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Variation in Morphometric Characteristics of Blackhand Paradise Fish (*Polynemus melanochir* Valenciennes, 1831) in Cai Rang, Can Tho and Long Phu, Soc Trang, Vietnam

Lam Thi Thao Vo and Quang Minh Dinh*

Faculty of Biology, School of Education, Can Tho University, Ninh Kieu District, Can Tho 900000, Vietnam

(*Corresponding author's e-mail: dmquang@ctu.edu.vn)

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Abstract

Polynemus melanochir is valuable in the Mekong Delta, but its morphology and variations remain unclear; therefore, this study was conducted. This study investigated the morphometric and morphometric ratios of *P. melanochir* at Cai Rang, Can Tho and Long Phu, Soc Trang. *P. melanochir* is randomly collected monthly at Cai Rang, Can Tho (freshwater) and Long Phu, Soc Trang (brackish water). 10% formalin is used for preservation before transportation to the laboratory for sex differentiation and to determine morphometric parameters and ratios. The variation in these parameters and ratios concerning sex and site was qualified using t-tests, and 2-way ANOVA was used to evaluate the combined effects of sex and site on these parameters at a 5% significance level. These tests were performed using Jamovi v.2.4.11. A total of 308 fish samples were analyzed for differences in traits. The results showed significant standard length, body depth, and head length differences between the 2 sampling sites, likely influenced by environmental factors like temperature, salinity, and pH. However, sex did not significantly affect most traits except for a few morphometric ratios. The interaction of sex and site factors also regulated the variation in the morphological characteristics of this fish. This study also observed morphometric ratios, noting differences across sites and between sexes. The study highlights the phenotypic plasticity of *P. melanochir* in adapting to different habitats within the Mekong Delta. The findings contribute valuable morphological data on this fish, provide insights into its ecological adaptability in the region, and contribute to species taxonomy, regional variations, and morphological differences influenced by environmental factors.

Keywords: Adaptability, Environment, Mekong delta, Morphometric ratios, Morphometrics, *Polynemus melanochir*, Plasticity

Introduction

Morphometric and meristic parameters of fish play an essential role in fish classification [1]. Several studies have applied these parameters to classify marine, brackish, and freshwater fish species [2]. However, until now, data on these indices of the species belonging to the Polynemidae family in the Mekong Delta region are not well known, especially for Blackhand paradise fish (*Polynemus melanochir*). The Polynemidae family has 9 genera with 42 species [3]. According to Froese and Pauly [4], the Polynemidae family has 2 freshwater genera, *Eleuthronema* (2 species) and *Polynemus* (8 species). However, in Vietnam, the genus *Polynemus* has 7 species [5]. In the Mekong Delta, according to Mai *et al.* [6], the genus *Polynemus* has 2 species: The Blackhand paradise fish (*Polynemus melanochir*) and the Eastern paradise fish (*Polynemus dubius*). They are primarily distributed in brackish and saline waters of tropical and subtropical regions [2], typically concentrated in estuaries and mainly living in freshwater as bottom-dwelling species, primarily inhabiting muddy or sandy- muddy bottoms, and adapting well to environmental conditions, with suitable temperatures ranging from 30°N to 30°S [7].

By 2024, several studies on *Polynemus melanochir* had been conducted. Most of these studies focused on distribution, feeding habits, and migratory behavior. They provided only brief insights into its morphological characteristics. Notable works included those by Motomura [3], Motomura *et al.* [8], Motomura and Sabaj [9], who discussed these ecological aspects, and Mustafa *et al.* [10], who provided biometric data for this species in East Malaysia. Additionally, Vu *et al.* [11] examined the migratory behavior of *Polynemus melanochir* in the Mekong Delta, and Dang *et al.* [12] researched the fish's gene pool in the same region. Despite the economic importance of *Polynemus melanochir* in the Mekong Delta, limited research has been conducted on its morphological features, particularly regarding potential morphological differences across its various distribution sites. This knowledge gap became particularly critical as saltwater intrusion and overfishing significantly impacted fish populations in the region. Consequently, this study aimed to investigate whether environmental changes at different sites within the Mekong Delta affected the morphological characteristics of *Polynemus melanochir* while also considering variations in these characteristics based on sex and site. The data from this research will contribute to the knowledge base on the morphological parameters of this species and will be used as a reference to understand the ecological adaptability of the fish in the study area.

