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Morphometric and Meristic Variability in *Butis koilomatodon* (Gobiiformes: Eleotridae) in Estuarine and Coastal Areas of the Mekong Delta

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Abstract

The study aimed to investigate morphometric and meristic variability in the mud sleeper *Butis koilomatodon* (Bleeker, 1849) in the Mekong Delta. This species is a commercial fish species with a small-size and is mainly distributed in some coastal areas from Tra Vinh to Ca Mau provinces. In the present research, the parameters of morphometry and measurement, including the head length, body depth, eye diameter, distance of the two eyes, and the interrelationships among the morphometric variables, were determined. The results revealed that the total length and weight of the fish changed by sex, season, habitat, and the interaction between the seasons and habitats. Likewise, the meristic criteria were different between males and females, and the dry and wet seasons, but not by their interactions. The growth rate of males was faster than females. The outcomes also showed that the body size of this species was larger in the dry season and the largest fish were found in Duyen Hai and Tra Vinh provinces. The Findings would be useful not only for further effects of environmental factors on morphology but also for comparisons between congeners *Butis* morphologically.

Keywords

Measurement, meristic criteria, morphometry, the growth rate, the mud sleeper

Introduction

Morphometric and meristic characters have played a crucial role in identifying fish stocks and establishing the evolutionary linkages between ancient and modern fish fauna (Turan, 2004). In fisheries biology, morphometric characteristics have been used to estimate the percentage of fish harvested from length-weight data, determine the effects of environmental improvement, and regulate fisheries

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(Ibáñez-Aguirre *et al.*, 2006). In classification, this information has been useful to classify fish (Nelson *et al.*, 2016) and measure differences and relationships among congeners (Turan *et al.*, 2006). Besides, they have also been used to study variations due to environmental factors (Hossain *et al.*, 2009). Sandlund *et al.* (1992) noted that the morphological characteristics of fish populations like body coloration, meristic characteristics, growth, size, and age at sexual maturity could differ in different habitats. Morphological characteristics may be the result of evolution over time to adapt to natural selective pressures, genetic modifications, food availability, habitat competition, or even simple coincidence (Burns & Sidlauskas, 2019; Thacker & Gkenas, 2019).

Butis koilomatodon (Bleeker, 1849) belongs to the family Eleotridae, order Gobiiformes, and is found along the Indo-Western Pacific region as a native species (Dawson, 1973). However, it is considered an invasive species in northeastern Brazil, competing with other native gobies for food and habitat (Macieira *et al.*, 2012; GuimarãEs *et al.*, 2017). This goby is a carnivore, and its main food items are crustaceans and small fish (Froese and Pauly, 2000). This mud goby usually dwells in estuaries and mangrove creeks with salinity from 3.8‰ to 37.0‰ (Contente *et al.*, 2016). In Vietnam, *B. koilomatodon* is found in the Mekong Delta (Rainboth, 1996; Tran *et al.*, 2013), especially in coastal areas. Because of its nutritional value, good flavor, and firm texture, the economic value of this fish is relatively high. Nevertheless, recent studies on the morphological characters of *B. koilomatodon* have been fragmented and insufficient (Soares *et al.*, 2012; Contente *et al.*, 2016; GuimarãEs *et al.*, 2017). Hence, this research aims to fill the knowledge gaps about the morphometric and meristic parameters of this species according to gender, season, and regions of several Vietnamese provinces, namely Duyen Hai (Tra Vinh); Cu Lao Dung and Tran De (Soc Trang); Hoa Binh and Dong Hai (Bac Lieu); and Dam Doi (Ca Mau).

