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Research Article

Growth Pattern and Condition Factor of *Butis humeralis* (Valenciennes, 1837) (Gobiiformes: Eleotridae) in Southern Vietnam

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Abstract: This study provides new knowledge of length-weight relationship (*LWR*), growth pattern and condition factor (*CF*) of *Butis humeralis*, one of target catching gobies for food supply in the Mekong Delta, based on a collection of 1,439 fish (580 females and 859 males). Gill nets are used to catch fish samples for twelve months, from April 2019 to March 2020, at six sites in estuaries in the Mekong Delta. The analyses show that the weight of males and females of different fish sizes, seasons and sites are determined by a given total length since the determination coefficients of *LWRs* are high (r^2>0.8 for all cases). As the slope coefficient values (*b*) are higher than the threshold of three, both males and females display positive allometric growth patterns. Likewise, fishes caught at two fish sizes in two seasons and five sites (except in Vinh Hau, *b*=2.97±0.12 SE) exhibit positive allometry. The *CF* of *Butis humeralis* fluctuates around the well-being parameter of one, ranging from 0.95±0.01 SE to 1.08±0.02 SE, which indicates that these six sites are suitable environments for fish growth. The results yield reliable biological data for further research on manageable and conservable strategies of this species.

Key words: *Butis humeralis*, condition factor, length-weight relationship, positive allometry, Vietnam.

Introduction

The length-weight relationship of fish (*LWR*) has been studied since the 19th century, being a crucial tool for assessing and managing fish populations under various environmental factors (Martin-Smith 1996, King 2013, Giarrizzo et al. 2015). The *LWR* allows the estimation of the average weight fish from a known length group based on mathematical correlation and *vice versa* (Beyer 1987). It helps to analyse the fish growth patterns, i.e. isometry or negative/positive allometry (Froese 2006). The

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length-weight data play a predictor role for the fish health (Le Cren 1951).

Butis humeralis (Valenciennes, 1837) is a species of the family Eleotridae (Thacker 2003). In the Mekong Delta, this genus has three species: *B. butis*, *B. humeralis* and *B. koilomatodon* (Tran et al. 2013). It is not difficult to separate *Butis koilomatodon* (sleeper goby) from other two congeners based on two of its characters: five to six dark-brown bands on surface body and one band on caudal peduncle (Yokoo et al. 2006) and the serrated process on the snout (Contente et al. 2016). Although *B. butis* has similar morphology to *B. humeralis,* it is relatively easy to differentiate these two species. Firstly, the head of *B. butis* is moderate-high, whereas *B. humeralis* head is long. Secondly, pelvic fins of *B. butis* are pale, whereas numerous melanophores cover them in *B. humeralis*. Thirdly, the caudal peduncle length in *B. butis* is longer than *B. humeralis* (22–29% SL and 19–27% SL, respectively). Finally, the lower jaw of *B. humeralis* reaches posteriorly below the iris' anterior edge but not in *B. butis* (Yokoo et al. 2006).

Butis humeralis is distributed mainly in Indo-Pacific and is adapted to freshwater, brackish and marine habitats (McDowall 1997, Froese & Pauly 2020). In Vietnam, Tran et al. (2013) record this species in the Mekong Delta, especially in mangrove estuaries. So far, very scantly information related to *B. humeralis* was known, especially about *LWR*, growth pattern and condition factor. This study aims to quantify the variations of *LWR*, type of growth and body condition factor in relation with gender, season, fish size and sampling site variables. The findings from this study provide fundamental data to manage sustainably of this fish source.

Materials and Methods

Study site

Six estuarine areas from Tra Vinh to Soc Trang, Bac Lieu and Ca Mau Provinces in the Mekong Delta were chosen to collect fish samples. They were Long Vinh, Duyen Hai, Tra Vinh (LV); An Thanh, Cu Lao Dung, Soc Trang (AT); Trung Binh, Tran De, Soc Trang (TB); Vinh Hau, Hoa Binh, Bac Lieu (VH); Dien Hai, Dong Hai, Bac Lieu (DH); and Tan Thuan, Dam Doi, Ca Mau (TT) (Fig. 1). *Avicennia marna* (Forssk.) Vierh. and *Sonneratia caseolaris* (L.) A. Engl. are the indicator plants of the mangrove ecosystem at sampling sites. With two nearly equal ebb and flow tides each day, the typical pattern is the semidiurnal tide. There are two distinct seasons: the dry season running from January to May with rare rain and the wet season lasting from June to December with roughly 99 % annual rainfall. The average temperature was 24–27°C, with only slight variations (Le et al. 2006).