Materials and methods

Sample collection and analysis

Samples of *Polynemus melanochir* were collected from the Mekong Delta. This region includes areas varying in salinity. Specifically, samples were taken from Long Phu, Soc Trang (LPST), a brackish water site, and from Cai Rang, Can Tho (CRCT), a freshwater area (**Figure 1**). Fish samples were collected from January to April 2024. Environmental characteristics such as pH, temperature, and salinity at the 2 sites were 7.74°C, 29.78°C, and 0‰ at CRCT and 7.64°C, 30.29°C, and 6.67‰ at LPST [13]. Each month, fish samples were collected at each site using various fishing gear to ensure diversity in fish sizes. The fish samples were then fixed in 10 % formalin before being sent to the laboratory for analysis. In the laboratory, fish samples were identified based on morphological characteristics, as described by *Tran et al.* [14]. The sex of the fish was distinguished based on the characteristics of the gonads, as described by Dinh and Le [15]. Since the study used dead fish as samples, there was no need for an animal research permit.

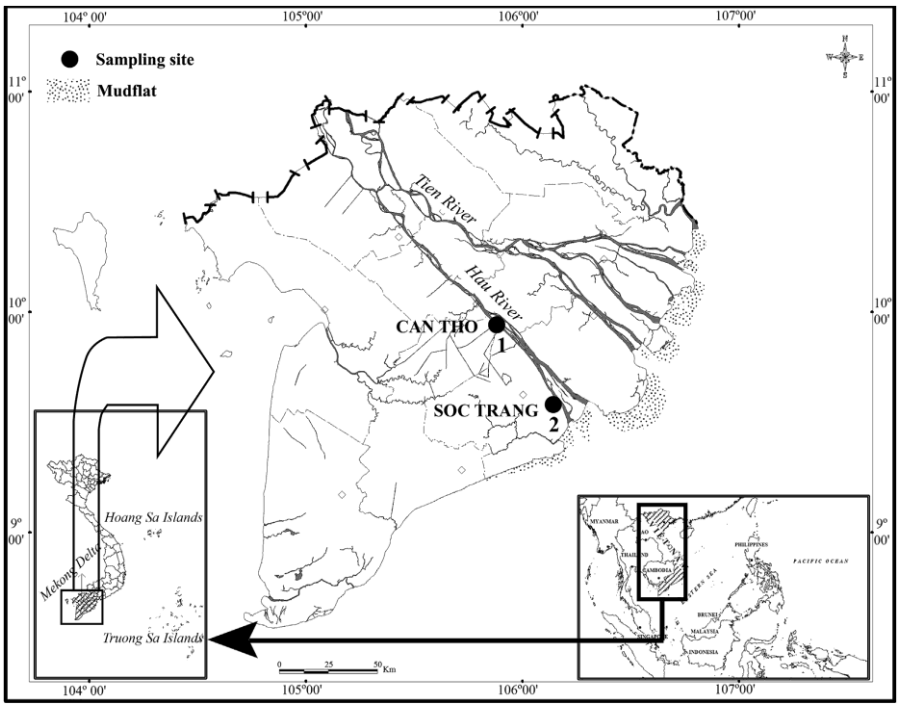

Figure 1 Map of the Mekong Delta showing the sampling sites (1: Cai Rang, Can Tho; 2: Long Phu, Soc Trang: Source: Modified from Dinh [16]).

Several morphological parameters were determined based on the Pravdin [17] method using an electronic micrometer (accuracy to 0.01 cm) (Moore & Wright MW110-15DBL), such as standard length (SL), eye diameter (ED), eye distance (DE), body depth (BD), and head length (HL) (**Figure 2**). Morphometric ratios used in fish classification, such as HL/SL, BD/SL, DE/HL, and ED/HL, were also determined [18,19].

