sites

The study results showed that the CRCT's environment differed from LPST. LPST had a significantly higher temperature than CRCT (t-test, t=-2.25, p=0.04). Specifically, the temperature values in these two areas were 30.24±0.20°C SE and 29.66±0.16°C SE, respectively. Unlike temperature, pH at LPST (7.62±0.04 SE) was significantly lower than at CRCT (7.73±0.02 SE) (t=2.47, p=0.02). The most significant difference was found in salinity at the two study sites (p<0.001). Salinity at CRCT had a value of 0 throughout all months,

indicating a source of freshwater in this area year-round. Meanwhile, the mean salinity value in the study months at LPST was 6.67±1.87‰ SE. However, salinity was only recorded in dry months, ranging from 2‰ (December) to 14‰ (February).

With the characteristic that there is a lot of rainfall during the wet season, the temperature in these two areas has changed seasonally. Specifically, the average temperature value at these sites in the dry season were 30.60±0.15°C SE. However, this value was significantly lower in the wet season at 29.67±0.14°C SE (t=4.02, p=0.00). During the dry months, LPST was affected by saltwater intrusion, leading to average salinity values at these research sites in the dry season (6.17±2.80‰ SE) were significantly higher than in the wet season (1.21±0.74‰ SE). Meanwhile, the pH value in the wet season (7.66±0.03 SE) was higher than in the dry season (7.72±0.03). However, the difference in pH between the two seasons was not statistically significant (t=1.10, p=0.28).

Variation in fish length and weight

During the study, 825 individuals were collected at two sampling sites along the Hau River, including 443 females and 382 males of *Mystus albolineatus*. The significant environmental differences between the two sites and seasons may affect this fish species' total length (*TL*) and weight (*W*). Regarding gender, there was a significant difference in total length between males and females (PEMANOVA, *Pseudo-F*=5.24, p=0.03). According to the statistical results, females were longer than males, with mean *TL* of 11.13±0.09 SE cm (n=443) and 10.68±0.10 SE cm (n=382), respectively. TL also showed significant differences between the dry and wet seasons when considering the seasons. Specifically, during the wet season (11.42±0.08 SE cm, n=497), *Mystus albolineatus* had significantly greater TL than during the dry season (10.15±0.10 SE cm, n=328) (*Pseudo-F*=94.50, p<0.01). However, there was no significant difference in *TL* between the two sampling sites (*Pseudo-F*=0.03, p=0.98). The mean *TL* at CRCT was 10.93±0.09 SE cm (n=408), and it was slightly lower at LPST with a mean *TL* of 10.91±0.10 SE cm (n=417).

Similarly to total length, the weight of *Mystus albolineatus* only showed significant differences by season (*Pseudo-F*=76.03, p<0.01) and gender (*Pseudo-F*=2.41, p=0.02) but not by sampling sites (*Pseudo-F*=0.43, p=0.53). Specific results showed that the fish had significantly higher weight during the dry compared to the wet season, with mean values of 10.39±0.05 SE g (n=497) and 9.58±0.08 SE g (n=328), respectively. Similarly, the mean weight of females (10.17±0.06 SE g, n=443) was significantly higher than that of males (9.95±0.07 SE g, n=382). Meanwhile, the mean weights of 10.03±0.06 SE g (n=408) and 10.10±0.07 (n=417) were recorded in CRCT and LPST, respectively.

In *Mystus albolineatus*, the interaction between gender and season affected TL (Pseudo-F=6.89, p=0.01) but did not significantly affect *W* (*Pseudo-F*=3.93, p=0.07). Moreover, interactions between the remaining factors had no significant impact on *TL* and *W* (p>0.05 for all cases).

Morphometric variations

Some morphological parameters, such as *ED* and *BH,* also showed significant differences by gender. For *ED*, females had significantly smaller sizes than males (*Pseudo-F*=5.78, *p*=0.02, Figure 3), although *TL* and *W* of this fish species were larger in females. On the other hand, *BH* showed a proportional relationship with *TL* and *W*, with a value of 1.95±0.02 SE cm in females and smaller in males with a value of 1.83±0.02 SE cm (*Pseudo-F*=16.34, *p*<0.01, Figure 4).

