Morphometric, growth and condition factor variations of *Boleophthalmus boddarti* in the Mekong delta, Vietnam

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Introduction

Information on length-weight relationship (LWR) is useful for fishery management and stock biomass assessment (Froese, 1998; Froese and Pauly, 2000; Gonzalez Acosta *et al*., 2004; Mahmood *et al*., 2012). Fish growth pattern is determined using the slope value (*b*) obtained from the LWR regression (Froese, 2006), and the differences in fish well-being between genders and locations are related to the variations in condition factor (*K*) (Abdoli et al., 2009). However, little is known about the morphometric changes, LWR and condition factor in many gobiid species that live in the muddy flat in the Mekong delta.

Boleophthalmus boddarti (Pallas, 1770) is an elongated mudskipper (Murdy, 1989) and a commercial fish in some Asian regions (Ip *et al*., 1990; Dinh, 2014). Although this fish is widely distributed (Froese and Pauly, 2015), information on it has been limited to its external morphology (Tran *et al.*, 2013), living habitat (Clayton and Vaughan, 1986; Dinh *et al.*, 2014), diet reference (Ravi, 2013; Dinh, 2015), growth pattern (Dinh, 2014) and reproductive biology (Dinh *et al*., 2015). Little has been known on the body condition and variation between genders, season and fish size of *B. boddarti*; and morphometric change of this fish has also been limited. Therefore, this study aims to understand body shape variations, growth pattern and condition factor (*K*) of this mudskipper species. The variations of growth threshold (e.g., slope value or *b* value) and *K* value with gender, season and fish size were also examined. The results of the present study will provide fundamental knowledge on this fish species.

Materials and methods

Sampling

This study was carried out from May 2014 to April 2015 in Tran De district, Soc Trang Province, Vietnam. Deep gill nets with 1.5 cm mesh were used to collect monthly fish specimens in the mudflat and mangrove forest (9°28'47.41"N, 106°12'25.96"E). Total length (*TL*, to the nearest 0.01 cm) and body weight (*W*, nearest 0.01 g) of fish specimens were measured, and fish were stored in 5% formalin and transported to the laboratory after being sexually identified using external morphology of genital papilla (oval for female and triangle for male) as described by Dinh *et al*. (2015). At the study site, the water temperature and salinity were measured on a monthly basis using a thermometer and a refractometer, respectively. These data were then used to confirm whether these factors influence the sex ratio or not.

Data analysis

Chi-square and Student t-test were performed to examine the difference in sex ratio, and the variations in *TL* and *W* of male and female *B. boddarti*, respectively. The length-weight relationship of male and female fish was quantified using equation $W = a * TL^b$ (Ricker, 1973), where, *W* is fish weight (g), *TL* is total length (cm), and *a* is the regression intercept and *b* is the slope those were estimated using the logarithm equation log*W* = log*a* + *b**log*TL* (Froese, 2006). The differences of the *b* values between males and females, and between dry (from January to May with no rain) and wet (from June to December with heavy rain) seasons were confirmed using t-test. The Student t-test was performed to test whether the *b* value was significantly different from the cubic value of 3 (Froese, 2006).

The equation $K = \frac{W}{aTL^b}$ (Le Cren, 1951) was used to estimate the condition factor of fish (*K*), where, *W* is fish weight (g), *TL* is total length (cm), and *a* is the regression intercept and *b* is the slope. The variations in K values with gender, season and fish size-classes (8–10, 10–12, 12–14, 14–16, and 16–18 cm) were quantified using ANOVA. Two-way ANOVA was subjected to test the possible interaction between season and fish size affecting the fish condition factor (*K*) variation. Student t-test was performed to confirm whether the *K* was equal to one or not (Mahmood *et al.*, 2012). The level of significant differences for all tests was set at $p<0.05$.

Results and discussion

Morphometric variations and sex ratio

The mean total length of female *B. boddarti* (12.07±0.08 cm, SEM) was not significantly higher than that of males (11.95±0.08 cm, SEM, t-test, $p>0.05$, Fig. 1a), and the average body weight of females (18.39±0.40 g) was similar to that of males (17.76±0.368 cm, SEM, t-test, $p>0.05$, Fig. 1b).