Data analysis

The variation in morphological parameters such as SL, ED, DE, BD, and HL concerning sex and site was analyzed using t-tests. These tests were performed to assess whether there were significant differences between males and females at each sampling site. Additionally, a 2-way Analysis of Variance (ANOVA) was used to evaluate the combined effects of sex and site on these parameters, allowing for the analysis of their interaction. This method provides a helpful understanding of how both factors influence fish morphology, particularly how the environmental conditions at different sites may interact with sex-based differences. All tests were conducted at a significance level of $\alpha = 0.05$ and performed using Jamovi v.2.4.11 software, ensuring the results were accurate and statistically reliable.

Figure 2 Female *Polynemus melanochir* collected from Long Phu, Soc Trang.

Results and discussion

Morphometric variation

The results of analyzing 308 *Polynemus melanochir* samples collected from Cai Rang, Can Tho and Long Phu, Soc Trang, showed that at CRCT, the standard length (SL) of fish reached an average value of 14.56 ± 0.16 SE cm, while at LPST, there was a significant difference with 12.67 ± 0.11 SE cm, and this difference was statistically significant ($p < 0.001$) (**Table 1**). Similarly to SL, body depth (BD) and head length (HL) did not change according to the site ($p < 0.001$ for all cases), but eye diameter (ED) and eye distance (DE) showed opposite results ($p > 0.05$ for all cases). ED and DE were not affected by site or sex, which may be due to these traits being less plastic than other body dimensions. Their stability may reflect the essential role of vision in all environments, as also suggested in *Glossogobius giuris* [20] and *Mystus mysticetus* [21].

Table 1 Variation in morphometric parameters of *Polynemus melanochir* by sampling site.

Morphometric parameters	Sites	Number	Mean	Standard error	t	p
SL	Cai Rang, Can Tho	143	14.56	0.16	9.81	<0.001
	Long Phu, Soc Trang	165	12.67	0.11		
ED	Cai Rang, Can Tho	143	3.56	0.06	0.21	0.83
	Long Phu, Soc Trang	165	3.54	0.05		
DE	Cai Rang, Can Tho	143	9.78	0.13	1.21	0.23
	Long Phu, Soc Trang	165	9.55	0.14		
BD	Cai Rang, Can Tho	143	29.90	0.46	9.40	<0.001
	Long Phu, Soc Trang	165	24.50	0.36		
HL	Cai Rang, Can Tho	143	35.10	0.37	7.59	<0.001
	Long Phu, Soc Trang	165	31.30	0.33		

(SL: standard length; ED: eye diameter; DE: eye distance; BD: body depth; and HL: head length)

The study's data suggest that the SL, BD, and HL changes between the sampling sites may be attributed to differing environmental conditions (pH, temperature, salinity) at the 2 sites [13]. These differences may indicate environmental or ecological variations between the 2 sampling sites. Specifically, the study highlights temperature and salinity as 2 key factors influencing the variation in morphological parameters of *Polynemus melanochir*. This variation was also observed in *Polynemus paradiseus* [22-24], where significant differences in morphometric characteristics such as total length (TL), fork length (FL), standard length, and pre-dorsal fin lengths were recorded in samples from the Sundarbans estuary. Chaklader *et al.* [24] suggested that SL changes in fish may reflect their adaptation to specific environmental conditions, particularly temperature and salinity, 2 factors that affect fish development. Similarly, Borah *et al.* [23] confirmed that such changes are likely linked to ecological conditions in different geographical regions, leading to morphological adjustments in fish species. Furthermore, Dinh [25] and Nguyen *et al.* [26] found that morphological (TL, ED, DE, BD, and HL) changes in other fish species in the Mekong Delta, such as *Boleophthalmus boddarti* and *Glossogobius sparsipapillus*, were also strongly associated with environmental factors like temperature and salinity. Notably, changes in body length and body ratios in these species reflect environmental adaptation and may also result from variations in the growth and development cycles of the fish as they respond to environmental stressors.

