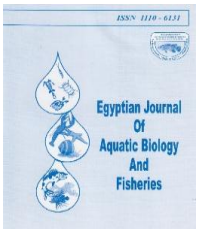
Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 25(2): 591 – 599 (2021)
www.ejabf.journals.ekb.eg



The intraspecific and spatio-temporal changes in growth pattern and condition factor of *Glossogobius aureus* inhabiting in the Mekong Delta, Vietnam

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ARTICLE INFO

Article History:
Received: Feb. 14, 2021
Accepted: March 30, 2021
Online: April 26, 2021

Keywords:
Condition factor,
Glossogobius aureus,
allometry,
isometry,
Vietnam

ABSTRACT

The present study was conducted in four sampling sites, from fresh to brackish waters, to contribute knowledge on the length-weight relationship, growth, and body condition factor of the commercial fish *Glossogobius aureus* (Gobiiformes: Gobiidae) in the Mekong Delta. Fish specimens were caught using gill nets from January to December 2020. Data analyzed results of 742 specimens (382 males and 360 females) showed that weights of males and females in various sizes, seasons, and sites are able to estimate from a fish given length due to high determination coefficients (r^2> 0.8, in all cases). The growth pattern of *Glossogobius aureus* fluctuated monthly from negative allometry to isometry and positive allometry as its slope (*b*) obtained from *LWRs* ranged from 2.583±0.119 SE to 3.123±0.066 SE. Likewise, *b* of this fish changes with fish size and site, but not season and gender. Albeit the growth pattern showed intraspecific and spatio-temporal variations, this goby displayed negative allometry since *b* (2.859±0.030) was lower than three. Likely, fish body condition factors, ranging from 0.937±0.022 SE to 1.218±0.030 SE, varied between fish sizes, sites, and months. The present findings contributed valuable data to understand fish adaptation and fishery management.

INTRODUCTION

The fish length-weight relationship (*LWR*) and the slope coefficient obtained from *LWR* are essential to evaluate fish stock and growth pattern, respectively **(Froese, 1998; Froese, 2006; Dinh *et al.*, 2016a)**. Condition factor (*CF*) is used to qualify the variations of fish well-being between species, regions **(Abdoli *et al.*, 2009a; Abdoli *et al.*, 2009b)**, genders, fish sizes, and seasons **(Froese, 2006; Dinh *et al.*, 2016b)**. *Glossogobius aureus* Akihito and Meguro, 1975 (Gobiiformes: Gobiidae) is one of three commercial species of

the genus *Glossogobius* that lives in brackish and freshwaters in Africa, Asia and Oceania regions **(Rainboth, 1996; Froese & Pauly, 2020)**. This species is a multiple spawner **(Nguyen *et al.*, 2014)** and displays a negative allometry in Cu Lao Dung, Soc Trang **(Dinh, 2014b)**, while it shows an isometry in Tran De, Soc Trang; Nha Mat, Bac Lieu; and Ganh Hao, Bac Lieu **(Dinh, 2019)**. In the Mekong Delta, *Glossogobius aureus* is a target catching fish for food supply **(Diep *et al.*, 2014; Dinh *et al.*, 2018)**, which lessens its natural yield **(Dinh *et al.*, 2021)**. Since this goby is widely distributed in coastal and riverine areas **(Dinh, 2009; Tran *et al.*, 2013; Dinh *et al.*, 2018; Nguyen & Tran, 2018)**, it is required to quantify whether its length-weight relationship, growth, and body condition factor change with sampling site, gender, fish size and season. The current findings would provide a database to comprehend fish adaptation and fishery management in the studied regions.

MATERIALS AND METHODS

Study site and fish collection

The present study lasted for one year (January 2020 to December 2020) from the freshwater region in Cai Rang, Can Tho (CR) to salinization in the dry season in Long Phu, Soc Trang (LP), and brackish water in Hoa Binh, Bac Lieu (HB) and Dam Doi, Ca Mau (DD) (Fig. 1). The semi-diurnal tide represents these places with ~1.2 m range, ~27 °C annual temperature and ~8.0 pH. It receives no rain in the dry season (January–May), only substantial showers are observed with ~400 mm monthly precipitation in the wet season (June–December) **(Le *et al.*, 2006; Tran *et al.*, 2020)**.

