Length-weight relationship, growth pattern and condition factor of *Glossogobius giuris* caught from coastal areas in the Mekong Delta

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Abstract. The present study contributes with data on length-weight relationship, growth pattern and condition factor of *Glossogobius giuris*, a commercial fish in the Mekong Delta, based on a collection of 600 individuals caught by gill nets from March 2016 to February 2017. As the coefficient of determination (r^2) of length-weight relationships are elevated, the weights of male and female *G. giuris* of two sizes, during two seasons and originating from three sites can be estimated from a specimen given length. The goby specimens show an isometric growth, as b (2.98±0.04 SE) is close to the corresponding thresholds. The coefficient b varies with the sex, but not with the fish size, season and site variables. Albeit the condition factor changes with sex, size, site and month: its value is significantly higher than the favorable environment threshold, suggesting that the species adapts well to the habitat. The findings supply helpful data on fish biology and ecology, useful for fishery management.
Key Words: Bac Lieu, isometric growth, Tra Vinh, Soc Trang, Vietnam.

Introduction. The fish stock assessment and management are related to the relationship of fish total length and weight (LWR) (Froese 1998). In order to determine the fish growth pattern, the slope (b) obtained from LWR is used (Froese 2006). The fish body condition factor (CF) regulated by season and propagative variables (Mahmood et al 2012; Dinh et al 2016) is used to confirm whether the fish well-being varies between species and space (Abdoli et al 2009). Meanwhile, the understanding of fish growth pattern and CF in the Mekong Delta is limited by a diversity of 58 species of gobies, often overexploited (Diep et al 2014).

The goby, *Glossogobius giuris,* is widely distributed from brackish to freshwaters in the regions from Africa to Oceania (Talwar & Jhingran 1991; Riede 2004; Froese & Pauly 2020). Its eco-biological traits in Bangladesh are documented by Islam (2004). In the Ganges, this goby species shows an isometric growth (Hossain et al 2009b), but in Haor (Khan et al 2002) and Netrakona (Saha et al 2016) it displays positive and negative allometry, respectively. Data on LWR of this species are documented by Froese (1998), Harrison (2001), Hossain et al (2009a), Garcia (2010), Que et al (2015), and Jumawan & Seronay (2017). The condition factor of this goby has been documented by Joadder (2009), Hossain & Sultana (2014), and Saha et al (2016) in Bangladesh, by Achakzai et al (2014) in Pakistan, and by Das et al (2017) in India. In Cu Lao Dung, *G. giuris* is a commercial fish and displays an isometric growth (Dinh & Ly 2014); however, this study has been performed for a short time (six months) and does not examine the variation of b (in the LWR mathematical expression) with the fish size and the study sites. Moreover, this goby species' population has been subjected to overfishing (Dinh et al 2017).

The study aimed to provide data on LWR, growth and condition factor of *G. giuris*, useful for the research on fish adaptation, sustainability management and aquaculture.

Material and Method

Study sites. The present study was performed in the mudflat and mangrove forests in Mekong Delta, covering the regions of Tra Vinh, Soc Trang and Bac Lieu (Figure 1) for 12 months, from March 2016 to February 2017. These places are represented by the semi-diurnal tide with ~1.2 m range, ~27°C annual temperature and ~8.0 pH. It rarely rains in the dry season, from January to May, but in the wet season, from June to December, there are substantial rains with a monthly precipitation of ~400 mm (Le et al 2006; Tran et al 2020).