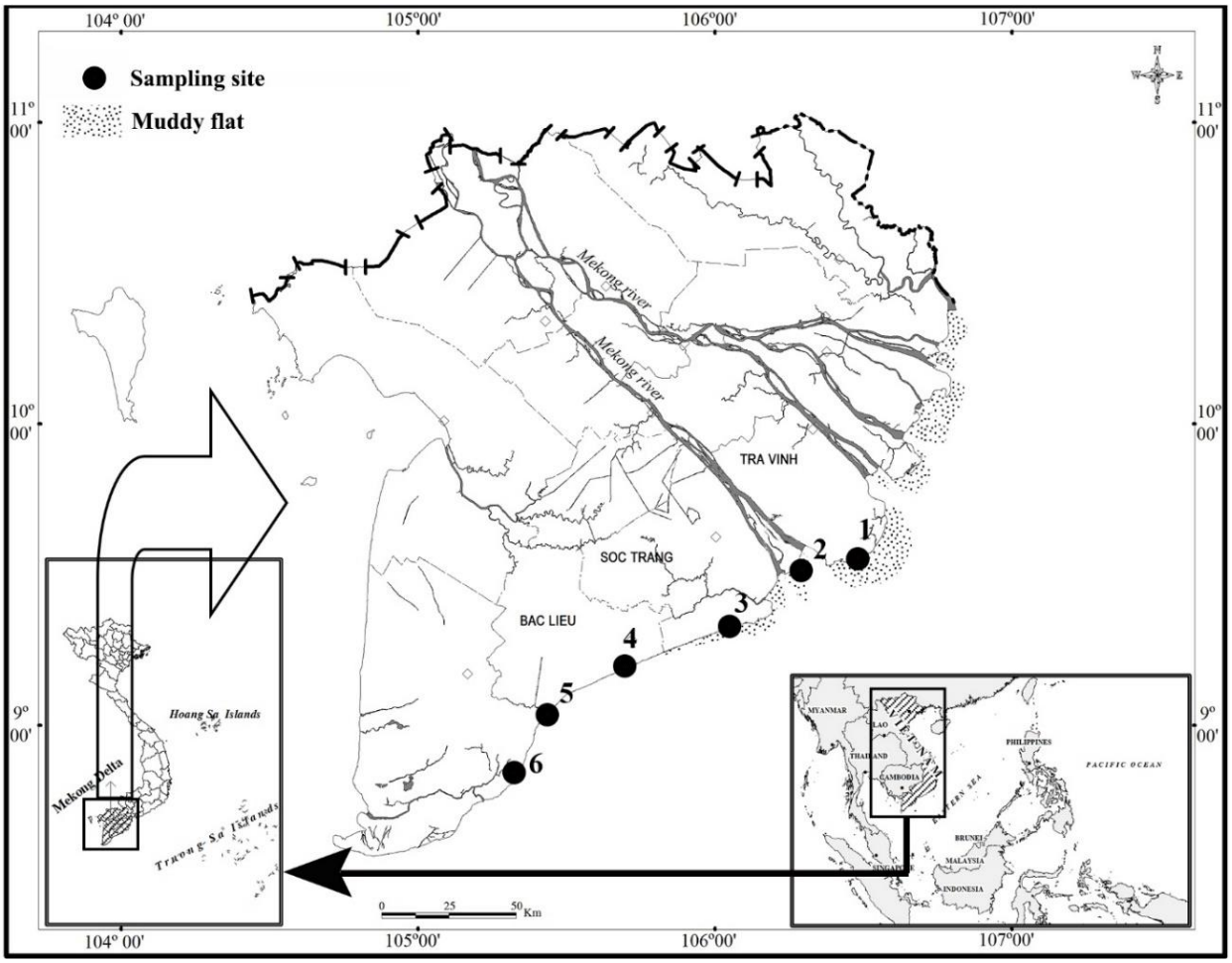
Materials and Methods

Study sites

Fish samples were collected from 04/2019 to 03/2020 in six different sites along estuarine regions, namely Duyen Hai, Tra Vinh (DHTV, 9°41'18.6"N 106°30'35.8"E); Cu Lao Dung (CLDST, 9°33'20.1"N 106°16'57.9"E); Tran De, Soc Trang (TDST, 9°29'26.8"N 106°11'58.5"E); Hoa Binh, Bac Lieu (HBBL, 9°12'24.8"N 105°42'54.9"E); Dong Hai, Bac Lieu (DHBL, 9°06'03.2"N 105°29'49.1"E); and Dam Doi, Ca Mau (DDCM, 8°58'17.5"N 105°22'51.8"E) (**Figure 1**). The dominant sources of vegetation were *Avicennia marina* and *Sonneratia caseolaris* in these places. Moreover, these locations had large mudflats and semi-diurnal tides making them ideal habitats for some aquatic animals. As well as in other subtropical areas, the typical climate is an annual monsoon with two seasons: the dry season (from January to May) with very little rainfall and the rainy season (from June to December) with a monthly rainfall of 400mm. The average annual temperature is about 27^{o}C (Le *et al.*, 2006). Some of the abiotic factors collected by the present work were water temperature, pH (by a thermometer-Model: HI98127), and salinity (by a refractometer-Model: 950.0100 PPT-ATC) in each of the six habitats.