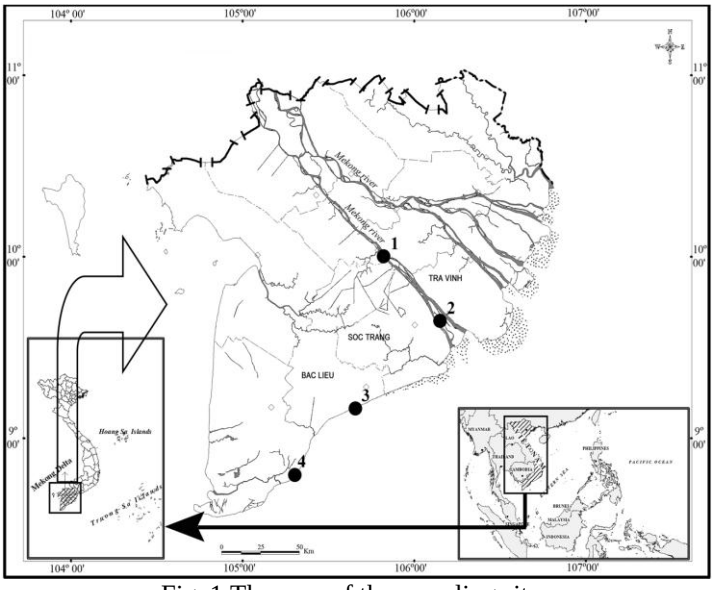

Fig. 1 The map of the sampling sites

Note: Sampling area; 1: Cai Rang, Can Tho; 2: Long Phu, Soc Trang; 3: Hoa Binh, Bac Lieu; 4: Dam Doi, Ca Mau. This figure was modified from figure 1 produced by Dinh (2018) with permission.

Fish specimens, according to **Dinh *et al.* (2015)**, were collected during a period of 48 h from each study site by using gill nets. Gill nets with 1.5 cm mesh in the cod end were set at the highest tide and retrieved after 2–3 h. Fish specimens were identified, using the external description given by **Akihito and Meguro (1975)** before fixation in 5% formalin buffer, and then were transferred to the laboratory.

Length-weight relationship, growth pattern, and condition factor determination

Fish specimens were sexed by using genital papilla morphology (triangle for males and oval for females) suggested by **Dinh (2014b)** before measuring the total length (*TL*, 0.1 cm) and the body weight (*W*, 0.01 g). The length-weight relationship was estimated using the equation: $W = a \times TL^b$ (*W* is fish weight (g), *TL* is fish total length (cm), *a* is the regression intercept, and *b* is the regression slope) **(Ricker, 1973)**. As suggested by **Le Cren (1951)**, the condition factor (*CF*) was calculated as $CF=W/(a \times TL^b)$ (*W*: fish weight (g); *TL*: total length (cm); *a*: the regression intercept; *b*: the slope).

Data analysis

Fish size was divided into immature and mature groups based on the length at first mature of males and females (unpublished data). The determination coefficient (r^2) was used to confirm the quality of the *LWRs* **(Metin *et al.*, 2011)**. T-test was used to verify if *b* within gender, fish size, season, month, and site variables were close to the threshold of three **(Morey *et al.*, 2003)**. The variation of *CF* among months was tested using one-way ANOVA, according to **Mahmood *et al.* (2012)**. T-test was used to confirm if *CF* varied within gender, season, and fish size and the significant difference of *CF* from the favorable conditions of one. All tests were set at $p<0.05$.

RESULTS

Length-weight relationship and growth pattern

The data analysis results on *LWRs* of 742 *Glossogobius aureus* collected from four sites revealed a close relationship due to $r^2> 0.850$ in all cases. This goby showed monthly fluctuation as *b* values obtained from *LWRs* (2.583±0.119 to 3.123±0.066 SE) varied monthly (Table 1). The *b* value of males (2.904 ± 0.044 SE) was similar to that of females (2.827 ± 0.040 SE, t-test, $p>0.05$), and this value in the dry season (2.790 ± 0.049 SE) was not significantly different from that in the wet one (2.914 ± 0.037 SE, $p>0.05$) (Table 2). The *b* values of males, females, dry season, and wet season were lower than the threshold of three ($p<0.05$) for all cases (Table 2). In contrast, the *b* value of this goby varied with fish sizes and sites ($p<0.05$ for two cases), reaching the highest value in HB (3.002±0.059 SE) and the lowest in CR (2.647±0.076) (Table 2). But, in general, the *b* value (2.859±0.030 SE) of this goby population was significantly lower than the three ($p<0.05$).

Table 1: Length-weight relationship and growth pattern of *Glossogobius aureus* from four different study sites from January to December 2020