These studies emphasize the importance of environmental factors, particularly temperature and salinity, in influencing the morphological changes of marine and brackish water fish species. Such changes are significant for fish species in the Mekong Delta and for understanding how aquatic organisms adapt to changing environmental conditions, especially in a climate change context, which increasingly impacts freshwater and marine ecosystems. Therefore, monitoring and evaluating the morphological changes in *Polynemus melanochir* and other fish species provide valuable insights into the effects of environmental factors on fish growth and distribution in the region. This information can inform effective conservation and management strategies for aquatic resources.

In contrast, when considering sex, there is no difference in SL (standard length) between males and females ($p > 0.05$). Males have an average value of 13.7 ± 0.16 SE cm, while females have 13.3 ± 0.14 SE cm. Additionally, other morphological parameters of the fish, such as ED, DE, BD, and HL, do not vary by sex ($p > 0.05$ for all cases, **Table 2**).

Table 2 Variation in morphometric parameters of *Polynemus melanochir* by sex.

Morphometric parameters	Sex	Number	Mean	Standard error	t	p
SL	Female	189	13.67	0.16	1.88	0.06
	Male	119	13.32	0.14		
ED	Female	189	3.51	0.05	–1.44	0.15
	Male	119	3.62	0.06		
DE	Female	189	9.56	0.12	–1.40	0.16
	Male	119	9.83	0.14		
BD	Female	189	27.20	0.47	0.93	0.35
	Male	119	26.60	0.39		
HL	Female	189	33.20	0.37	0.60	0.55
	Male	119	32.90	0.36		

(SL: standard length; ED: eye diameter; DE: eye distance; BD: body depth; and HL: head length)

Both sex and site significantly influence the morphological parameters of fish, with their interaction having a notable impact on the variation of specific traits. The results show that the interaction between sex and site significantly affects the morphological parameters (SL, DE, BD, and HL). The 2-way ANOVA analysis revealed strong effects for the interaction between sex and site for these parameters ($p < 0.001$ for all cases, as shown in **Figure 3**). This suggests that the interaction between sex and environmental or ecological conditions at different sites plays a crucial role in determining the morphological characteristics of *Polynemus melanochir*. However, the same interaction does not significantly affect ED, where the statistical result ($p > 0.05$) indicates no meaningful difference.