Fish collection

Fish collection was conducted monthly during 2019 by dragging bottom trawl nets. The nets were 5 m long with 1.5 cm mesh size in the cod-end and 2.5 cm in the mouth. When the tide was the highest, trawl nets were set up near the edge of the mangrove forest. After 2-3 h as the tide receded, the nets were pulled up to collect the fish. The collected specimens were preserved in 5.0% formalin and classified based on their external morphology according to the report of Tran *et al.* (2013) in the laboratory. The fish sexes were differentiated based on the morphology of urogenital papilla, e.g., round in females and narrow in males (Dinh *et al.*, 2020). In the zoological laboratory, *B. koilomatodon* specimens were measured for total length (nearest 0.1cm) and weighted (nearest 0.01g). Some of the morphometric and meristic data were taken according to Murdy (1989) and Daud *et al.* (2005) (**Figure 2**). Ratios such as head length/



Note: •: Sampling area; 1: Duyen Hai, Tra Vinh, 2: Cu Lao Dung, Soc Trang, 3: Tran De, Soc Trang, 4: Hoa Binh, Bac Lieu, 5: Dong Hai, Bac Lieu, and 6: Dam Doi, Ca Mau.

Figure 1. Sampling locations map in the Mekong Delta

standard length (HL/SL), body depth/standard length (BD/SL), eye diameter/head length (ED/HL), and distance of two eyes/head length (DE/HL) were also calculated. In parallel, meristic data such as the number of scales along the body, circumferential scales, and the number of rays in first and second dorsal fins were taken.

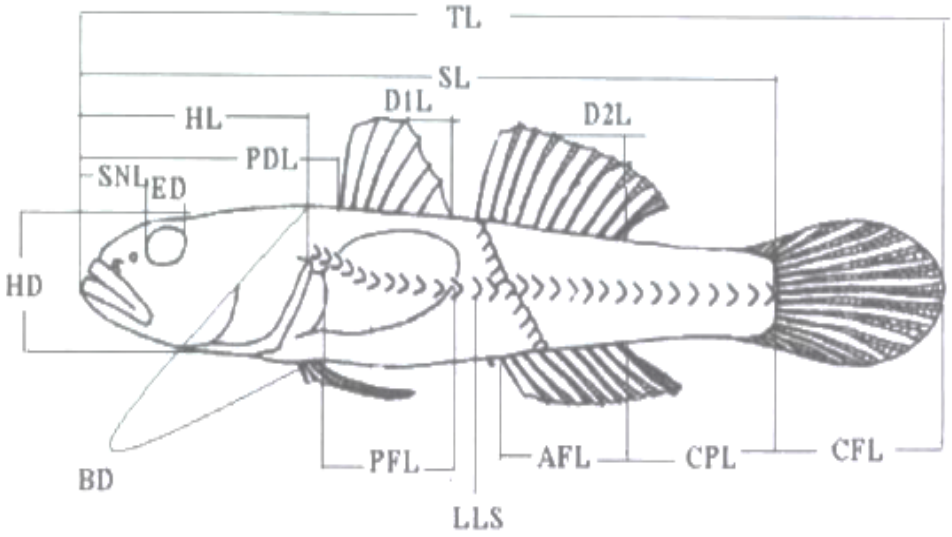
Data analysis

The t-test was used to examine the variation in total length (TL) and weight (W) between genders and seasons. When the TL and W significantly varied among the six sites, one-way ANOVA was then used to test if the differences were significant. Two-way ANOVA was also used to test the interaction of three variables, *viz*. gender × season, gender × site, and season × site. In addition, one-way ANOVA was applied to test the differences of morphometric and meristic parameters (head length/standard length (HL/SL), body depth/standard length (BD/SL), eye diameter/head length (ED/HL), and distance of two eyes/head length (DE/HL)). SPSS software v.21 was used to analyze the data at a 5% significance level for all the tests.

Results and Discussion

Vegetation and water environment parameters

There were many kinds of mangrove vegetation in the sampled sites such as *Nypa fruticans* Wurmb, *Avicennia marna* (Forssk.) Vierh., *Sonneratia caseolaris* (L.) A. Engl., *Bruguiera gymnorrhiza* (L.) Savigny, *Rhizophora apiculata* Blume, and *Acanthus ebracteatus* Vahl. The dominating flora in Cu



Note: Total length (TL), Standard length (SL), Head length (HL), Body depth (BD), Eye diameter (ED), and Distance of two eyes (DE) (Daud et al., 2005).

Figure 2. Morphometric characters used for B. koilomatodon in the present study

Table 1. Water parameters among the sampling sites (average ± standard deviation)

Sampling sites	Temperature (°C)	pH	Salinity (‰)
Duyen Hai	30.03 ± 2.48	7.92 ± 0.08	20.60 ± 9.29
Tran De	28.38 ± 1.65	7.84 ± 0.15	22.60 ± 9.76
Cu Lao Dung	29.20 ± 1.06	7.75 ± 0.10	18.00 ± 8.04
Hoa Binh	28.15 ± 1.68	7.73 ± 0.16	24.83 ± 3.92
Dong Hai	27.85 ± 2.61	7.78 ± 0.25	28.67 ± 4.13
Dam Doi	28.70 ± 2.34	7.82 ± 0.08	26.33 ± 5.32

Lao Dung and Tran De (Soc Trang province) was *Avicennia marna* while *Bruguiera gymnorrhiza* was predominant in Hoa Binh and Dong Hai (Bac Lieu province). These two kinds of mangroves were also found mainly in Dam Doi, Ca Mau province. In Duyen Hai, *Sonneratia caseolaris* dominated.