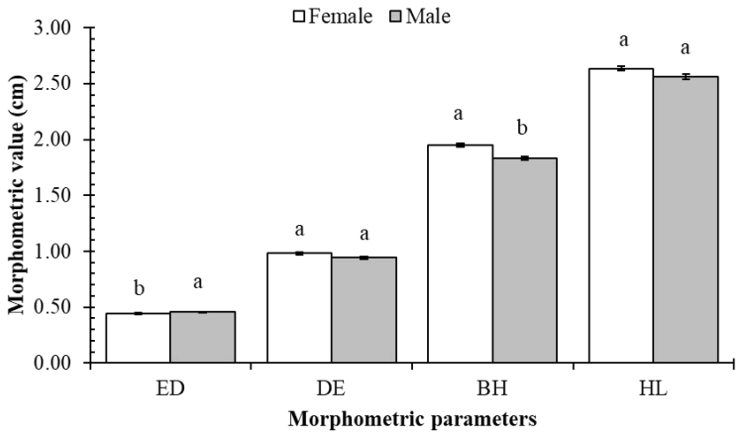

Figure 3 The morphometric parameters in *Mystus albolineatus* varied by gender (different letters: significant differences; vertical bars: standard error; *ED*: eye diameter; *DE*: distance between two eyes; *BH*: body height; *HL*: head length).

In addition, both *HL/TL* and *ED/HL* ratios also showed gender differences ($Pseudo\text{-}F_{HL/TL}$=4.12, $p_{HL/TL}$=0.04, $Pseudo\text{-}F_{ED/HL}$=24.94, $p_{ED/HL}$<0.01) Both ratios were lower in females compared to males (Figure 4).

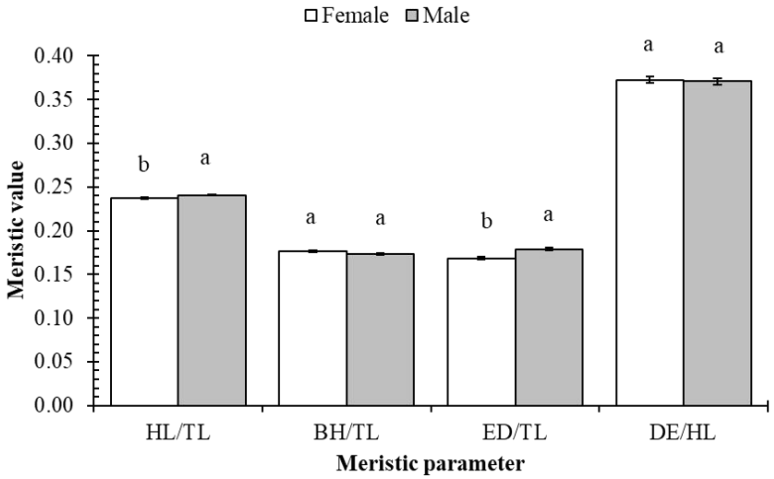

Figure 4 The meristic parameters in *Mystus albolineatus* varied by gender (different letters: significant differences; vertical bars: standard error; *HL*: head length; *TL*: total length; *BH*: body height; *ED*: eye diameter; *DE*: distance between two eyes).

When examined by season, all other morphometric parameters of *Mystus albolineatus,* including *ED*, *DE*, *BH*, and *HL* showed significant differences by season (*Pseudo-*F_{ED}=51.43, p_{ED}<0.01, *Pseudo-*F_{DE}=31.57, p_{DE}<0.01, *Pseudo-*F_{BH}=82.08, p_{BH}<0.01, *Pseudo-*F_{HL}=84.87, p_{HL}<0.01, Figure 5). This indicates that the season factor significantly affects the morphology of this fish species. These morphometric parameters all had higher values during the wet season. However, all the morphometric ratios did not show significant differences by season (Figure 6).

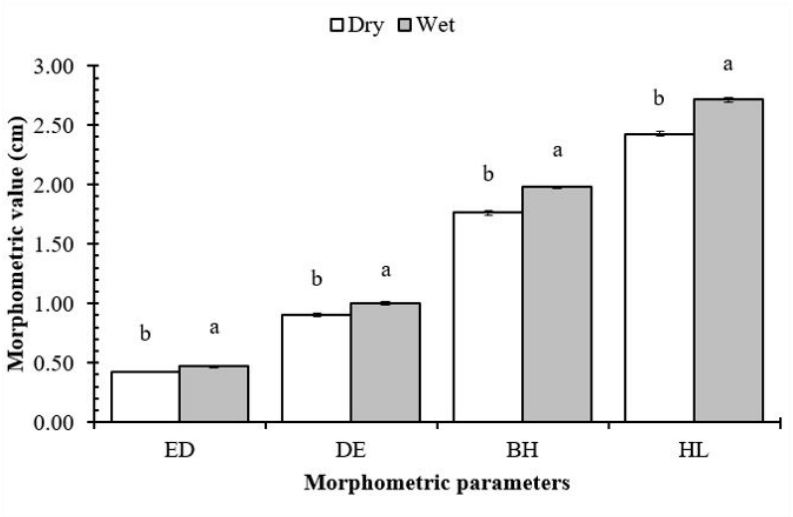

Figure 5 The morphometric parameters in *Mystus albolineatus* varied by season (different letters: significant differences; vertical bars: standard error; *ED*: eye diameter; *DE*: distance between two eyes; *BH*: body height; *HL*: head length).