Fish collection

The fish collection was monthly conducted from April 2019 to March 2020 by gill nets (permitted sampling tool); the cod-end mesh size was 1.5 cm, the mouth mesh size was 2.5 cm, the length and depth were 5 m and 10 m, respectively. When the tide was highest, the gill nets were set near the side of the mangrove forest. When the tide was lowest after 2–3 hours, the nets were retrieved to collect fishes following the method described by Dinh et al. (2015). All specimens of fish were classified following the description of external morphology (Yokoo et al. 2006, Tran et al. 2013). A maximum of 30 *B. humeralis* specimens were collected per month at each habitat. The remaining fish specimens (which were not *B. humeralis*) were released back to the river. Sampled specimens were fixed in formalin buffer 5% and shipped to the lab within a day.

Sex identification

The identification of the sex of *B. humeralis* specimens was based on the outward shape of the genital papilla. Females have oval-shaped genital spines while males have triangle-shaped genital spines. The sex was confirmed again by observing the gonadal morphology after dissecting specimens and removing viscera.

Fish and data analysis

We examined 1,439 fish specimens (580 females and 859 males). In the laboratory, we measured the total length (*TLs*) (to nearest 0.1 cm) and the body weight (*Ws*) (to nearest 0.01g).

We used the formula of Ricker (1973) to estimate the relations of weight and fish length:

$$W = a \times \mathrm{TL}^{b},$$

where *a* is the regression intercept and *b* is the regression slope, was used.

At the population level, the fish body condition factor (*CF*) was obtained from the function of Le Cren (1951):

$$\mathrm{CF} = \frac{\mathrm{W}}{a \times \mathrm{TL}^{b}},$$

where *W* is fish body weight, *TL* is fish total length, *a* is the regression intercept and *b* is the slope. The two parameters *a* and *b* of the population were inferred from the logarithm formula Log*W* = log*a* + *b*′Log*TL* (Froese 2006).