The average values of temperature, pH, and salinity in the six sites are presented in **Table 1**. The results showed that there were no remarkable differences in the average temperature and pH values among the six studied habitats. The temperature ranged from 27.85 to 30.03°C, and pH maintained at about 7.0 to 8.0. On the other hand, significant changes in salinity were recorded. The lowest salinity value was in Cu Lao Dung (18.00‰), and the highest was in Dong Hai (28.67‰). Among the six sampling sites, only Cu Lao Dung was an island and this geographic feature is a possible reason for the difference in the salinity parameter.

External morphological variation

The external characteristics of *B. koilomatodon* were the same as the descriptions of Macieira *et al.* (2012) and GuimarãEs *et al.* (2017) of this species along the Brazilian coast, and of Yokoo *et al.* (2006) in a Thai mangrove estuary. The body coloration of live and fresh specimens was pale beige to greyish beige, with four to seven dark-brown diffuse bands (the last band at the caudal peduncle) (**Figure 3**). The first and second brown dorsal fins were 8-9 rays and 5-6 rays, respectively. The number of scales along the body was from 26 to 28, and the number of half-circumferential scales was 12. The number of bands on the body (four to seven) and serrated snout were the important characters

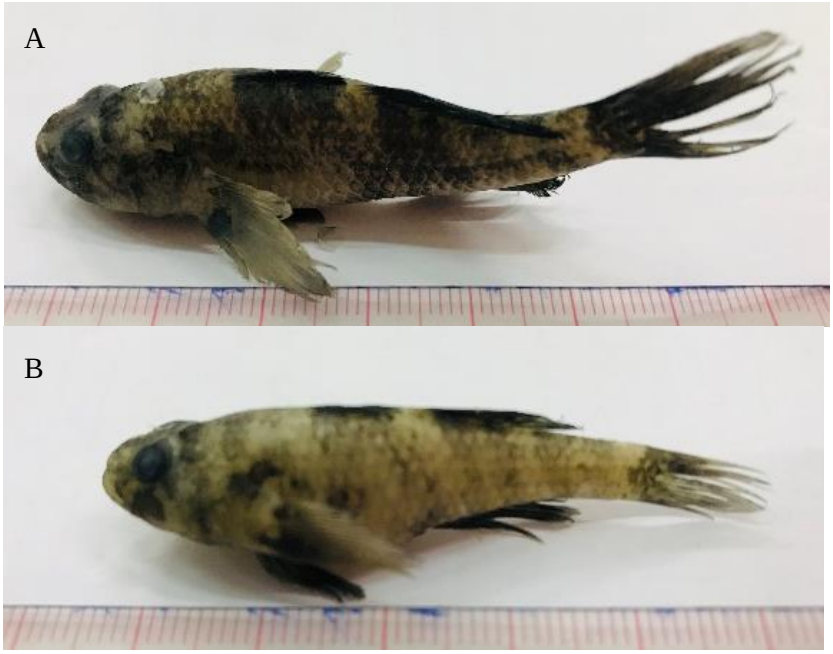


Figure 3. Specimens of *Butis koilomatodon* (A: Male and B: Female) collected in coastal areas in the Mekong Delta

Table 2. The changes in total length and body weight of *B. koilomatodon* specimens according to gender and season.

Morphometry	Category	Number of fish	Mean ± SE
Fish total length (cm)	Male	768	7.35 ± 0.04
	Female	295	6.54 ± 0.05
Fish body weight (g)	Male	768	6.01 ± 0.09
	Female	295	4.44 ± 0.11
Fish total length (cm)	Dry	461	7.39 ± 0.05
	Wet	602	6.92 ± 0.04
Fish body weight (g)	Dry	461	6.05 ± 0.13
	Wet	602	5.21 ± 0.09

to differentiate *B. koilomaton* from *Butis congeners* (Yokoo *et al.*, 2006).

The variable comparison of total length (TL) and body weight (W) of the 1,063 studied specimens of *B. koilomatodon* (295 females and 768 males) is presented in **Table 2**. The results of the t-test showed the average weight and the total length of males were significantly higher than in females (t-test, $t_{Ws} = 10.930$, $t_{TLs} = 12.734$, P< 0.01). Additionally, the TL and W average values were higher in the dry season than the wet season at the significance level of 1% (t-test, $t_{Ws} = 5.459$, $t_{TLs} = 7.450$, $P< 0.01$).