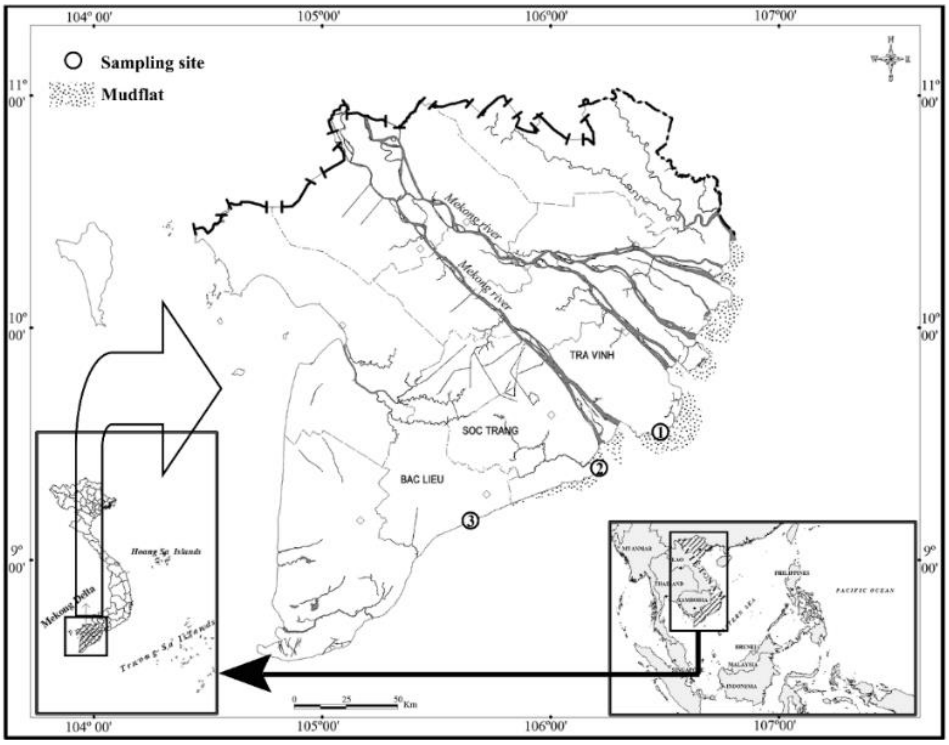

Figure 1. Sampling site map in the Mekong Delta, modified from Dinh (2018). (1-Duyen Hai, Tra Vinh; 2-Tran De, Soc Trang; 3-Hoa Binh, Bac Lieu).

Fish collection and analysis. In order to collect fish specimens, gill nets with the cod-end of mesh size 1.5 cm were used. After setting up at the highest tide for 2-3 h, the gill nets were retrieved in order to collect fish specimens described by Dinh et al (2015). Fish was identified using the external description Akihito & Meguro (1975), using papilla shape which was oval in females and triangle in males (Dinh & Ly 2014). After fixing with 5% formalin, samples were transported to the laboratory in order to measure fish total length (TL), to the nearest 0.1 cm and weight (W) to the nearest 0.01 g.

Length-weight relationship, growth pattern and condition factor determination. Data of TLs and Ws of 600 *G. giuris* were used to determine the fish length and weight relationship as $W=a\times TL^b$ (a-the regression intercept; b-the regression slope) (Ricker 1973). The condition factor was estimated as $CF=W/a\times TL^b$ (Le Cren 1951).

The fish length at first sexual maturity (TL of 8.0 cm for female and 9.2 cm for male) (Dinh et al 2018) was used to divide fish into immature and mature groups. The determination coefficient (r^2) was used to confirm the quality of the LWRs according to Metin et al (2011). The t-test as $t_s=(b-3)/s_b$ (t_s: t-test value, b: the slope, and s_b: the slope-related standard error) was used to qualify if b of males and females at different fish sizes, seasons and study sites were close to isometry or allometry (Martin 1949). The variations of CF between months and sites were quantified using 1-way ANOVA (Mahmood et al 2012). The t-test was used to test if CF varied with the gender, season and fish size, and if its values have significant differences. All tests were set at $p<0.05$.

Results and Discussion

Length-weight relationship. Dinh et al (2016) reported that both male and female *Parapocryptes serperaster* display positive relationships between TLs and Ws. Likewise, TLs of male and female *G. giuris* in two fish sizes, two seasons and three study sites had a positive relationship with Ws (Table 1), coinciding with previous studies conducted in Cu Lao Dung (Dinh & Ly 2014), Bangladesh (Khan et al 2002; Hossain et al 2009a,b; Joadder 2009; Alam et al 2013; Hossain & Sultana 2014; Roy et al 2014; Saha et al 2016), India (Kaur & Rawal 2013; Singh et al 2015; Das et al 2017), and Pakistan (Achakzai et al 2014). This assumption was also confirmed by the study of some gobies living in the Mekong Delta, e.g., *Glossogobius aureus* (Dinh 2014a) and *Boleophthalmus boddarti* (Dinh 2014b).