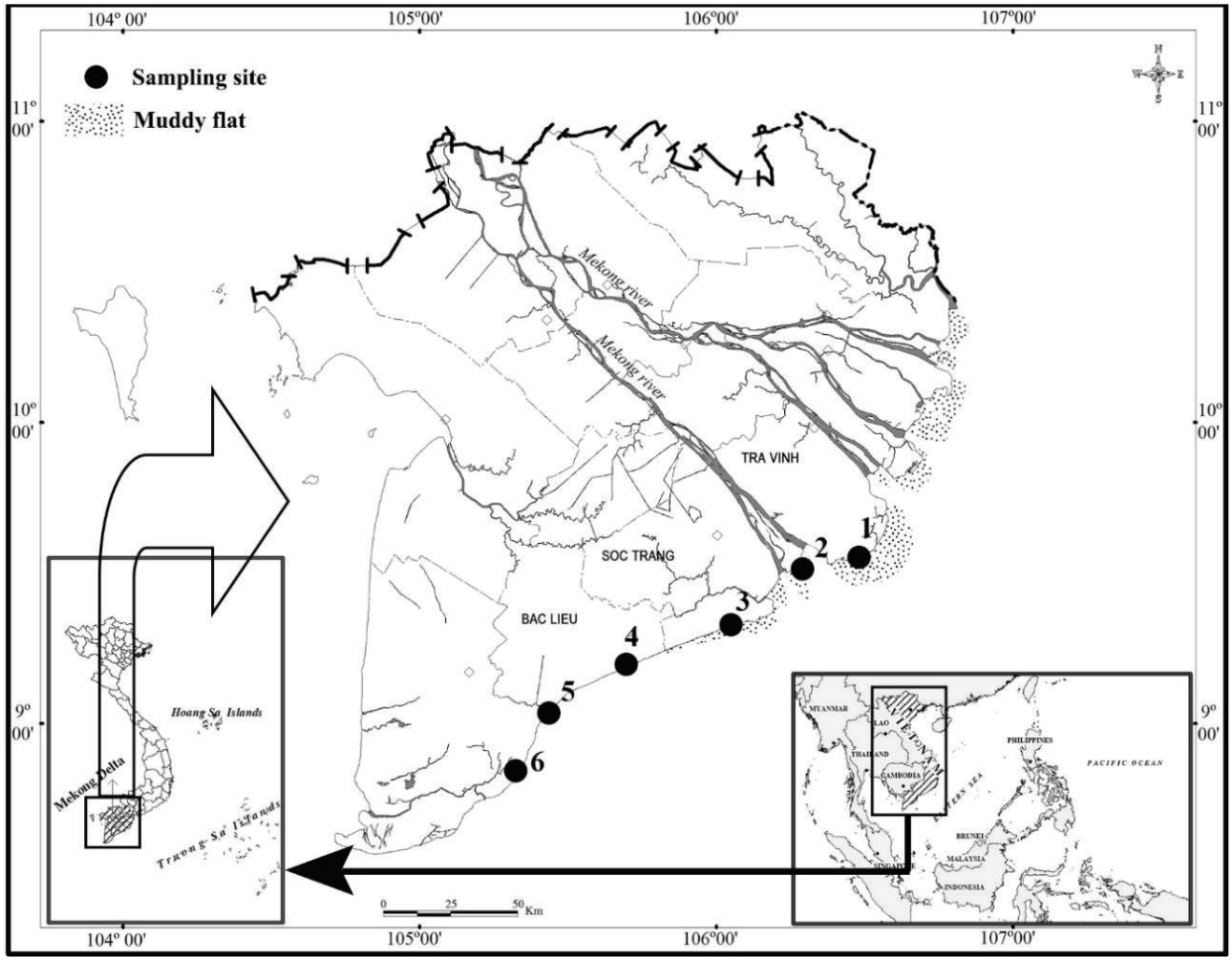

Fig. 1. The sampling map in the Mekong Delta. Circles are the sampling areas: 1: Long Vinh, Duyen Hai, Tra Vinh; 2: An Thanh, Cu Lao Dung, Soc Trang; 3: Trung Binh, Tran De, Soc Trang; 4: Vinh Hau, Hoa Binh, Bac Lieu; 5: Dien Hai, Dong Hai, Bac Lieu, and 6: Tan Thuan, Dam Doi, Ca Mau). This figure was modified from Tran & Dinh (2020), with permission.

The variations in *TLs*, *Ws*, the slope (*b*) and *CF* between males and females, dry and wet seasons, and immature and mature specimens were examined by t-test. For the variation of *TLs*, *Ws*, *b* value and *CF* according to sampling sites and months, the statistical method used was one-way ANOVA (Mahmood et al. 2012). The fish samples were grouped based on total length. If *TLs* were greater than a fish length at the first maturity (L_m = 7.94 cm, unpublished data), the fish was categorised as a mature group. The interactions gender × season, site × fish size, season × fish size, season × site influenced *b* and *CF* were tested by two-way ANOVA (Dinh 2016a). The growth type was determined on the value of the slope (*b* value). The growth type was isometry (*b*=3), positive allometry (b>3) and negative allometry (b<3) (Froese 2006). Additionally, the t-test was used to check if the *CF* value differed from the favourable condition of one. The SPSS software V. 21 was applied to analyse all data at $p<0.05$.

Results

Morphometrics

The data about the sample size (number of fishes), total length (*TLs*), weight (*Ws*) and condition factors (*CF*) according to genders, seasons, fish sizes and sampling sites are presented in Table 1. The weight of fish did not changed with genders (t-test, $t_{W\text{-}gender}$=2.608, $p>0.05$, Table 1) but seasons, fish sizes ($t_{w\text{-}season}$=14.070, $t_{W\text{-}size}$=101.216, $p<0.01$, Table 1) and sampling sites (One-way ANOVA, $F_{W\text{-}site}$=25.319, $p<0.01$, Table 1). The statistical results revealed that the species reached the heavier weight when growing up (15.66±0.30) in the dry season (14.77±0.48) at TB (18.86±0.79). The statistical results also showed that all four examined factors affected *TL* values. Total lengths of *B. humeralis* were higher in adult male (10.73±0.05 and 10.76±0.07, respectively) in the wet season (10.54±0.07) ($t_{TL\text{-}gender}$=12.970, $t_{TL\text{-}size}$=57.336, $t_{TL\text{-}season}$=23.936, $p<0.01$,

Table 1. Variations of growth pattern and condition factor of females and males *Butis humeralis* during the dry and wet seasons in six sampling sites of the Mekong Delta, Vietnam.