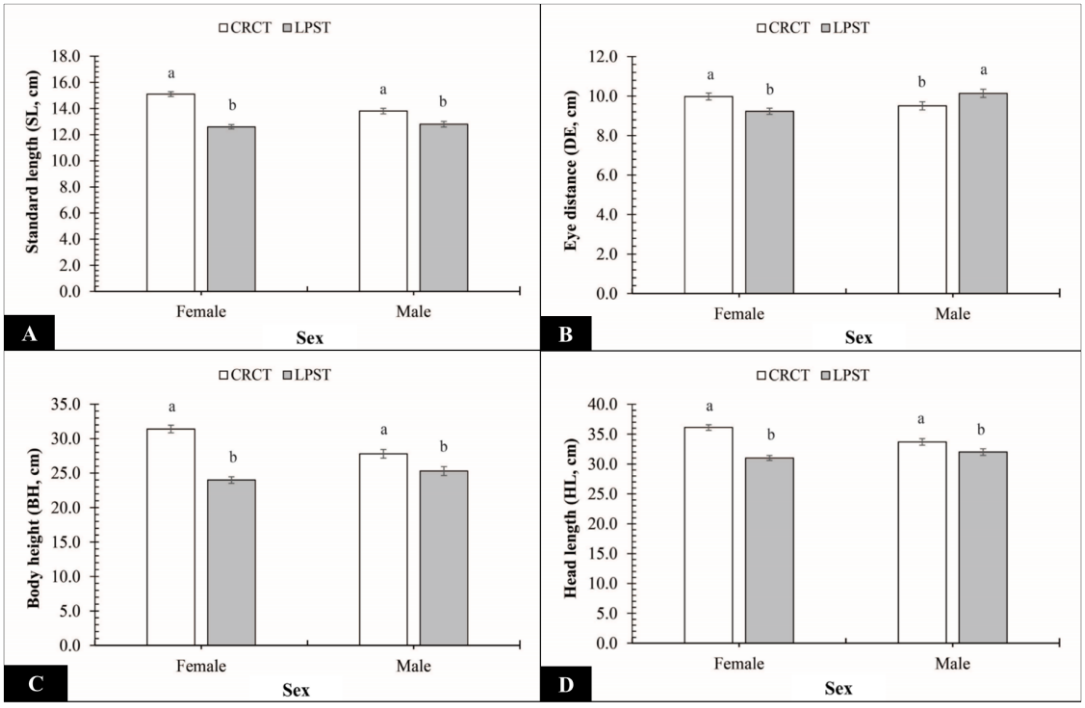

Figure 3 Variation of some morphological indicators with the interaction of site and sex (A: The standard length (SL), B: Eye distance (DE), C: Body depth (BD), D: Head length (HL); Different letters: statistically significant difference; vertical bar: standard error).

The finding that the interaction between sex and site influences various morphological traits is consistent with the literature, where similar trends have been observed in other fish species. For example, Vo *et al.* [21] reported similar findings in *Mystus mysticetus*, where sex and environmental factors (such as location-specific conditions) influenced the fish morphology (TL, ED, DE, BD, and HL). Additionally, studies on *Boleophthalmus boddarti* [27] and *Glossogobius sparsipapillus* [28] highlighted the significant effects of sex-site interactions on their morphological parameters (TL, ED, DE, BD, and HL), supporting the results observed in *Polynemus melanochir*. Furthermore, Le *et al.* [29] demonstrated similar patterns in *Periophthalmus chrysospilos*, where the combination of sex and site-specific environmental conditions played an essential role in shaping the morphometrics (TL, ED, DE, BD, and HL) of the species.

The significant interaction of sex and site in determining the morphological traits of *P. melanochir* emphasizes the complexity of ecological adaptation in aquatic organisms. This interaction likely reflects the adaptive responses of fish to the diverse environmental conditions present at different sites, such as temperature, salinity, and habitat type, which can vary between locations. The differences in sex and site-specific traits may also indicate sexual dimorphism or reproductive strategies. Males and females could exhibit distinct morphological characteristics based on the environmental pressures at each site, such as food availability, predator presence, and habitat type. These results underline the importance of considering biological factors (sex) and environmental variables (site) in studies of morphological adaptation. Understanding the interplay between these factors can offer valuable insights into the evolutionary and ecological processes that shape the morphological diversity of fish species. In addition, this knowledge can contribute to more informed conservation and management strategies, particularly in the face of ongoing environmental changes that may further influence aquatic organisms' distributions and physical traits.

Morphometric ratios

Considering the sampling site of *Polynemus melanochir*, this factor significantly affects several morphological characteristics of the fish. Therefore, this difference was statistically significant between the 2 sampling sites for all ratios, such as HL/SL, BD/SL, ED/HL, and DE/HL ($p < 0.05$ in all cases). All these ratios are presented in **Table 3**. This morphological variation reflects the fish's adaptation to local environmental conditions at each site, such as salinity and temperature. Such adaptation is also observed in other species in the Mekong Delta, including *Glossogobius sparsipapillus* [30], *Mystus mysticetus* [21], *Stigmatogobius pleurostigma* [31], and *Butis butis* [32].

Table 3 Changes in morphometric ratios of *Polynemus melanochir* according to sampling site.