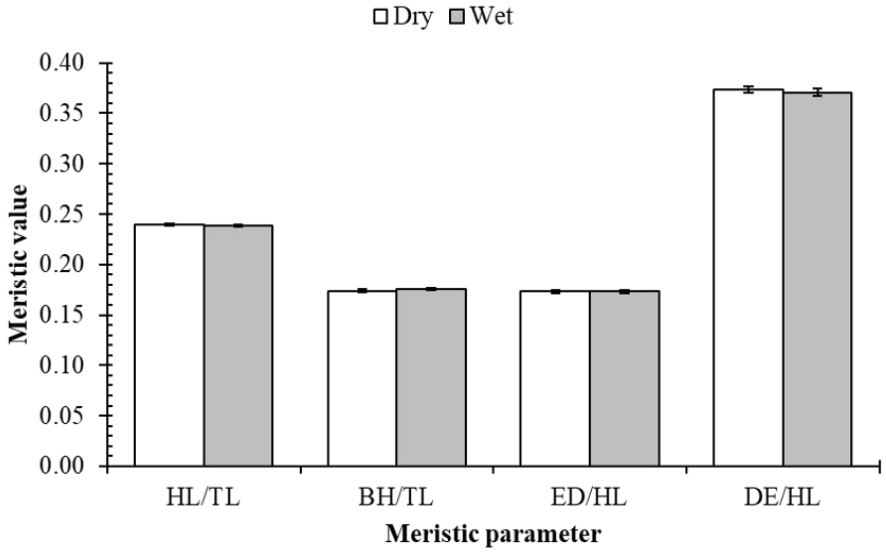

Figure 6 The meristic parameters in *Mystus albolineatus* varied by season (vertical bars: standard error; *HL*: head length; *TL*: total length; *BH*: body height; *ED*: eye diameter; *DE*: distance between two eyes).

Although there were significant differences between the two study environments, these differences did not significantly affect the morphological characteristics of this fish species. All morphological parameters did not differ between individuals in CRCT and LPST (Table 1). However, two morphological ratios, *HL/TL* and *DE/HL*, showed significant differences between the two study sites. Specifically, the *HL/TL* ratio was higher in the LPST area, while the *DE/HL* ratio was higher in the CRCT area.

Table 1 Changes in parameters indicators of *Mystus albolineatus* by site (CRCT: Cai Rang, Can Tho; LPST: Long phu, Soc Trang)

Parameters	Site	*N*	Mean	SE	Pseudo-F	*p-value*
ED	CRCT	408	0.45	0.01	1.46	0.24
	LPST	417	0.45	0.00		
DE	CRCT	408	0.98	0.01	1.33	0.25
	LPST	417	0.95	0.01		
BH	CRCT	408	1.90	0.02	0.02	0.87
	LPST	417	1.89	0.02		
HL	CRCT	408	2.59	0.02	0.91	0.30
	LPST	417	2.61	0.02		
HL/TL	CRCT	408	0.23	0.00	8.30	<0.01
	LPST	417	0.24	0.00		
BH/TL	CRCT	408	0.17	0.00	0.01	0.89
	LPST	417	0.18	0.00		
ED/HL	CRCT	408	0.18	0.00	6.20	0.02
	LPST	417	0.17	0.00		
DE/HL	CRCT	408	0.38	0.00	3.25	0.07
	LPST	417	0.37	0.00		

DISCUSSION

The research results on the environment in the two sites of CRCT and LPST showed a significant difference between these two environments. The results also showed that the LPST area was affected by saltwater intrusion, leading to substantial fluctuations in salinity between the wet and dry seasons. In addition, the temperature in LPST was relatively higher compared to CRCT. The different environmental factors between the two sites and the two seasons contributed to changes in the morphological characteristics of Mystus albolineatus.