Fish groups		No. of fish	W	TL	*b*	*a*	r^2	t_s	Growth type	*CF*
			Mean±SE		Mean± SE					Mean± SE
Genders	Female	580	13.55±0.47	9.97±0.09^{b}	3.34±0.04	0.005±0.001	0.92	8.50	P	1.04±0.01^{a}
	Male	859	15.46±0.36	10.76±0.07^{a}	3.39±0.02	0.004±0.001	0.96	19.50	P	0.97±0.01^{b}
Seasons	Dry	611	14.77±0.48^{a}	10.32±0.09^{b}	3.43±0.02	0.004±0.001	0.97	21.50	P	1.00±0.01
	Wet	828	14.63±0.35^{b}	10.54±0.07^{a}	3.24±0.04	0.006±0.001	0.90	6.00	P	1.00±0.01
Fish sizes	Immature	123	4.28±0.16^{b}	7.43±0.08^{b}	3.33±0.12	0.005±0.001	0.87	2.75	P	1.01±0.02
	Mature	1316	15.66±0.30^{a}	10.73±0.05^{a}	3.35±0.03	0.005±0.001	0.93	11.67	P	1.00±0.01
Sampling sites	Long Vinh, Duyen Hai, Tra Vinh	269	14.67±0.57^{b,c}	10.66±0.11^{a,b}	3.33±0.05	0.005±0.001	0.95	6..60	P	1.00±0.01^{b}
	An Thanh, Cu Lao Dung, Soc Trang	354	16.82±0.60^{a,b}	11.00±0.11^{a}	3.41±0.06	0.004±0.001	0.91	6.83	P	1.00±0.01^{a,b}
	Trung Binh, Tran De, Soc Trang	273	18.86±0.79^{a}	11.19±0.13^{a}	3.52±0.04	0.003±0.001	0.96	13.00	P	1.01±0.01^{a}
	Vinh Hau, Hoa Binh, Bac Lieu	145	12.87±0.69^{cd}	10.17±0.15^{b}	2.97±0.12	0.012±0.003	0.81	-0.25	I	1.02±0.02^{a}
	Dien Hai, Dong Hai, Bac Lieu	214	11.28±0.75^{d,e}	9.39±0.16^{c}	3.38±0.04	0.005±0.001	0.97	9.50	P	1.00±0.01^{a,b}
	Tan Thuan, Dam Doi, Ca Mau	184	9.80±0.40^{e}	9.40±0.11^{c}	3.20±0.06	0.007±0.001	0.95	3.33	P	1.02±0.01^{a}

Note: Letters in each category show significant differences.

Table 2. Monthly variations of the growth pattern and the condition factor of ***Butis humeralis*** from the Mekong Delta, Vietnam.