Morphometric ratios	Site	Number	Mean	Standard error	t	*p*
HL/SL	CRCT	143	2.42	0.02	–2.67	0.01
	LPST	165	2.47	0.02		
BD/SL	CRCT	143	2.05	0.02	4.83	<0.001
	LPST	165	1.92	0.02		
ED/HL	CRCT	143	0.10	0.00	–4.87	<0.001
	LPST	165	0.11	0.00		
DE/HL	CRCT	143	0.28	0.00	–5.61	<0.001
	LPST	165	0.31	0.00		

(SL: Standard length; ED: Eye diameter; DE: Eye distance; BD: Body depth; and HL: Head length)

Besides the influence of research sites, sex is also recognized to play an essential role in morphological changes. The changes in the HL/SL and DE/HL ratios in males and females were statistically significant ($p < 0.05$ for all cases, **Table 4**). In contrast, sex did not affect the BD/SL and ED/HL ratios ($p > 0.05$ for all cases, **Table 4**). Changes in these values (TL, SL, ED, DE, BD, and HL) were also observed in other fish species distributed in the Mekong Delta, such as *P. serperaster* [33], *G. sparsipapillus* [26], *B. koilomatodon* [18], *G. giuris* [20], and *G. aureus* [19].

Table 4 Changes in morphometric ratios of *Polynemus melanochir* according to sex.

Morphometric ratios	Site	Number	Mean	Standard error	t	*p*
HL/SL	Female	189	2.43	0.01	–2.03	0.02
	Male	119	2.48	0.02		
BD/SL	Female	189	1.97	0.02	–2.28	0.20
	Male	119	2.00	0.02		
ED/HL	Female	189	0.11	0.00	–1.29	0.20
	Male	119	0.11	0.00		
DE/HL	Female	189	0.29	0.00	–2.03	0.04
	Male	119	0.30	0.00		

(SL: Standard length; ED: Eye diameter, DE: Eye distance, BD: Body depth, and HL: Head length)

The following paragraph describes the interaction between sex and site concerning HL/SL and DE/HL. At the same time, this interaction does not significantly affect HL/SL and DE/HL ratios ($p > 0.05$ for all cases). However, the BD/ SL and DE/ HL ratios showed opposite results, influenced by the sex × site interaction ($p < 0.05$ for all cases). These findings were compared with the research on *G. giuris* [20] and *M. mysticetus* [21]. It appears that the sex×site factor has a contrasting impact on *P. melanochir*. Specifically, Dinh and Nguyen [20] examined *G. giuris* across different locations in the Mekong Delta and found that morphometric traits were influenced by both sex and site, with notable interaction effects shaping body proportions. Similarly, Vo *et al.* [21] demonstrated that in *M. mysticetus*, sex and environmental site conditions significantly interacted to affect morphometric variability. In contrast, for *P. melanochir*, although some morphometric ratios (e.g., BD/SL and DE/HL) were affected by the sex×site interaction, others (such as HL/SL and ED/HL) were not, indicating a different pattern of morphological response to environmental and biological factors.

Conclusions

This study revealed significant morphometric and morphometric ratio differences in *P. melanochir* between freshwater and brackish habitats in the Mekong Delta, Vietnam. These findings underscore the species' phenotypic plasticity, particularly in body depth, head length, and standard length, which appear to respond to environmental conditions like salinity and temperature. Such plasticity has important implications for fisheries management and conservation. As ecological changes, especially salinity intrusion and habitat alteration, become more pronounced due to climate change and anthropogenic pressures, monitoring morphological traits could be an early indicator of habitat shifts or population stress in *P. melanochir*. Adaptive morphometric traits may also inform localized management strategies, including habitat protection or site-specific harvesting regulations that account for fish population structure and condition. However, the study was limited by its short sampling duration and geographic scope, which may not fully capture seasonal or regional variability. Future research should expand temporal and spatial coverage to better understand this species' adaptive responses.

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Declaration of Generative AI in Scientific Writing

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CRediT Author Statement

Lam Thi Thao Vo: Conceptualization, Investigation, Methodology, Funding acquisition, Writing – original draft.

Quang Minh Dinh: Supervision, Validation, Writing – original draft.

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