The study results on TL and W of this fish species showed variations according to gender and season. The results demonstrated that females may be competitive over males due to their larger total length and weight. This can be explained by the fact that females of this species need to have a larger size to serve the reproductive needs of the species. Females carry eggs in their abdominal cavity for a long period, so they often have a larger weight than males. Another fish species belonging to the genus *Mystus* studied in a similar area, *Mystus mysticetus*, also showed similar results with significantly larger length and weight in females than in males (Vo et al., 2021). Meanwhile, typical gender-based variations were not observed in the same areas but in some other fish species, such as in Glossogobius aureus (Phan et al., 2021) and *Glossogobius giuris* (Nguyen and Dinh, 2021).

Regarding the differences in TL and W according to the season in *Mystus albolineatus*, it showed significantly lower values during the dry compared to the wet season. The more favorable environmental conditions during the wet season, with lower temperatures and salinity, could cause this difference. Therefore, this species can be predicted to adapt well to freshwater environments. In contrast to the study by Vo et al. (2021) on *Mystus mysticetus* in CRCT and LPST, this species had utterly opposite results. Additionally, some other fish species in this area also showed significant differences in morphological values according to the season, such as *Parapocrytes serperaster* (Dinh et al., 2016), *Glossogobius sparsipapillus* (Nguyen et al., 2019), *Glossogobius aureus* (Phan et al., 2021) and *Glossogobius giuris* (Nguyen and Dinh, 2021). This showed that depending on the behavior and characteristics of each species, there are different morphological changes.

Although there are differences between the two environments in the two sites, it did not affect the morphological values of *Mystus albolineatus*. This shows that this fish species can adapt well to the environment and develop at the same level in each area. In contrast, *Mystus mysticetus* showed a morphological advantage in the area with higher salinity, LPST. The results of the morphology of these two species showed that although they are of the same species, the two populations had relatively different distribution areas. *Mystus mysticetus* developed its morphology mainly in brackish water areas, while *Mystus albolineatus* was more evenly distributed in both areas. The result from this study differ from some other fish species in the area with seasonal changes in morphological values, such as *Boleophthalmus boddarti* (Dinh, 2017), *Glossogobius sparsipapillus* (Nguyen et al., 2020), and *Periophthalmus chrysospilos* (Dinh et al., 2022). *Mystus nigriceps* also showed significant differences in W in Indonesia, according to the research points (Syafrialdi et al., 2020). In contrast, *Mystus seenghala* in India showed no differences in TL and W at different research sites (Saini et al., 2008). These studies showed that depending on each species, morphological characteristics may or may not rely on environmental conditions.

Similar to TL and W, the other parameters also changed regarding gender and season. Gender only affects two parameters, ED and BH. Unlike *Mystus albolineatus*, in *Mystus mysticetus*, most of the other parameters of this fish species showed higher value in females (Vo et al., 2021). In addition, the two ratios HL/TL and ED/HL also showed significant differences according to gender. The differences in these ratios can be applied to determine the gender of this fish species. The relationship between fish morphological parameters has been demonstrated in some other fish species that can be used to determine the gender of fish such as *Glossogobius sparsipapillus* (Dinh et al., 2021c), *Mystus mysticetus* (Phan et al., 2022), *Caragobius urolepis* (Nguyen et al., 2023). Seasonal differences in *Mystus albolineatus* were reflected in this fish species' other four morphological parameters. However, this difference did not affect the change in morphological ratios. Thus, it was shown that the four morphological parameters were equally affected by seasonal factors. Differences in morphological parameters and ratios according to season are also found in some fish species of the genus *Mystus* such as *Mystus vittatus* (Chattopadhyay et al., 2014) and *Mystus mysticetus* (Vo et al., 2021).

CONCLUSIONS

The research results showed a significant dependence of the total length and weight of *Mystus albolineatus* on gender and season. This fish species can have larger sizes in females and develop best during the wet season. However, the gender × season interaction only affected *TL* and not *W*. Both the morphological parameters (*ED*, *DE*, *HL*, *BH*) and the morphometric ratios (*ED*/*HL*, *DE*/*HL*, *BH*/*TL*, and *HL*/*TL*) of this fish were also significantly influenced by season and gender. These results provide the most basic data on the morphological characteristics of this fish species in two different research areas in VMD, demonstrating their ability to adapt well to environmental conditions in CRCT and LPST.

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AUTHOR CONTRIBUTIONS

Ton Huu Duc Nguyen; Conceptualization and design of the experiment, investigation, supervision, editing, and finalization

Quang Minh Dinh; Investigation, methodology, formal analysis, manuscript preparation

CONFLICT OF INTEREST

We have no conflict of interest.