Sampling times	Number of fish	W	TL	*b*	*a*	r^2	t_s	Growth type	*CF*
		Mean± SE		Mean± SE					Mean± SE
January	124	17.26±1.10^{a,b}	10.91±0.19^{a}	3.40±0.08	0.004±0.001	0.94	5.00	P	1.01±0.02^{b,c}
February	114	18.09±1.41^{a}	10.75±0.28^{a,b}	3.38±0.05	0.004±0.001	0.98	7.60	P	1.00±0.02^{b,c,d}
March	120	8.61±0.82^{c}	8.84±0.19^{c}	3.40±0.05	0.004±0.001	0.98	8.00	P	0.95±0.01^{d}
April	138	15.69±0.95^{a,b}	10.66±0.17^{a,b}	3.37±0.05	0.005±0.001	0.98	7.40	P	1.01±0.01^{b,c,d}
May	115	14.11±0.81^{a,b}	10.40±0.15^{a,b}	3.48±0.08	0.004±0.001	0.95	6.00	P	1.02±0.01^{a,b,c}
Jun	125	16.01±0.97^{a,b}	10.85±0.17^{a,b}	3.38±0.07	0.004±0.001	0.95	5.43	P	0.98±0.01^{b,c,d}
July	122	13.45±0.70^{b}	10.50±0.14^{a,b}	3.34±0.09	0.005±0.001	0.92	3.78	P	0.96±0.01^{c,d}
August	132	14.13±0.85^{a,b}	10.55±0.17^{a,b}	3.15±0.13	0.007±0.002	0.83	1.15	P	0.97±0.01^{c,d}
September	109	12.80±0.84^{b,c}	10.04±0.18^{b}	3.06±0.07	0.010±0.002	0.95	0.86	P	1.04±0.01^{a,b}
October	109	14.87±0.84^{a,b}	10.46±0.17^{a,b}	3.06±0.08	0.010±0.002	0.93	0.75	P	1.08±0.02^{a}
November	116	14.93±0.99^{a,b}	10.56±0.19^{a,b}	3.21±0.14	0.007±0.002	0.82	1.50	P	1.00±0.02^{b,c,d}
December	115	16.13±1.17^{a,b}	10.73±0.21^{a,b}	3.43±0.06	0.004±0.001	0.97	7.17	P	0.96±0.01^{c,d}

Note: Letters indicate significant differences in condition factor (*CF*).

Table 1) of two communes of Soc Trang Province, i.e. AT and TB ($F_{TL\text{-}site}$=37.032, p<0.01, Table 1).

The variation of *Ws* and *TLs* amongst months were presented in Table 2. The temporal factor was the leading cause of the statistically significant differences in these values (One-way ANOVA, F_W=6.299, F_{TL}=8.889, p<0.01, Table 2). The *Ws* of this goby reached the highest in February (18.09±1.41) and lowest values in March (8.61±0.82). TL value was lowest in March (8.84±0.19) and highest in January (10.91±0.19).

The season × site showed the influence on *Ws* (Fig. 2) and *TLs* (Fig. 3) of *B. humeralis* specimens (two-way ANOVA, F_W=11.169, F_{TL}=8.117, p<0.01). In contrast, the gender × fish size, season × fish size and fish size × site did not cause the differences on *Ws* ($F_{gender\ x\ size}$ = 2.231, $F_{season\ x\ size}$ = 0.695, $F_{size\ x\ site}$ = 0.672, all p>0.05) and *TLs* ($F_{gender\ x\ size}$ = 1.997, F_{season}

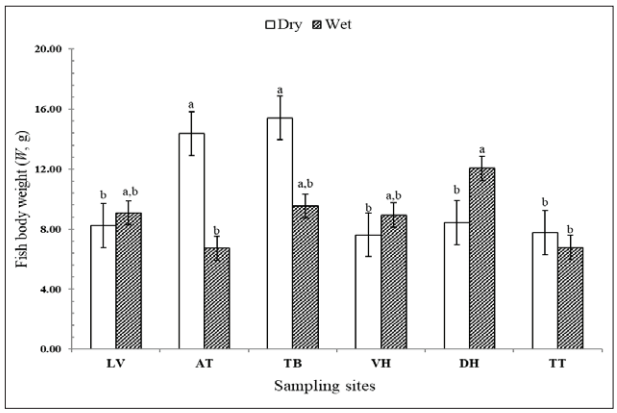

Fig. 2. The effect of seasons and sampling sites on the variation of fish body weight (LV: Long Vinh, Duyen Hai, Tra Vinh; AT: An Thanh, Cu Lao Dung, Soc Trang; TB: Trung Binh, Tran De, Soc Trang; VH: Vinh Hau, Hoa Binh, Bac Lieu; DH: Dien Hai, Dong Hai, Bac Lieu, and TT: Tan Thuan, Dam Doi, Ca Mau. The vertical bar was the standard error of mean. Different letters in each category show significant differences.