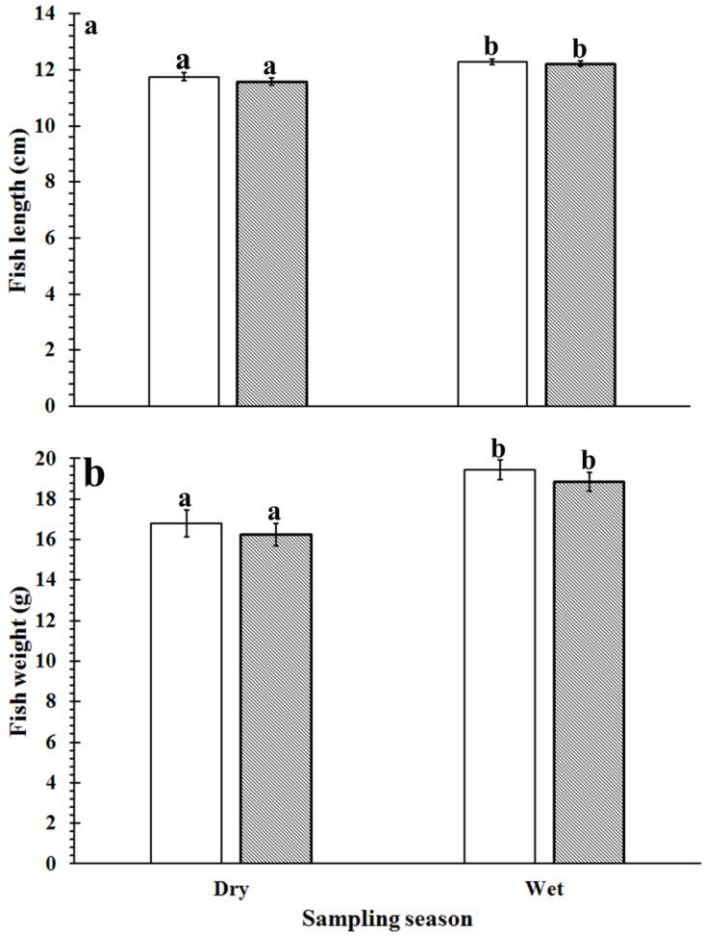

Figure 1: Mean of total length (a) and body weight (b) of male and female *Boleophthalmus boddarti* in dry and wet seasons. Vertical lines represent standard error.

It meant that males and females shared the same pattern in fish growth, which was also found in other co-occurring gobies such as *Parapocryptes serperaster* (Dinh *et al*., 2016a), *Periophthalmodon schlosseri* (Dinh, 2016a) and *Trypauchen vagina* (Dinh, 2016b). However, the total length of *B. boddarti* was significantly higher in the wet season (12.24±0.07 cm, SEM) compared to that in the dry season (11.65±0.09 cm, SEM, t-test, $p<0.001$, Fig. 1a). Likewise, the average body weight in the wet season (19.15±0.34 cm, SEM) was significantly different from that in the dry season (16.50±0.43 cm, SEM, t-test, $p<0.001$, Fig. 1b). Larger fish were collected in the wet season as this is its spawning period (Dinh *et al*., 2015). The fluctuation in total length (Two-way ANOVA, $p>0.05$, Fig. 1a) and body weight (Two-way ANOVA, $p>0.05$, Fig. 1b) of males and females did not depend on seasonal changes as there was no positive interaction between genders and seasons, which was also found in *P. elongatus* (Tran 2008), *Periophthalmus barbarus* (Chukwu and Deekae 2011) and *Parachaeturichthys ocellatus* (Panicker *et al*. 2013).

The female (391 specimens) to male (384 specimens) ratio in this study region was not significantly different within or between seasons (χ^2, $p>0.05$ in all cases, Table 1). Water temperature in the study region was not significantly different between dry (28.70±2.57°C, SD) and wet seasons (28.41±0.90°C, SD, t-test, $p>0.05$), while salinity in the dry season (8.86±3.75‰, SD) in the study site was significantly different from that in the wet season (2.68±2.28‰, SD. t-test, $p<0.001$). Like *B. boddarti*, the proportion of male *P. elongatus* that lived in the same habitat was not significantly different from females (Tran, 2008). Similarly, the male to female ratio of 1:1 were also found in some co-occurring gobies like *Pa. serperaster* (Dinh *et al*., 2016b), *Pe. schlosseri* (Dinh, 2016a), *T. vagina* (Dinh, 2016b). This suggests that the minor variations in temperature and salinity did not significantly influence the sex ratio of these fishes in the Mekong Delta. However, the sex ratio in *Pomatoschistus minutus and Apistogramma* species was strongly regulated by temperature variations (Kvarnemo, 1996; Baroiller and D'Cotta, 2001).