Sampling times	Number of fish				Sum	*b*	*A*	r^2	t_s	*P*	Growth pattern	*CF*
	CR	LP	HB	DD		Mean± SE	Mean± SE					Mean± SE
Jan-20	-	-	18	16	34	2.917±0.080	0.010±0.002	0.977	-1.13	0.27	Isometry	$1.076±0.014^{c}$
Feb-20	13	12	19	18	62	2.583±0.119	0.021±0.006	0.888	-3.50	0.00	Negative allometry	$1.006±0.024^{a.b.c}$
Mar-20	19	14	12	18	63	2.996±0.097	0.008±0.002	0.940	0.00	1.00	Isometry	$1.007±0.017^{a.b.c}$
Apr-20	10	15	15	14	54	2.697±0.069	0.016±0.003	0.967	-4.57	0.00	Negative allometry	$0.970±0.017^{a.b}$
May-20	14	15	7	19	55	2.550±0.107	0.022±0.006	0.915	-4.09	0.00	Negative allometry	$0.937±0.022^{a}$
Jun-20	10	20	13	25	68	2.668±0.091	0.018±0.004	0.929	-3.67	0.00	Negative allometry	$1.076±0.017^{c}$
Jul-20	14	18	17	23	74	3.073±0.123	0.007±0.002	0.897	0.58	0.56	Isometry	$1.050±0.019^{b.c}$
Aug-20	31	16	21	20	88	3.034±0.101	0.008±0.002	0.913	0.30	0.76	Isometry	$1.047±0.019^{b.c}$
Sep-20	16	13	20	15	64	3.064±0.162	0.007±0.003	0.852	0.38	0.71	Isometry	$1.069±0.024^{b.c}$
Oct-20	10	13	16	16	55	3.096±0.109	0.007±0.002	0.939	0.91	0.37	Isometry	$1.071±0.026^{b.c}$
Nov-20	15	14	20	19	68	3.123±0.066	0.006±0.001	0.971	1.71	0.09	Isometry	$1.045±0.018^{b.c}$
Dec-20	14	15	16	13	58	3.086±0.073	0.008±0.001	0.969	1.29	0.20	Positive allometry	$1.218±0.030^{d}$

Note: Different letters (a, b, c and d) in condition factor *(CF)* category show significant differences (p<0.05). CR: Cai Rang, Can Tho; LP: Long Phu, Soc Trang; HB: Hoa Binh, Bac Lieu; DD: Dam Doi, Ca Mau.

Table 2: Length-weight relationship, growth pattern and condition factor of male and female *Glossogobius aureus*

Fish groups		Number of fish	*b*	*A*	Growth pattern	r^2	*CF*
			Mean± SE	Mean± SE			Mean± SE
Gender	Male	382	$2.904±0.044^{a}$	0.010±0.001	Negative allometry	0.921	$1.039±0.009^{a}$
	Female	360	$2.827±0.040^{a}$	0.012±0.001	Negative allometry	0.932	$1.057±0.009^{a}$
Fish size	Immature	380	$3.054±0.052^{a}$	0.007±0.001	Isometry	0.902	$1.038±0.008^{a}$
	Mature	362	$2.694±0.053^{b}$	0.017±0.002	Negative allometry	0.878	$1.057±0.010^{b}$
Season	Dry	278	$2.790±0.049^{a}$	0.013±0.002	Negative allometry	0.921	$1.036±0.011^{a}$
	Wet	464	$2.914±0.037^{a}$	0.010±0.001	Negative allometry	0.931	$1.054±0.008^{a}$
Sites	Cai Rang, Can Tho	166	$2.647±0.076^{a}$	0.019±0.004	Negative allometry	0.882	$1.041±0.014^{a,b}$
	Long Phu, Soc Trang	165	$2.824±0.061^{a}$	0.012±0.002	Negative allometry	0.929	$1.033±0.012^{a,b}$
	Hoa Binh, Bac Lieu	194	$3.002±0.059^{b}$	0.008±0.001	Isometry	0.930	$1.030±0.011^{a}$
	Dam Doi, Ca Mau	217	$2.912±0.059^{b}$	0.010±0.001	Isometry	0.920	$1.080±0.014^{b}$

Note: Different letters (a and b) in each category (gender, fish size, season, and study area) show significant differences (p<0.05).

Condition factor

The *CF* of *Glossogobius aureus* varied with months (ANOVA, F=9.262, p<0.05), reaching the lowest value in May (0.937±0.022 SE) and the highest in December (1.218±0.030 SE) (Table 1). Though the *CF* did not change with genders and seasons, a change was detected with seasons and sites. Specifically, *CF* of females (1.057±0.009 SE) was similar to males (1.039 ± 0.009 SE) (t-test, t=1.339, p>0.05), but of the mature fish (1.057±0.010 SE) it was higher than that of the immature fish (1.038 ± 0.008 SE) (t=-1.448, p<0.01) (Table 2). In terms of spatio-temporal change, *CF* of the dry season (1.036±0.011 SE) was similar to the wet season (1.054±0.008 SE) (t=-1.296, p>0.01), and this value reached the highest point in DD (1.080 ± 0.014 SE) and the lowest in LP (1.033 ± 0.012 SE) (one-way ANOVA, F=3.267, p<0.05) (Table 2).