REFERENCES

Baird, I., Inthaphaisy, V., Kisouvannalat, P., Phylaivanh, B., Mounsouphom, B., 1999. The fishes of Southern Lao. Lao Community Fisheries and Dolphin Protection Project. Ministry of Agriculture and Forestry, Lao PDR, pp. 162. (in Lao)

Breder, C.M., Rosen, D.E., 1966. Modes of reproduction in fishes. TFH Publications, New Jersey, pp. 941.

Cadrin, S.X., Silva, V.M., 2005. Morphometric variation of yellowtail flounder. ICES. J. Mar. Sci. 62(4), 683-694.

Chattopadhyay, S., Nandi, S., Saikia, S.K., 2014. Mouth morphometry and architecture of freshwater cat fish Mystus vittatus Bloch (1974) (Siluriformes, Bagridae) in relation to its feeding habit. J. Sci. Res. 6(1), 169-174.

Dinh, Q.M., Qin, J.G., Dittmann, S., Tran, D.D., 2016. Morphometric variation of Parapocryptes serperaster (Gobiidae) in dry and wet seasons in the Mekong Delta, Vietnam. Ichthyol. Res. 63(2), 267-274.

Dinh, Q.M., 2017. Morphometric, growth and condition factor variations of Boleophthalmus boddarti in the Mekong Delta, Vietnam. Iran. J. Fish. Sci. 16(2), 822-831.

Dinh, Q.M., 2018. Aspects of reproductive biology of the red goby Trypauchen vagina (Gobiidae) from the Mekong Delta. J. Appl. Ichthyol. 34(1), 103-110.

Dinh, Q.M., Lam, T.T.H., Nguyen, T.H.D., 2021a. Study on external morphology of Butis humeralis in the coastline regions of Mekong Delta. Sci. Tec. J. Agr. Res. Dev. 10, 146-153.

Dinh, Q.M., Nguyen, H.T.T., Nguyen, T.H.D., Truong, N.T., 2021b. Study on factor influencing morphological traits of graceful mudskipper Periophthalmus gracilis Eggert, 1935. Can Tho Uni. J. Sci. 57, 139-149. (in Vietnamese)

Dinh, Q.M., Nguyen, T.H.D., Nguyen, T.T.K., 2021c. Allometry variation in morphometrics of Glossogobius sparsipapillus caught along Hau river, from Can Tho to Soc Trang provinces. TNU J. Sci. Tec. 226(5), 3-7. (in Vietnamese)

Dinh, Q.M., Nguyen, T.H.D., Truong, N.T., Tran, L.T., Nguyen, T.T.K., 2022. Morphometrics, growth pattern and condition factor of Periophthalmus chrysospilos Bleeker, 1853 (Gobiiformes: Oxudercidae) living in the Mekong Delta. Egypt. J. Aquat. Res. 48(2), 157-161.

Ferraris, C.J., 2007. Checklist of catfishes, recent and fossil (Osteichthyes: Siluriformes), and catalogue of siluriform primary types. Zootaxa. 1418(1), 1-628.

Froese, R., Pauly, D., 2023. FishBase. Available online: https://fishbase.mnhn.fr/search.php

General Statistics Office, 2021. Statistical Yearbook of Viet Nam. Statistical Publishing House, Ha Noi, pp. 1056. (in Vietnamese)

Lam, T.T.H., Dinh, Q.M., 2020. Morphometric and meristic variability in Butis koilomatodon in estuarine and coastal areas of the Mekong Delta. Vie. Agr. Sci. J. 3(4), 806-816. (in Vietnamese)

Langerhans, R.B., Layman, C.A., Langerhans, A.K., Dewitt, T.J., 2003. Habitat-associated morphological divergence in two Neotropical fish species. Bio. J. Lin. Soc. 80(4), 689-698.