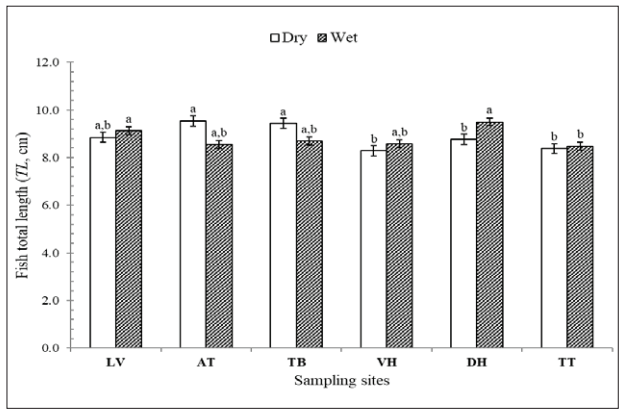

Fig. 3. The effect of seasons and sampling sites on the variation of fish total length. Sampling sites: LV: Long Vinh, Duyen Hai, Tra Vinh; AT: An Thanh, Cu Lao Dung, Soc Trang; TB: Trung Binh, Tran De, Soc Trang; VH: Vinh Hau, Hoa Binh, Bac Lieu; DH: Dien Hai, Dong Hai, Bac Lieu, and TT: Tan Thuan, Dam Doi, Ca Mau. The vertical bar shows the standard error of mean. Different letters in each category show significant differences.

$_{x\ size}$ = 0.052, $F_{size\ x\ site}$ = 1.463, all p>0.05). This fish *W* values did not change with gender × season and gender × site ($F_{gender\ x\ season}$ = 0.081, $F_{gender\ x\ site}$ = 2.116, all p>0.05). The *TLs* varied with gender × site ($F_{gender\ x\ site}$ = 4.592, p<0.01) (Fig. 4) but not gender × season ($F_{gender\ x\ season}$ = 0.657, p=0.418).

Length-weight relationship and growth pattern

The *Ws* positively related to *TLs* because of the high determination coefficients of *LWRs* (r^2> 0.80 for all cases). The regression coefficients (*b*) of fish ranged from 2.97 to 3.48. Both female and male growth patterns were positive allometry because their *b* values were higher than three (t-test, t_{female}=83.62, t_{male}=139.14, p<0.01, Table 1). Likewise, positive allometry was also the growth model of *B. humeralis* observed in dry and wet seasons; at different fish sizes and five sites, except Vinh Hau, Bac Lieu (b>3, p<0.01 in all cases, Table 1). Isometry (b=3) was recognised for *B. humeralis* in Vinh Hau, Bac Lieu (b=2.97, $t_{Bac\ Lieu}$=25.01, p<0.01, Table 1). Table 2 shows that all regression slopes of the twelve-month study were positive allometry due to higher than the threshold of three (b>3, p<0.01 in all cases, Table 2).

Condition factor

The condition factor (*CF*) of *B. humeralis* varied from 0.95 to 1.08 and approximated to one – the standard well-being parameter (Table 1 and 2). This parameter was regulated by genders, sampling sites (t-test, t_{gender}=5.482, t_{site}=4.370, p<0.05, Table 1) and sampling months (one-way ANOVA, F_{CF}=7.040, p<0.01, Table 2). *CF* values showed that the adaptation of female (1.04±0.01) to habitat was better than male, and both sexes adapted better in TB, VL and TT (1.01±0.01, 1.02±0.02, and 1.02±0.01, respectively). The *CF* of *B. humeralis* reached an apex in October 2019 and plunged to the bottom in March 2020 (1.08±0.02 and 0.95±0.01, respectively, see Table 2). Furthermore, the interaction of genders and seasons (Fig. 5) and seasons and sampling sites (Fig. 6) also caused the differences in *CF* values (two-way ANOVA, $F_{gender\ x\ season}$=11.034, $F_{season\ x\ site}$=3.104, p<0.01). *CF* did not change by season, site, gender × fish size, gender × site, season × site,