The results indicated that males grew more quickly than females. Observations have shown that the larger males are, the more successful they are in competing for a nest site and attracting females to their nest. If a male was unfortunate in failing to build a nest, another male would replace his role quickly (Lindström & Hellström, 1993). The males were larger than females, which was corroborated by the proposed results of Soares *et al.* (2012) who reported lengths of 4.75 ± 0.35cm and 4.40 ± 0.76cm for males and females, respectively. A similar result was described in two-spotted gobies (Houde, 2001). Thus, body size may be a criterion for allowing active mate choice.

The TLs and Ws in the dry season were also significantly greater than in the wet season. The seasonal change of environmental factors such as temperature, rainfall, salinity, and pH were the main causes that influenced the body size of

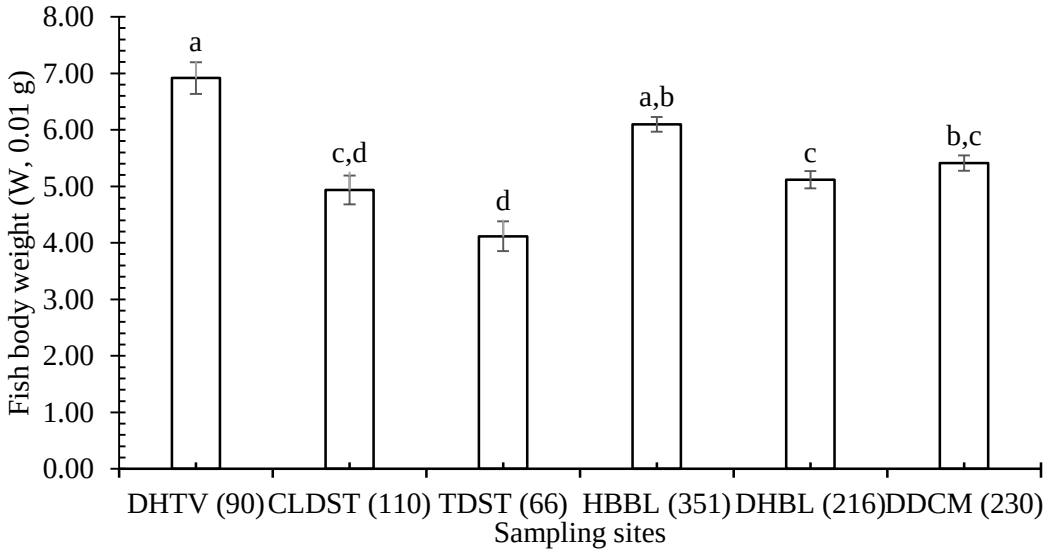
these specimens. In contrast, a study conducted in Pakistan revealed that gobies were not affected by the seasons (Mahmood *et al.*, 2012; Dinh *et al.*, 2016a). The TLs and Ws of some gobiid species co-living in the Mekong Delta were higher in the wet season than in dry season, for instance for *Parapocryptes serperaster* (Richardson, 1846) (Dinh *et al.*, 2016b), *Trypauchen* vagina (Bloch & Schneider, 1801) (Dinh, 2016), Boleophthalmus boddarti (Pallas, 1770) (Dinh, 2017a), and Stigmatogobius pleurostigma (Bleeker, 1849) (Dinh, 2017b). Typically, the dry season is harsher than the rainy season because of less rainfall and saline intrusion. This result suggested that *B. koilomatodon* could reach the highest TL and W values in the dry season.

In **Figure 4**, the average weight values were different by habitat, with the highest value in DHTV (6.92 ± 0.28 g) and lowest value in TDST (4.12 ± 0.26 g) (one-way ANOVA, F=17.737, P< 0.01). Similarly, the TLs were also influenced by the spatial variation with the highest values in DHTV and HBBL (7.73 ± 0.09cm; 7.41 ± 0.05 cm, respectively) and the lowest values in the remaining four sampling sites CLDST, TDST, DHBL, and DDCM (F = 20.199, P< 0.01, **Figure 5**). These data suggest that the TLs and Ws of this species change by habitat and reached the highest values in the DHTV habitat.

The Ws did not depend on the interaction of gender × season (**Figure 6**) (two-way ANOVA, F = 0.056, P> 0.05) or gender × site (F = 1.223, P> 0.05) but were affected by season × site (F = 5.755, P< 0.01, **Figure 7**). Likely, the changes in the TLs of *B. koilomatodon* did not depend on the interaction of gender × season (F = 0.145, P> 0.05, **Figure 8**) or gender × site (F = 1.136, P> 0.01) but were impacted by the interaction between season and site (F = 5.214, P< 0.01, **Figure 9**). This revealed that mud sleepers have different growth depending on the different kinds of habitats and seasons.