Length-weight relationships

This mudskipper can be estimated for fishing management as the monthly weight of male and female fish could be estimated from fish length due to high value of determination coefficients ($r^2>0.74$ in all cases, $p<0.05$, Table 1). Similarly, both female and male *B. boddarti* showed strong positive relationship between total length and body weight because of high value of determination coefficients ($r^2>0.89$, $p<0.05$ in all cases, Fig. 2).

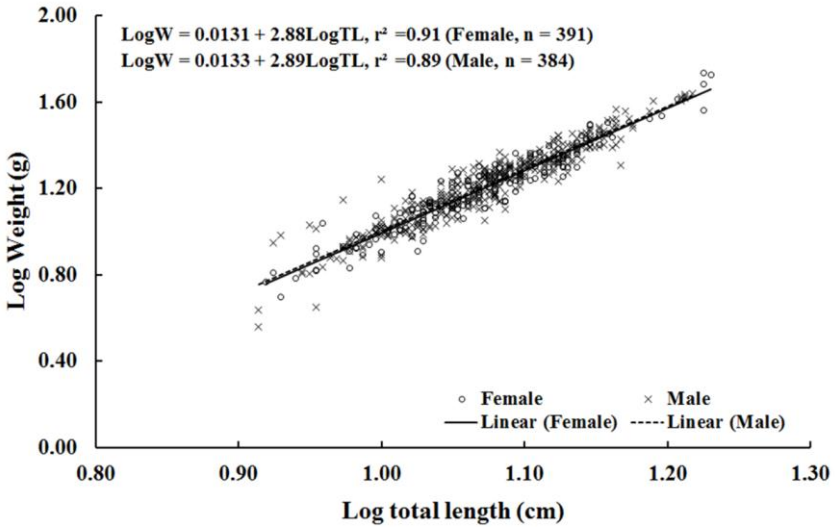

Figure 2: Length-weight relationship of male and female *Boleophthalmus boddarti*.

Table 1: The sex ratio and regression slope (*b*) of *Boleophthalmus boddarti* in the study site.

Sampling time	Female	Male	Sex ratio	*P*-value	Female			Male		
					b	*a*	r^2	*b*	*a*	r^2
May-14	24	24	1 : 1.00	1.00	3.18	0.0063	0.95	2.49	0.0356	0.90
Jun-14	26	27	1 : 1.04	0.89	2.99	0.0100	0.93	3.22	0.0055	0.80
Jul-14	36	36	1 : 1.00	1.00	2.57	0.0298	0.83	2.04	0.1122	0.87
Aug-14	42	40	1 : 0.95	0.83	2.83	0.0163	0.90	2.96	0.1114	0.89
Sep-14	27	23	1 : 0.85	0.57	3.31	0.0172	0.84	2.68	0.2310	0.88
Oct-14	26	28	1 : 1.08	0.79	3.01	0.0094	0.90	3.09	0.0076	0.95
Nov-14	45	42	1 : 0.93	0.75	3.08	0.0079	0.98	2.99	0.0099	0.93
Dec-14	34	28	1 : 0.82	0.45	2.90	0.0118	0.91	3.18	0.0063	0.88
Jan-15	40	40	1 : 1.00	1.00	3.18	0.0066	0.96	3.15	0.0066	0.92
Feb-15	30	46	1 : 1.53	0.07	2.77	0.0180	0.75	2.95	0.0117	0.80
Mar-15	31	30	1 : 0.97	0.80	2.79	0.0156	0.89	2.94	0.0112	0.93
Apr-15	30	20	1 : 0.67	0.16	2.61	0.0248	0.86	2.55	0.0289	0.89
Dry season sum	155	160	1 : 1.03	0.78	2.79	0.0132	0.91	2.83	0.0151	0.87
Wet season sum	236	224	1 : 0.95	0.57	2.97	0.0107	0.89	2.91	0.0122	0.91
Total	391	384	1 : 0.98	0.80	2.88	0.0131	0.91	2.89	0.0133	0.89

The goby *P. elongatus* also shows strong positive length-weight relationship (Tran, 2008), and other fishes *Periophthalmus barbarus* (Chukwu and Deekae, 2011) and *Parachaeturichthys ocellatus* (Panicker *et al*., 2013), *Pa. serperaster* (Dinh *et al*., 2016b), *Pe. schlosseri* (Dinh, 2016a), *T. vagina* (Dinh, 2016b) also have strong positive relationship between total length and body weight.