Growth pattern variation. The growth parameter (b) obtained from LWRs of *G. giuris* showed a monthly variation with the isometric pattern during the study period, except for a negative allometry in April and a positive allometry in October and December (Table 1). Similarly to previous studies in Atrai River (Joadder 2009), Mithamoin Haor (Hossain & Sultana 2014), and Payra River in Bangladesh (Roy et al 2014), in the present study the b of this goby varied with the gender (t-test, $p<0.05$, Table 2). This *G. giuris* does not show sexual variation in Manchar Lake, Pakistan (Achakzai et al 2014) and Cu Lao Dung, Soc Trang (Dinh & Ly 2014). However, males and males display negative allometry in Bangladesh and Pakistan (Joadder 2009; Achakzai et al 2014; Hossain & Sultana 2014; Roy et al 2014), but isometry in Cu Lao Dung (Dinh & Ly 2014) and in the present study's region of investigation. *G. giuris* males in the Ganges of Northwestern Bangladesh show allometry, whereas females show positive allometry. It seems that the gonadal developmental stage is possibly related to changes in the growth pattern of *G. giuris*, as also found in *P. serperaster* (Dinh et al 2016) and *Trypauchen vagina* (Dinh 2016b), but not in *G. aureus* (Dinh 2014a) and *Stigmatogobius pleurostigma* (Dinh 2017). The influence of gonadal developmental stage on the change of the growth pattern was also identified in *Gobius niger* in Turkey (Kalaycı et al 2007), but not *Periophthalmus barbarus* in Nigeria (King & Udo 1998; Chukwu & Deekae 2011).

The growth pattern of *G. giuris* did not vary with fish sizes ($p>0.05$, Table 2), seasons ($p>0.05$, Table 2) and study sites ($p>0.05$, Table 2), whereas this species displays a seasonal variation in Cu Lao Dung (Dinh & Ly 2014). The difference in the growth pattern of this goby species between the present and the previous study could be caused by a time limitation of six months in the previous study. *G. aureus* displays a similar growth pattern during the dry and wet seasons (Dinh 2014a), as also found in *S. pleurostigma* (Dinh 2017), but not *Periophthalmdon schlosseri* (Dinh 2016a). Similarly to *G. giuris*, *P. serperaster* (Dinh et al 2016) shows an intraspecific variation of b, whereas *T. vagina* displays a similar growth pattern between fish sizes (Dinh 2016b).

Albeit the growth pattern varied with the gender and month variables, the species in the present study displayed isometry since its b value (2.98±0.04 SE) was close to the isometric growth pattern ($n=12$, $p>0.05$). It suggested that this goby species fell into the well-being category described by Froese & Binohlan (2000), coinciding with the previous study in Cu Lao Dung (Dinh & Ly 2014) and the Ganges, Bangladesh (Hossain et al 2009a,b). By contrast, *G. giuris* shows positive allometry in Haor, Bangladesh (Khan et al 2002), Sukhna Lake, India (Kaur & Rawal 2013) and negative allometry in some regions in Bangladesh including Atrai River (Joadder 2009), Chapai Nawabganj (Alam et al 2013), Manchar Lake (Achakzai et al 2014), Mithamoin Haor (Hossain 2014), Payra River (Roy et al 2014), Netrakona (Saha et al 2016) and in two other study sites in India consisting of Pumlen Lake (Singh et al 2015) and Assam (Das et al 2017).