DISCUSSION

The weights of male and female *Glossogobius aureus* of different fish sizes, seasons, and sites were directly estimated from a given length as the determination coefficients (r^2) obtained from *LWRs* were high. It coincides with the previous finding on *Glossogobius aureus* caught Cu Lao Dung, Soc Trang **(Dinh, 2014b)**, Tran De, Soc Trang; Nha Mat, Bac Lieu; and Ganh Hao, Bac Lieu **(Dinh, 2019)**. This result in species is similar to many other fish species such as *Trypauchen vagina* **(Dinh, 2016b)**, *Boleophthalmus boddarti* **(Dinh, 2014a)**, *Glossogobius giuris* **(Dinh and Ly, 2014)**, *Pseudapocryptes elongatus* **(Tran, 2008)**. Besides, this positive correlation was found in *Neogobius melanostomus* caught from Southern Lake Michigan, USA (r^2>0.9) **(Duemler *et al.*, 2016)** and *Neogobius melanostomus*, *Neogobius fluviatilis*, and *Babka gymnotrachelus* caught from the Danube river in Serbia (r^2>0.8) **(Krpo-Ćetković *et al.*, 2018)**.

This fish species recorded a higher growth rate in the dry season, suggesting that this fish adapted well to the saltiness of the environment. *Glossogobius aureus* in the present study belonged to a negative allometric growth pattern (b <3), showing that fish had an advantageous development length compared to its weight, which was also found in the previous study in Cu Lao Dung, Soc Trang **(Dinh, 2014b)**. On the contrary, the growth pattern was isometry in Tran De, Soc Trang; Nha Mat, Bac Lieu, and Ganh Hao, Bac Lieu **(Dinh, 2019)**. This assumption indicated that fish growth pattern related to the environmental condition, which was found in *Periophthalmodon schlosseri* as it showed a negative allometry growth in Bangladesand **(Zhang *et al.*, 2003)** but isometry in the Mekong Delta **(Dinh, 2016a)**. Females were often larger than males because the female was usually in fatness and gonadal development to optimize reproductive capability **(Le Cren, 1951)**. However, in *Glossogobius aureus*, the difference in b value between females and males was not statistically significant, suggesting that both females and males had the role of developing the body to prepare for reproduction. Likely, this goby's growth pattern in the previous study was not regulated by gender **(Dinh, 2019)**. This

species could adapt well to saltwater regions than in the other places, as it showed isometry in HB and DD but a negative allometry in CR and LP, whereas in the previous study this goby did not show spatial variation **(Dinh, 2019)**. Some other gobies also exhibited a positive allometric growth pattern, such as rock goby *Gobius paganellus* in Portugal **(Azevedo & Simas, 2000)**; *Periophthalmus argentilineatus* and *Periophthalmus spilotus* **(Khaironizam & Norma-Rashid, 2002)**; and in mature *Trypauchen vagina* in Mekong Delta of Southern Vietnam **(Dinh, 2016b)**.

Unlike the study of **Dinh (2019)**, the *CF* of *Glossogobius aureus*, in the present study, was not regulated gonadal developmental stage. The current result coincides with that found in *Periophthalmus barbarus* **(King and Udo, 1998; Chukwu and Deekae, 2011)** and *Stigmatogobius pleurostigma* **(Dinh, 2017)**. However, it was not found in *Parapocryptes serperaster* **(Dinh *et al.*, 2016a)**. *Glossogobius aureus* was also regulated by fish developmental stage due to the difference in *CF* between immature and mature fish, coinciding with the study of **Dinh (2019)**. In contrast, *Periophthalmodon schlosseri* **(Dinh, 2016a)** and *T. vagina* **(Dinh, 2016b)** distributing in the Mekong Delta did not vary with fish sizes. *Glossogobius aureus*' *CF* changed with months, fish sizes, and study sites; this value was close to the favorable environment, suggesting that it adapted well to their habitats. This assumption was found in a previous study on this fish species **(Dinh, 2019)**. Moreover, the same supposition was obtained concerning some other gobies: *Pseudapocrytpes elongatus* **(Tran, 2008)**, *Parapocryptes serperaster* **(Dinh *et al.*, 2016a)**, *Trypauchen vagina* **(Dinh, 2016b)**, and *Stigmatogobius pleurostigma* **(Dinh, 2017)**.

CONCLUSION

The male and female weights in various sizes, seasons, and sites were estimated from a fish given length due to the high determination coefficients. The growth pattern of *Glossogobius aureus* fluctuated monthly from negative allometry to isometry and positive allometry, and it changed with fish size and site, but not season and gender. This fish's growth pattern showed intraspecific and spatio-temporal variations, and this species generally displayed a negative allometry. Likely, fish body condition factors varied between fish sizes, sites, and months, but they were close to one. The results were helpful in understanding fish adaptation and fishery management.

ACKNOWLEDGMENT

This research is funded by the Ministry of Education and Training of Vietnam under grant number B2020-TCT-13. We are grateful to local fishers for sample collection and confirm that fish specimens are performed following the Government's current laws.

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