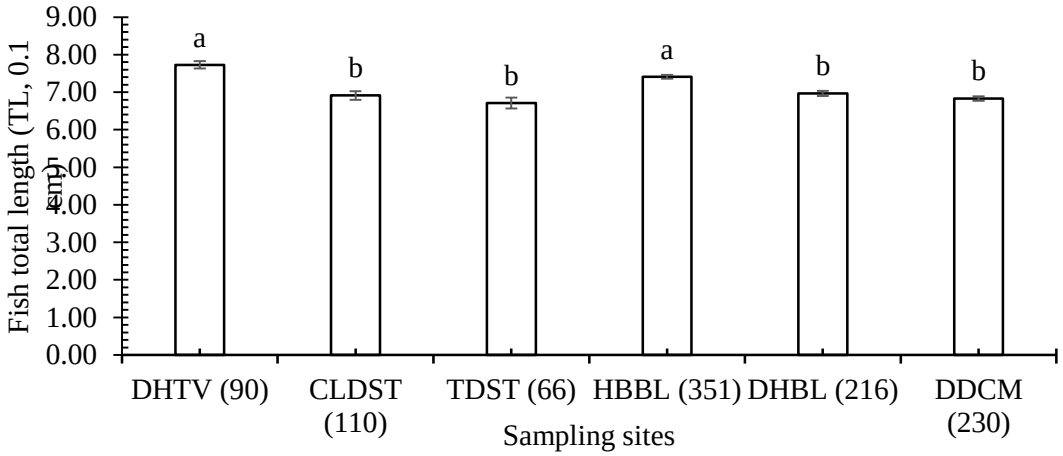
Meristic variation

Table 3 shows the meristic parameters ED, DE, BD, HL, HL/TL, and BD/TL between males and females of the mudsleeper B. koilomatodon. The results revealed that some of the factors depended on the gender. For example, BD, HL, and DE/HL had significant differences between females and males at the 5.0% level (one-way ANOVA, P< 0.05). The reason for these differences was that the body size of males was more massive than females. There were no statistical differences in the other parameters (ANOVA, P> 0.05).



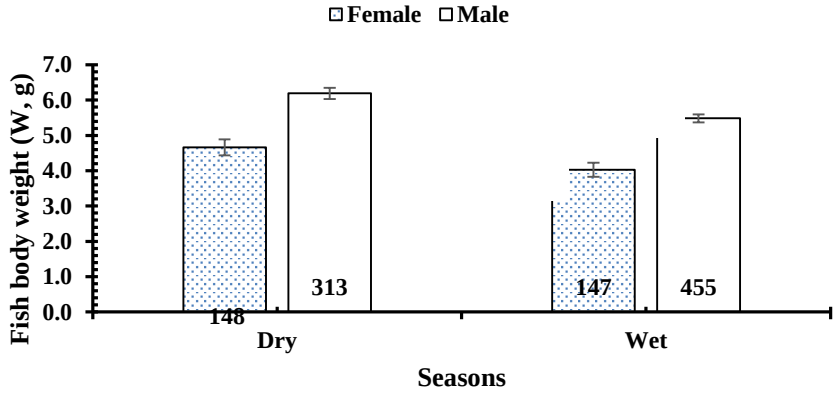
Note: DHTV: Duyen Hai, Tra Vinh; CLDST: Cu Lao Dung, Soc Trang; TDST: Tran De, Soc Trang; HBBL: Hoa Binh, Bac Lieu; DHBL: Dong Hai, Bac Lieu and DDCM: Dam Doi, Ca Mau; number in parentheses: number of fish collected at each site; the vertical bar is the standard error of the mean; different letters (a, b, c, and d) represent the significant differences.