Table 1

The length-weight relationship and growth pattern of *Glossogobius giuris*

Sampling time	Number of fish			Sum	b	a	r^2	t_s	Growth	Condition factor
	Tra Vinh	Soc Trang	Bac Lieu		Mean±SE	Mean±SE				Mean±SE
March-16	-	3	15	18	3.19±0.13	0.005±0.002	0.97	1.45	Isometry	1.01±0.03[c,d]
April-16	20	26	8	54	3.25±0.08	0.005±0.001	0.97	3.29	Positive allometry	1.01±0.01[c,d]
May-16	-	9	36	45	3.00±0.08	0.008±0.001	0.97	0.00	Isometry	0.97±0.01[b,c]
June-16	-	1	23	24	2.86±0.11	0.009±0.002	0.97	-1.22	Isometry	0.87±0.02[a]
July-16	-	-	65	65	3.00±0.11	0.008±0.002	0.92	0.00	Isometry	0.98±0.02[b,c]
August-16	-	7	16	23	2.92±0.11	0.009±0.002	0.96	-0.71	Isometry	0.91±0.03[a,b]
September-16	6	50	42	98	3.10±0.06	0.006±0.001	0.97	1.74	Isometry	0.97±0.01[b,c]
October-16	3	34	13	50	2.79±0.07	0.012±0.002	0.97	-3.00	Negative allometry	0.98±0.02[b,c]
November-16	9	15	87	111	2.88±0.14	0.011±0.003	0.80	-0.87	Isometry	1.08±0.01[d]
December-16	20	27	25	72	2.85±0.07	0.011±0.002	0.96	-2.10	Negative allometry	1.00±0.01[b,c,d]
January-17	2	12	46	60	3.07±0.06	0.007±0.001	0.98	1.16	Isometry	1.05±0.01[c,d]
February-17	-	9	31	40	2.89±0.16	0.010±0.004	0.90	-0.70	Isometry	1.04±0.02[c,d]

Different letters (a, b, c, and d) showed significant differences in condition factor between months.

Table 2

The length-weight relationship, growth pattern and condition factor of male and female *Glossogobius giuris*

Fish groups		Number of fish	b	a	r^2	Condition factor
			Mean±SE	Mean±SE		Mean±SE
Gender	Male	297	2.94±0.04[a]	0.009±0.001	0.95	0.99±0.01[a]
	Female	363	3.06±0.04[b]	0.007±0.001	0.93	1.02±0.01[b]
Fish size	Immature	502	2.97±0.03[a]	0.008±0.001	0.84	1.00±0.01[a]
	Mature	158	2.70±0.26[a]	0.016±0.009	0.96	1.03±0.01[b]
Season	Dry	217	3.03±0.04[a]	0.005±0.001	0.97	1.00±0.01[a]
	Wet	443	2.95±0.04[a]	0.009±0.001	0.94	1.01±0.01[a]
Study area	Tra Vinh	60	2.99±0.04[a]	0.008±0.001	0.99	1.02±0.01[a]
	Soc Trang	193	2.99±0.04[a]	0.008±0.001	0.96	0.96±0.01[b]
	Bac Lieu	407	2.97±0.05[a]	0.009±0.001	0.91	1.02±0.01[a]

Different letters (a and b) between b and the condition factor in each category (genders, fish sizes, seasons and sites) showed significant differences.

The regional changes in the growth pattern suggested that the growth pattern of this species could be strongly related to the study regions, which was found in *P. schlosseri* since its b is <3 in Bangladesh (Saha 2013), but ~3 in Malaysia (Khaironizam & Norma-Rashid 2002) and Vietnam (Dinh 2016a). Like *G. giuris*, *P. serperaster* (Dinh et al 2016), *P. schlosseri* (Khaironizam & Norma-Rashid 2002; Dinh 2016a) and *T. vagina* (Dinh 2016b) also showed isometry, whereas *Periophthalmus argentilineatus* and *Periophthalmus spilotus* in Malaysia displayed positive allometry (Khaironizam & Norma-Rashid 2002) and *P. schlosseri* in Bangladesh (Saha 2013), *G. aureus* (Dinh 2014a) and *S. pleurostigma* (Dinh 2017) in Mekong Delta presented a negative allometry.