Le, V.D., Le, T.H., 2017. Artificial reproduction of Ca lang fish (Hemibagrus guttatus Lacepède, 1803) in Quang Binh Province. Hue Uni. Sci. Agr. Res. Dev. 126(3C), 69-76. (in Vietnamese)

Mai, Y.D., Nguyen, T.V., Nguyen, T.V., Le, Y.H., Hua, L.B., 1992. Identification of freshwater fishes of South Vietnam. Science and Technology Publishing House, Ha Noi, pp. 351. (in Vietnamese)

Nguyen, H.D.T., Nguyen, T.T.H., Tran, C.C., Dang, H.T., Nguyen, T.N.Y., Dinh, Q.M., 2019. Morphological and histological characteristics of testis of the goby Glossogobius sparsipapillus living from coastal Estuaries from Bac Lieu to Ca Mau. VNU J. Sci. Nat. Sci. Tec. 35(4), 81-87. (in Vietnamese)

Nguyen, P.L.H., Tran, L.T.C., Phan, T.T.A., Nguyen, T.K., Vo, L.T.T., Dinh, Q.M., 2023. Morphometrics allometry changes and sexual dimorphism in Caragobius urolepis (Gobiiformes: Gobiidae). Vet. Integr. Sci. 21(1), 29-36.

Nguyen, T.H.D., Nguyen, H.T.T., Tran, T.C., Nguyen, Y.T.N., Dinh, Q.M., 2020. Morphometric and meristic variations of Glossogobius sparsipapillus along the coastline in the Mekong Delta, Vietnam. Int. J. Zoo. Ani. Bio. 3(1), 1-9.

Nguyen, T.H.D., Dinh, Q.M., 2021. Morphometric and meristic variations in Glossogobius giuris distributed in different locations in the Mekong Delta. TNU J. Sci. Tec. 226(10), 31-38. (in Vietnamese)

Nguyen, T.L., VMai, V.V., Tran, D.D., Huynh, V.H., Naoki, T., 2018. Evaluation of fishing activities in the Mekong Delta. Can Tho Uni. J. Sci. 54(7), 102-109. (in Vietnamese)

Nguyen, T.T., Pham, T.K., Doan, V.N., 2012. Artificial reproduction experience and Chot nghe fish (Mystus gulio Hamilton, 1822). Hue Uni. J. Sci. 75(6), 43-47. (in Vietnamese)

Phan, D.P., Phan, T.L.A., 2015. Artificial reproduction of Lang duoi do fish Hemibagrus wyckioides (Fang & Chaux, 1949) in Dak Lak province. Hue Uni. J. Sci. 104(5) (in Vietnamese)

Phan, G.H., Dinh, Q.M., Truong, N.T., Nguyen, T.H.D., 2021. Variation in morphometric characteristics of Glossogobius aureus distributed from Can Tho to Ca Mau. Vie. Agri. Sci. J. 19(7), 863-874. (in Vietnamese)

Phan, T.Q., Tran, A.N., Vo, L.T.T., Dinh, Q.M., 2022. Sex discrimination based on morphological traits in Mystus mysticetus Roberts, 1992. Vet. Integr. Sci. 20(3), 659-667.

Rainboth, W.J., 1996. Fishes of the Cambodian Mekong. FAO, Roma, pp. 265.

Saini, A., Dua, A., Mohindra, V., 2008. Comparative morphometrics of two populations of giant river catfish (Mystus seenghala) from the Indus river system. Integr. Zoo. 3(3), 219-226.

Siddik, M., Chaklader, M., Hanif, M., Islam, M., Sharker, M., Rahman, M., 2016. Stock identification of critically endangered olive barb, Puntius sarana (Hamilton, 1822) with emphasis on management implications. J. Aqua. Res. Dev. 7(2), 1-6.

Strauss, R.E., Bond, C.E., 1990. Taxonomic methods: Morphology. In: Schreck, C.B., Moyle, P.B. (Eds.), Methods for fish biology. American Fisheries Society, Maryland, pp. 109-140.

Syafrialdi, S., Dahelmi, D., Roesma, D.I., Syandri, H., 2020. Morphometric variations of twospot catfish (Mystus nigriceps) from Kampar Kanan, Kampar Kiri, and Tebo Batang Alai rivers, Indonesia. AACL. 13(4), 2107-2115.

Tran, D.D., Shibukawa, K., Nguyen, T.P., Ha, P.H., Tran, X.L., Mai, V.H., Utsugi, K., 2013. Fishes of Mekong Delta, Vietnam. Can Tho University Publisher, Can Tho, pp. 174.

Vo, L.T.T., Tran, A.N., Phan, T.Q., Dinh, Q.M., 2021. Morphometrics variations of Mystus mysticetus Roberts, 1992 in the Mekong Delta, Vietnam. AACL. 14(6), 3423-3431.

Vo, T.T.B., Nguyen, T.T.T., Pham, M.C., 2020. Induced spawning of Asian bumblebee catfish (Pseudomystus siamensis Regan, 1913). J. Agri. Dev. 19(1), 49-58.

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