The *b* value in the present study of female fish (*b*=2.85±0.01, SEM) was similar to that of males (*b*=2.93±0.07, SEM, t-test, $p>0.05$); and this value in the wet season (2.92±0.09, SEM) was not significantly different from that in the dry season (2.86±0.08, SEM, t-test, $p>0.05$). These indicated that the seasonal changes and the gonadal development did not influence the growth pattern of this fish, and this fish can adapt well in the study region. Like this mudskipper, the growth pattern of *Ilisha melastoma* in Pakistan is not affected by seasonal changes (Mahmood *et al*., 2012). Besides, the growth index of *Per. barbarus* (King and Udo, 1998; Chukwu and Deekae, 2011) and *Par. ocellatus* (Panicker *et al*., 2013) are not be regulated by gonadal development. However, the *b* value of *Gobius niger* in Turkey was significantly higher in females compared to males due to gonadal development (Kalaycı *et al*., 2007).

Like a previous study on length-weight relationship of *B. boddarti* by Dinh (2014), the *b* value of this mudskipper in the present study (*b*=2.89±0.06, SEM) was not significantly different from the standard threshold of 3 (t-test, $p>0.05$), indicating that this fish exhibited

isometric growth and fell into the "well-being" category as described by Froese and Binohlan (2000). This is ometric growth was also found in *P. elongatus* (Tran, 2008). The coincidence of the present study with the previous study indicated that environmental conditions, where *B. boddarti* lived, were suitable for fish feeding and growth, and these conditions could be imitated for fish culture. Besides, some other fish such as *Barbatula barbatula* (Oscoz *et al.*, 2005), *Per. barbarus* (King and Udo, 1998), *Pa. serperaster* (Dinh *et al*., 2016b), *Pe. schlosseri* (Dinh, 2016a), *T. vagina* (Dinh, 2016b) show isometric growth as well. Although these fish live in different habitats, they share a similar growth pattern, suggesting that they live in a favorable environment. By contrast, some fish *Periophthalmus argentilineatus* (Khaironizam and Norma-Rashid, 2002) and *I. melastoma* (Mahmood *et al.*, 2012), show allometric growth, indicating that growth pattern is species-specific. Moreover, the growth pattern of fish is regulated by environmental conditions. For example, *Gobius niger* has a different growth index in different habitats, ranging from 2.81 in the Black Sea, 2.89 in Egypt, to 3.85 in Mediterranean (Kalaycı *et al*., 2007).

The condition factor (K)

Both female and male *B. boddarti* adapted well in the study region as their condition factors (*K*) were not significantly different which was 1.00±0.14 (SD) for females and 1.00±0.13 (SD) for males (t-test, $p>0.05$). Similarly, the value in the wet season (1.01±0.13, SD) was not significantly higher than that in the dry season (1.00±0.14, t-test, $p>0.05$, and the condition factor of *B. boddarti* was not significantly different between fish-size classes (ANOVA, $p>0.05$, Fig. 3). This means that gonadal maturation did not influence the variation of *K* values of this mudskipper. The similarity in condition factors between gender and season is also found in *P. barbarus* (King and Udo, 1998; Chukwu and Deekae, 2011), but the *K* value of *I. melastoma* is affected by fish gonadal developmental stages (Mahmood *et al*., 2012).

Body condition of this mudskipper fluctuated monthly (ANOVA, $p<0.05$, Fig. 4) which was similar to *I. melastoma* (Mahmood *et al*., 2012) and *P. barbarus* (King and Udo, 1998; Chukwu and Deekae, 2011). However, the *K* value of *B. boddarti* in the present study was not significantly different from the well-being value of 1 (K = 1.01±0.13, SD, t-test, $p>0.05$), which was also found in the co-occurring goby *P. elongatus* (Tran, 2008), *Pa. serperaster* (Dinh *et al*., 2016b), *Pe. schlosseri* (Dinh, 2016a), *T. vagina* (Dinh, 2016b) and *I. melastoma* (Mahmood *et al*., 2012).