Condition factor variation. The species displayed a monthly variation in CF with the highest point in November and the lowest in June (ANOVA, p<0.001, Table 1). The goby *P. serperaster,* according to the study of Dinh et al (2016), shows a strong relationship between the condition factor and the gonadal developmental stage because of a lower CF in males during the wet season. Similarly, the CF of *G. giuris* was higher in females than males (t-test, p<0.05, Table 2), suggesting that CF could be regulated by the gonad developmental stage. By contrast, the CF of male *G. giuris* does not significantly differ from females observed in Atrai River, Bangladesh (Joadder 2009), Mithamoin Haor, Bangladesh (Hossain & Sultana 2014), Manchar Lake, Pakistan (Achakzai et al 2014) and Netrakona, Bangladesh (Saha et al 2016). Conversely, the CF of some other gobies of the family Gobiidae such as *P. barbarus* (King & Udo 1998; Chukwu & Deekae 2011) in Nigeria and *S. pleurostigma* in Mekong Delta (Dinh 2017) are not affected by genders.

When studying *G. giuris* caught from Mithamoin Haor, Bangladesh, Hossain & Sultana (2014) reported that their CF showed intraspecific variation due to the differences between fish size groups. The CF of *G. giuris* in the present study also varied with the fish size, due to a higher CF in mature fish (p<0.05, Table 2), suggesting that larger fish could adapt better to the habitat than smaller fish. Moreover, the CF of this species could show spatial variation, due to differences between the study sites, but not seasonal change, due to similarities between the seasons. Likewise, the CF of *P. serperaster* (Dinh et al2016), *P. schlosseri* (Dinh 2016a) and *T. vagina* (Dinh 2016b) did not vary with fish sizes.

The CF of this goby species was not significantly different between the dryand wet seasons (p>0.05, Table 2), but it was lower in Soc Trang than in Tra Vinh and Bac Lieu (ANOVA, p<0.001, Table 2). Although the CF of the species varied with genders, fish sizes, months and study sites, the CF of all fish (1.00±0.01 SE, n=660) was near to one (t-test, p>0.05). The change of CF of male and female *G. giuris* depended on the study sites (ANOVA, p<0.001) but not on the fish sizes (p>0.05) and seasons (p>0.05). Although the CF varied with the month, gender, fish size and site, its values indicated a favorable environment (CF values near 1), suggesting a satisfactory condition of this species in the studied regions. This assumption coincided with some previous studies of this gobiid species, observed in Bangladesh (Joadder 2009; Alam et al 2013; Hossain & Sultana 2014; Saha et al 2016), Pakistan (Achakzai et al 2014) and India (Das et al 2017). Similarly, some co-occurring gobies such as *P. serperaster* (Dinh et al 2016), *T. vagina* (Dinh 2016b) and *S. pleurostigma* (Dinh 2017) also adapt well to habitat, as the CF of these three species is near to the standard threshold of 1. The variation of CF in males and females did not depend on the seasons and study regions, indicating that the variety of food resources in the study site could not influence the growth of *G. giuris*, which was also found in *S. pleurostigma* living in the same habitat (Dinh 2017). The changes in the CF of *T. vagina* (Dinh 2016b) and *P. barbarus* (King & Udo 1998; Chukwu & Deekae 2011) is not affected by the seasonal environmental changes, whereas the variation of CF in male and female *P. serperaster* depends on the season variable, due to the change of food resource in the environment in the dry-wet season pattern (Dinh et al 2016).

Conclusions. *G. giuris* showed an isometric growth. The growth pattern of this goby species displayed sexual variation but not intraspecific, seasonal and spatial changes. The condition factor of this goby varied with the genders, fish sizes, sites and months (instead of seasons), but this parameter was closed to 1, suggesting that the species lived in a favorable condition for growth. Males and females at the different fish sizes, in the dry-wet season pattern fed actively during both the diurnal and nocturnal periods. The present study contributed to the enhancement of the biological data on this goby species, usable for the fish sustainable management and in aquaculture.

Acknowledgements. The authors are grateful to the fishermen for supporting the sampling efforts.

Conflict of interest. The authors declare no conflict of interest.

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Received: 19 March 2021. Accepted: 17 May 2021. Published online: 01 June 2021.
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How to cite this article:
Phan G. H., Linh L. T. T., Dinh Q. M., Truong N. T., Nguyen T. H. D., 2021 Length-weight relationship, growth pattern and condition factor of *Glossogobius giuris* caught from coastal areas in the Mekong Delta. AACL Bioflux 14(3):1478-1485.