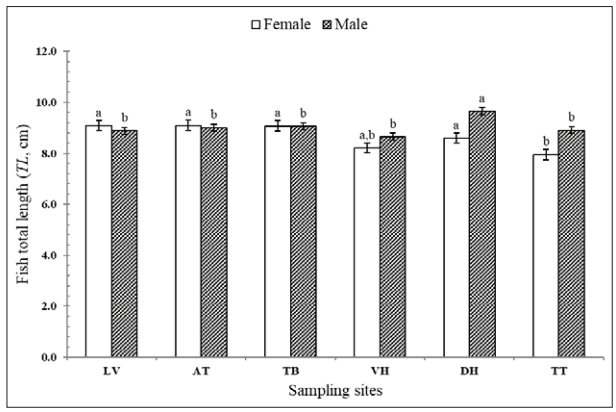

Fig. 4. The effect of genders and sampling sites on the variation of fish total length. Legend: LV: Long Vinh, Duyen Hai, Tra Vinh; AT: An Thanh, Cu Lao Dung, Soc Trang; TB: Trung Binh, Tran De, Soc Trang; VH: Vinh Hau, Hoa Binh, Bac Lieu; DH: Dien Hai, Dong Hai, Bac Lieu, and TT: Tan Thuan, Dam Doi, Ca Mau. The vertical bar shows the standard error of mean. Different letters in each category show significant differences.

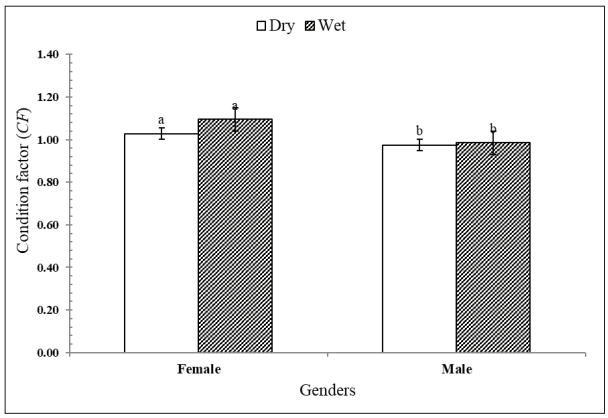

Fig. 5. The effect of genders and seasons on the variation of fish condition factor. The vertical bars show the standard error of mean. Different letters in each category indicate significant differences.

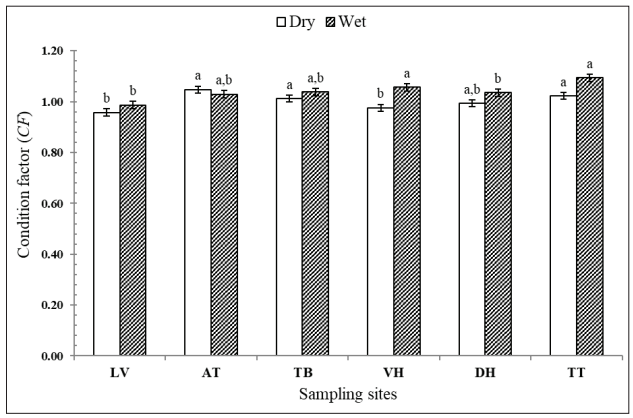

Fig. 6. The effect of seasons and sampling sites on the variation of fish condition factor. Legend: LV: Long Vinh, Duyen Hai, Tra Vinh; AT: An Thanh, Cu Lao Dung, Soc Trang; TB: Trung Binh, Tran De, Soc Trang; VH: Vinh Hau, Hoa Binh, Bac Lieu; DH: Dien Hai, Dong Hai, Bac Lieu, and TT: Tan Thuan, Dam Doi, Ca Mau. The vertical bar shows the standard error of mean. Different letters in each category indicate significant differences.

and fish size × site (F_{season} = 2.582, F_{size} = 1.776, $F_{gender\ x\ size}$ = 1.336, $F_{gender\ x\ site}$ = 1.006, $F_{season\ x\ size}$ = 1.654, $F_{size\ x\ site}$=0.976, all p>0.05).

Discussion

The determination coefficients (r^2) of *B. humeralis* was high (>0.8 for all cases), indicating that the weight was directly proportional to the length and could be estimated from a given size. In particular, *B. butis*, a congener of *B. humeralis* in the Mekong Delta, also displayed positive length-weight relationships. Some of the co-occurring gobies in the Mekong Delta showed positive length-weight relationships, i.e. *B. butis* (see Dinh 2017), *Pseudapocrytpes elongates* (see Tran 2008), *Boleophthalmus boddarti* (see Dinh 2014) and *Oxyeleotris urophthlamus* (see Dinh 2016b).