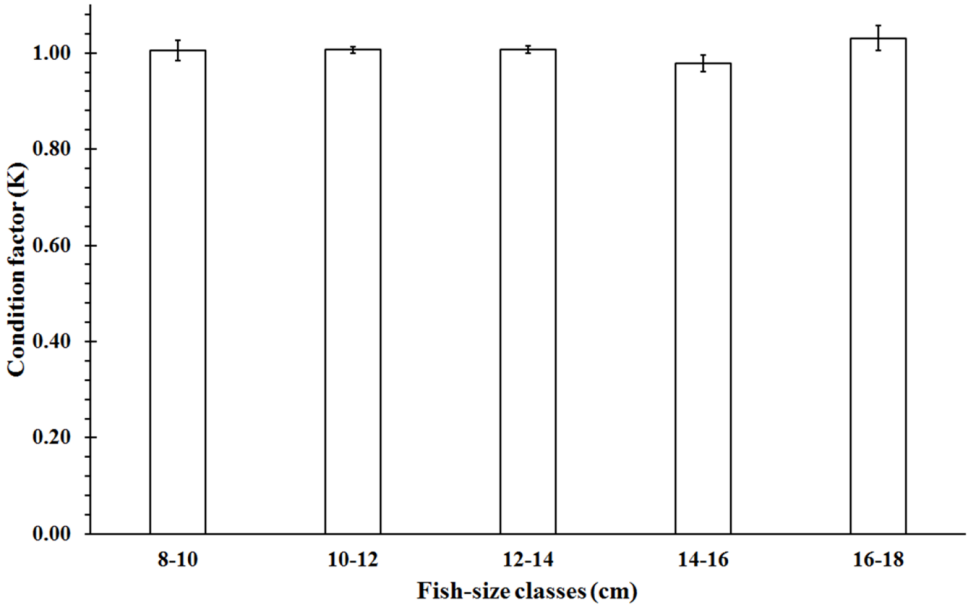

Figure 3: Condition factors of *Boleophthalmus boddarti* in five size-classes.

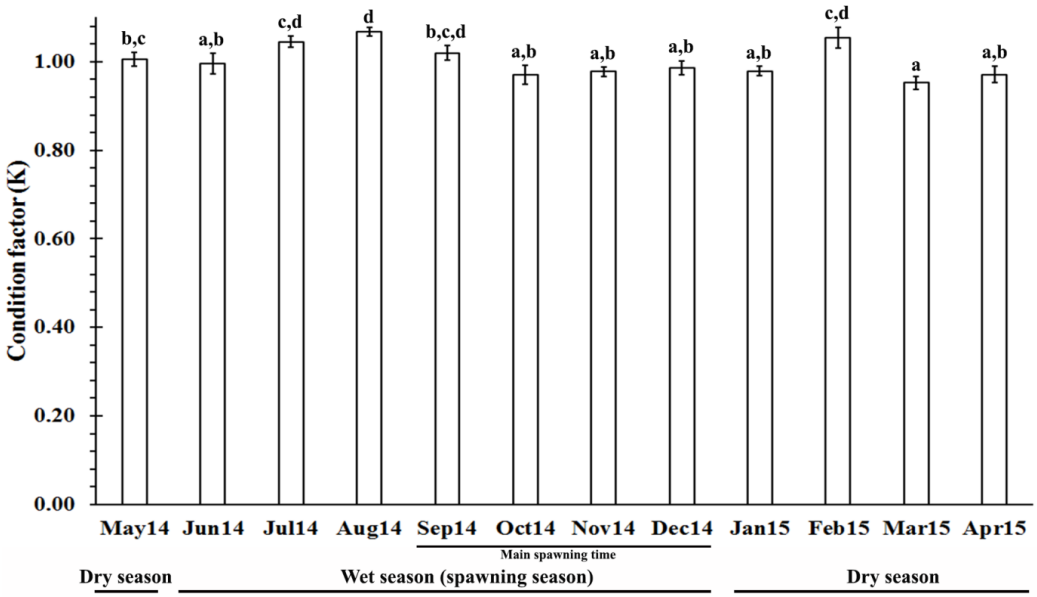

Figure 4: Monthly variations of condition factors of *Boleophthalmus boddarti*. Different letters show the significant difference between fish size-classes. Vertical lines represent standard error.

There was no positive interaction between gender and season, gender and fish size and fish size and season regarding the variations in condition factor of this mudskipper (Two-way ANOVA, $p>0.05$ in all cases). This shows that both male and female *B. boddarti* and *P. elongatus* live in suitable environmental conditions for fish growth, which was similar to *I. melastoma* (Mahmood *et al*., 2012), *P. barbarus* (King and Udo, 1998;

Chukwu and Deekae, 2011), *Pa. serperaster* (Dinh *et al*., 2016b), *Pe. schlosseri* (Dinh, 2016a), *T. vagina* (Dinh, 2016b).

To sum up, the sex ratio of *B. boddarti* was 1:1 between dry and wet seasons and it exhibited isometric growth. Its the slope values were similar within genders and seasons. The condition factors of this mudskipper varied monthly, but overall they were close to 1, suggesting that this fish lives in a favorable site and can become a potential species for future aquaculture in this region.

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