Figure 4. The variation in body weight at the six sampling sites



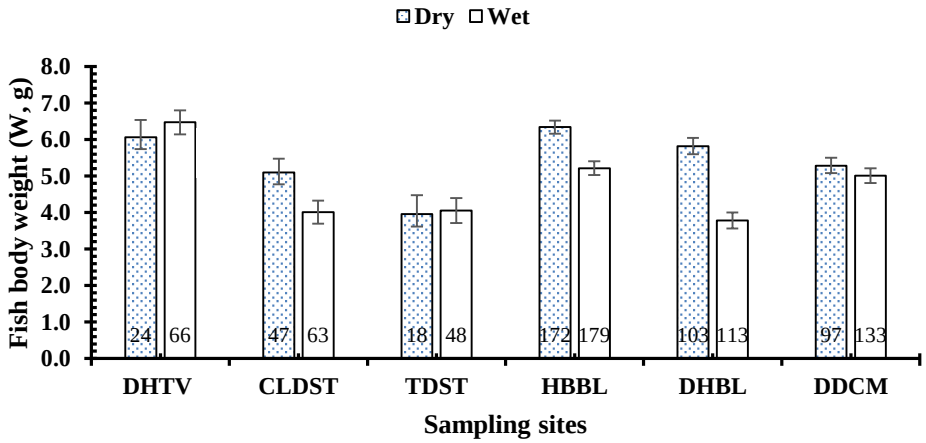
Note: DHTV: Duyen Hai, Tra Vinh; CLDST: Cu Lao Dung, Soc Trang; TDST: Tran De, Soc Trang; HBBL: Hoa Binh, Bac Lieu; DHBL: Dong Hai, Bac Lieu, and DDCM: Dam Doi, Ca Mau; number in parentheses: number of fish collected at each site; the vertical bar is the standard error of the mean; different letters (a and b) represent the significant differences.

Figure 5. The variation in fish total length at the six sampling sites



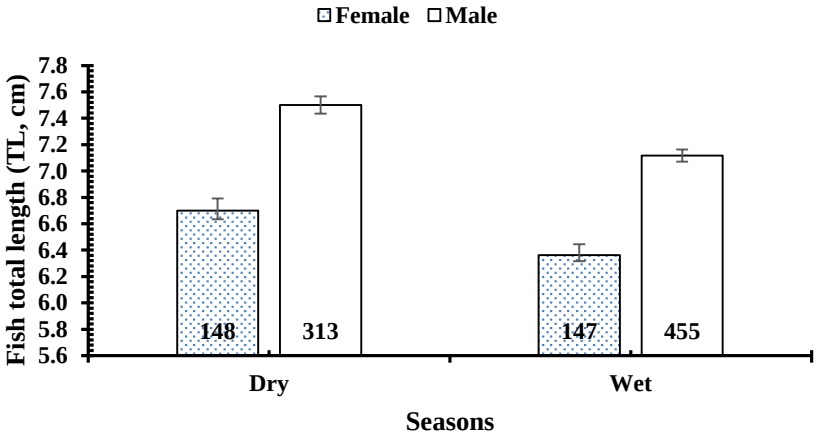
Note: Number in each column: number of fish collected in each season; the vertical bar is the standard error of the mean; different letters (a and b) represent the significant differences.

Figure 6. **The influence of season × gender on the variation of fish body weight**



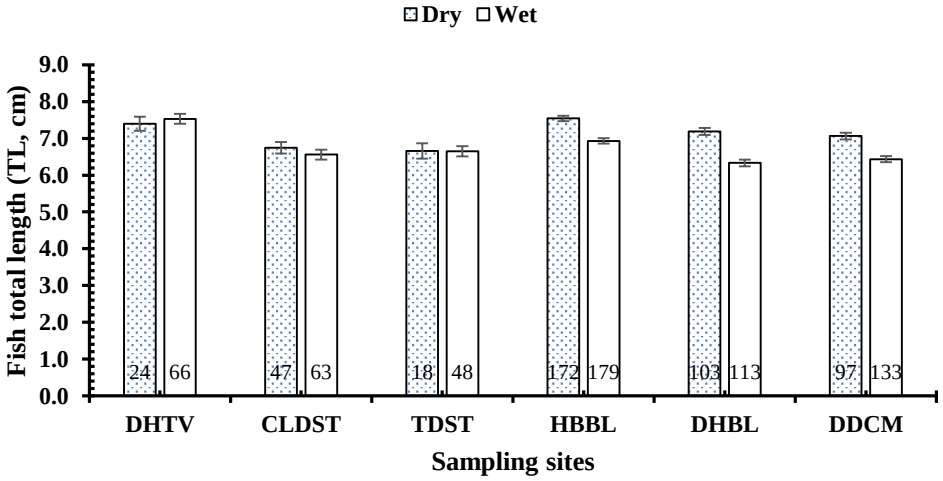
Note: DHTV: Duyen Hai, Tra Vinh; CLDST: Cu Lao Dung, Soc Trang; TDST: Tran De, Soc Trang; HBBL: Hoa Binh, Bac Lieu; DHBL: Dong Hai, Bac Lieu, and DDCM: Dam Doi, Ca Mau; the number in each column: number of fish collected at each site; the vertical bar is the standard error of the mean; different letters (a, b, and c) represent the significant differences.