In the wet season, the number of *B. humeralis* collected specimens was higher than in the dry season. Likewise, in southern Thailand, *B. humeralis* were found only in the rainy seasons (Yokoo et al. 2006). In general, the total length and body weight of *B. humeralis* varied between dry and wet seasons. Nevertheless, the growth pattern in both seasons was positive allometry meaning that the growth of this goby was not influenced by seasons. *Butis humeralis* could adjust body size to adapt to the different living conditions such as the seasonal variations of salinity, precipitation and food availability. Similar results were obtained by Mahmood et al. (2012) on *Ilisha melastoma* in Pakistan and Dinh et al. (2016) on *Parapocryptes supertaster* in the Mekong Delta. This also corroborated with the statements of Swennen et al. (1995) and Miller et al. (1989) that some of the gobies could live and adapt to any type of water body, from marine to freshwater.

The males were longer than females but the weight of males was not different statistically from that of females. The proportional correlation between weight and length revealed that the growth pattern of both males and females was positive allometry, showing that the fish would be plumped as fish grew. Typically, females are often larger than males because the females are fatter than their counterparts, and their gonads are more developed to optimise reproductive capability (Le Cren 1951). In contrast, in *Gobiusculus lavescens*, males were larger than females because they were responsible for protecting the burrow and actively flirting with mates (Houde 2001). Therefore, the fish body size varied by sex that could aim to optimise reproductive ability.

In the same way, positive allometry was found monthly and at five sampling sites: Duyen Hai, Cu Lao Dung, Tran De, Dong Hai and Dam Doi. In general, the positive allometry indicates that this species has successfully adapted to the environmental variation (Piria et al. 2011). Only in the isometric growth pattern (the desired model b~3), when fish may balance in growth, has been detected in Vinh Hau. Kuriakose (2017) stated that fish growth depended on the food source, the number of fish competing for the same food source and the water quality. The cause of this phenomenon could be related to the differences in food source and the water body's quality

between Vinh Hau and the other five sites. Further studies about environmental factors such as salinity, pH and turbidity should be conducted to verify the above argument. Some other goby species were also well adapted to their habitats due to their positive allometric growth pattern, such as rock goby *Gobius paganellus* in Portugal (Azevedo & Simas 2000); *Periophthalmus argentilineatus* and *Periophthalmus spilotus* in Malaysia (Khaironizam & Norma-Rashid 2002) and *Trypauchen vagina* in the Mekong Delta of Southern Vietnam (Dinh 2016a).

Karakulak et al. (2006) and Fontoura et al. (2010) stated that the fish growth pattern could change depending on the genders, seasons, physiological condition, habitats, food availability and interrelationship. Interestingly, only the season and sampling site interaction had a remarkable impact on fish's body size, but the regression slopes (*b*) did not change excessively. This implied that this fish species still grew well despite the changes in examined factors.

In general, the condition factor (*CF*) of *B. humeralis* was greater than the one-threshold showing the good conditions of the fish species in the study areas (Wade 1992). There was a close correlation between *CF* and monthly variation in sampling sites, especially in females. *CF* increased during pre-breeding, afterwards decreased quickly in post-spawning (Le Cren 1951, Froese 2006). In the present study, *CF* was affected by sexes, sampling sites and months as well as the interaction between seasons and sampling sites. The *CF* of females was higher than males because females were more sensitive than males to environmental changes (Le Cren 1951). Despite having differences in *CF* values at six sampling sites, *CF* had just fluctuated around one-threshold. This implied that *B. humeralis* lived in a suitable environment. The variation in *CF* value found monthly could reveal the spawning season. However, there was no clear tendency of *CF* values found amongst twelve months in 2020, suggesting that this species could be iteroparous (spawning many times in a year-cycle). The congener *B. butis* is also iteroparous (Dinh & Le 2017). More studies on the reproductive traits of *B. humeralis* in the Mekong Delta should be conducted to support this assumption.

Conclusion

There is a close mutual relationship between weight and length of *B. humeralis* because the determination coefficients of *LWRs* were high. This goby shows positive allometry as the regression coefficient is higher than the threshold of three. *Butis humeralis* lives in good conditions at surveyed places since the condition factor is greater than one.

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