Figure 7. The influence of season × site on the variation of fish body weight



Note: Number in each column: number of fish collected in each season; the vertical bar is the standard error of the mean; different letters (a and b) represent the significant differences.

Figure 8. The influence of season × gender on the variation of fish total length



Note: DHTV: Duyen Hai, Tra Vinh; CLDST: Cu Lao Dung, Soc Trang; TDST: Tran De, Soc Trang; HBBL: Hoa Binh, Bac Lieu; DHBL: Dong Hai, Bac Lieu, and DDCM: Dam Doi, Ca Mau; the number in each column: number of fish collected at each site; the vertical bar is the standard error of the mean; different letters (a, b and c) represent the significant differences.

Figure 9. The influence of season × site on the variation of fish body weight

Table 4 reveals the differences of the meristic parameters between the dry and wet seasons. The season factor had more of an effect than gender on all the criteria except BD, BD/TL, and HL/TL (one-way ANOVA, $P > 0.05$). The HL/TL ratio of *B. koilomatodon* was independent of all three interactions consisting of gender × season, gender × site, and season × site (two-way ANOVA, $F_{GenxSea} = 0.536$, $F_{GenxSite} = 0.556$, $F_{SeaxSite} = 0.700$, $P > 0.05$). A similar result was also found for the BD/TL meristic parameter. The other parameters did not change by the interactions of gender × season, gender × site, and season × site at a significance level of 5% ($F_{GenxSea} = 4.311$, $F_{GenxSite} = 3.161$, $F_{SeaxSite} = 14.134$, $P > 0.05$). Particularly, the DE/HL ratio was only affected by season × site ($F_{SeaxSite} = 13.815$, $P < 0.05$). Last but not least, ED/HL was impacted by season x site plus the gender x site interaction ($F_{GenxSite} = 3.719$, $F_{SeaxSite} = 8.941$, $P < 0.05$). The results suggested that sexes, seasons, habitats, and the interaction between them did not have a clear affect on the meristic criteria of *Butis koilomatodon*. Similar results

were found in *Periophthalmodon septemradiatus* (Dinh *et al.*, 2018) and in *Glossogobius Sparsipapillus* (Nguyen *et al.*, 2020), two goby species that co-habitat with *B. koilomatodon* in the Mekong delta.

Conclusions

In this research, the specimens of *Butis koilomatodon* expressed differences in morphometric and meristic criteria according to

Table 3. The variation in meristic parameters of *B. koilomatodon* between genders

Morphometric parameter	Gender	Number of fish	Mean	Standard deviation	t	*P*
ED	Female	295	0.34	0.05	5.16	0.53
	Male	768	0.36	0.05		
DE	Female	295	0.31	0.08	3.73	0.73
	Male	768	0.33	0.08		
BD	Female	295	1.28	0.23	7.62	0.01
	Male	768	1.41	0.27		
HL	Female	295	1.68	0.22	11.76	0.005
	Male	768	1.86	0.26		
HL/TL	Female	295	31.89	2.59	1.24	0.33
	Male	768	31.89	2.42		
BD/TL	Female	295	24.19	2.72	0.02	0.85
	Male	768	23.97	2.63		
ED/HL	Female	295	27.35	5.41	2.95	0.08
	Male	768	26.31	5.07		
DE/HL	Female	295	24.11	6.24	1.55	0.001
	Male	768	23.47	5.49		

Table 4. The variation in meristic parameters of *B. koilomatodon* between seasons

Morphometric parameter	Season	Number of fish	Mean	Standard deviation	t	*P*
ED	Dry	461	0.35	0.06	0.66	0.00
	Wet	602	0.36	0.05		
DE	Dry	461	0.34	0.09	6.01	0.00
	Wet	602	0.31	0.07		
BD	Dry	461	1.43	0.27	6.00	0.08
	Wet	602	1.33	0.25		
HL	Dry	461	1.84	0.29	2.74	0.00
	Wet	602	1.79	0.24		
HL/TL	Dry	461	31.44	2.43	5.25	0.22
	Wet	602	32.23	2.44		
BD/TL	Dry	461	24.35	2.75	3.44	0.81
	Wet	602	23.79	2.56		
ED/HL	Dry	461	25.39	4.73	6.85	0.01
	Wet	602	27.52	5.33		
DE/HL	Dry	461	23.95	6.09	1.48	0.00
	Wet	602	23.41	5.41		

genders, sites, and seasons as well as the interactions between them. The data indicated that this species reached the highest values of body size in the dry season. In addition, the highest values of its body size were recorded in DHTV. These results would provide useful information for further studies about the influence of food availability and geographical environment on the morphological characteristics of this mud sleeper.

Acknowledgements

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