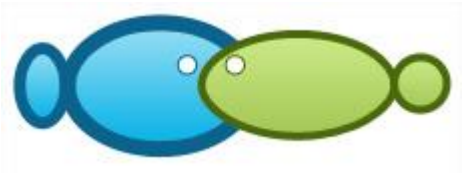

The intraspecific and spatio-temporal variations in relative gut length and gastro-somatic indexes of *Glossogobius sparsipapillus* in the Mekong Delta, Vietnam

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Abstract. The study provides data on the feeding habits and intensity of *Glossogobius sparsipapillus*, a potential candidate for aquaculture, by analyzing the relative gut length (RGL) and gastro-somatic (GaSI) indexes. Samples of 661 *G. sparsipapillus* individuals (331 males and 330 females) were collected using gill nets in estuarine regions, ranging from Hoa Binh to Dong Hai and Dam Doi, in the Mekong Delta from December 2019 to November 2020. The analyzed results show that the *G. sparsipapillus'* RGL changes with the fish size, gender, season, month and site variables, indicating that the goby's feeding habit displays sexual, intraspecific and spatio-temporal variations. Males and females at different fish sizes, seasons, months, and sites fall into the carnivorous category, since RGLs are significantly lower than the threshold of 1. Like the RGL, the *G. sparsipapillus*' GaSI varies between genders, fish sizes, seasons, months and sites, suggesting intraspecific and spatio-temporal variations in both males' and females' feeding intensity. The *G. sparsipapillus*' feeding habit is not regulated by the interactions fish size × site, fish size × season and site × season. The feeding intensity of this species is influenced by the fish size × site and fish size × season combinations of factors, but not to by the site × season combination. This contribution to the knowledge on *G. sparsipapillus*' feeding habit and intensity supports a better understanding of the species' adaption and aquaculture in the study region.
Key Words: carnivore, feeding habit, feeding intensity, gastro-somatic index, relative gut length.

Introduction. With 29 species, *Glossogobius* is known as one of the largest genera of Gobiidae reported by Hoese et al (2015), but only three species have been recorded in the Mekong Delta, Vietnam stated by Tran et al (2013): *Glossogobius giuris*, *Glossogobius aureus*, and *Glossogobius sparsipapillus*. *G. sparsipapillus* (Akihito & Meguro 1976) is widely distributed from brackish to freshwater in Africa, Asia, and Oceania regions (Rainboth 1996; Froese & Pauly 2020), including Vietnam (Dinh 2009; Tran et al 2013; Nguyen et al 2019; Nguyen et al 2020b; Tran et al 2020a), displaying negative allometrics (Dinh 2015) and showing a spatiotemporal morphometric variation (Nguyen et al 2020b). It is a multiple spawner and spawns throughout the year, with the main peak from July to October (Nguyen et al 2019; Ho et al 2020; Nguyen et al 2020a). *G. sparsipapillus* is a commercial fish for food supply (Diep et al 2014; Nguyen & Dinh 2020), being subjected to overfishing. The knowledge on the diet and feeding ecology of this species is inadequate.

The relative gut length (RGL) is helpful for feeding habit determination (Al-Hussaini 1947), and the gastro-somatic index (GaSI) is used to examine the feeding intensity (Desai 1970). Therefore, this study aimed to provide new knowledge on RGL and GaSI, and on the variation of these two indexes, in the studied species, with the fish size, place, season and month. The results will help understand the fish feeding habit and intensity, being used to evaluate the fish adaption and aquaculture.

Material and Method

Fish collection and analysis. The present study was conducted in three locations from Hoa Binh, Bac Lieu (HBBL, 9°12'24.8 "N 105°42'54.9 "E) to 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). *Avicennia marina* and *Sonneratia caseolaris* were the two types of dominant vegetation. These three sites are characterized by tremendous tidal flats, semidiurnal tides, ~27°C annual temperature and ~8.0 pH, no rain in the dry season (January–May), but substantial showers with ~400 mm monthly precipitation in the wet one (June–December) (Le et al 2006; Tran et al 2008; Tran et al 2020b).

Fish specimens were collected monthly, from December 2019 to November 2020, using gill nets with a mesh of 1.5 cm. After being set at the high tide, in each study site, the gill nets were retrieved to catch the fish and this activity was performed for 48 h (Dinh et al 2015). After the species identification using Akihito & Meguro (1975) external description, the selected fish specimens were fixed in 5% formalin to be transported to the laboratory.

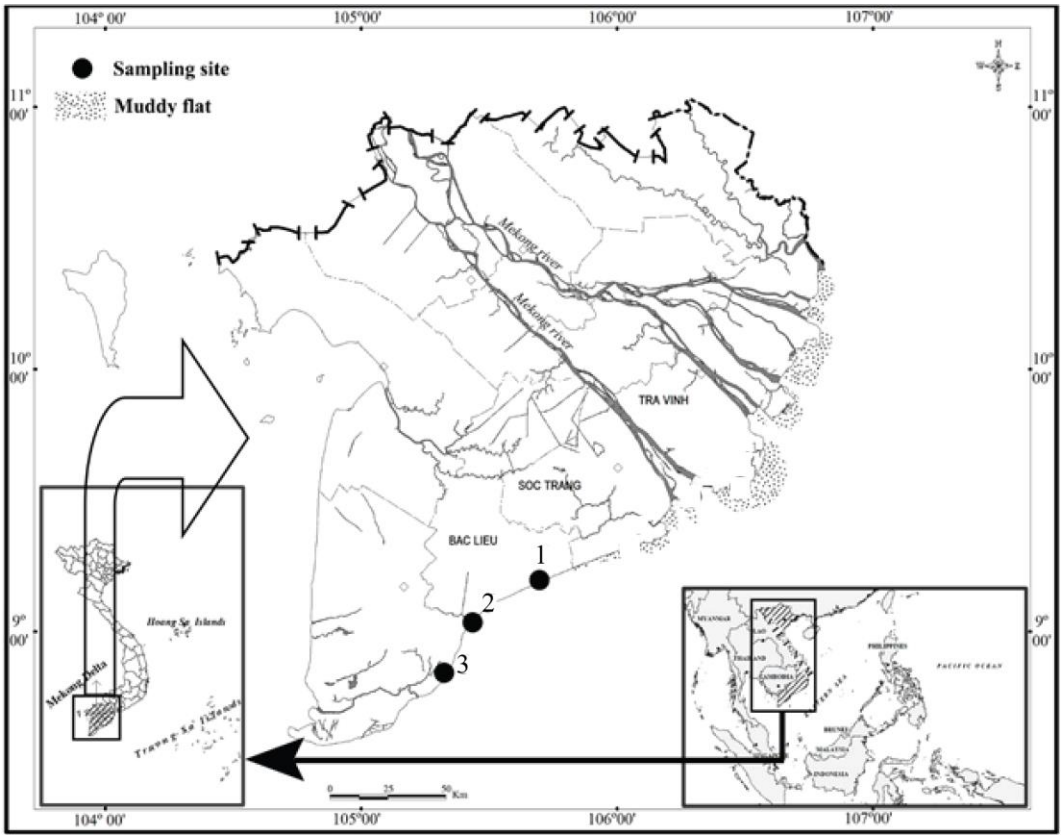

Figure 1. The sampling map along the coastline in the Mekong Delta (modified from Dinh 2018) (• sampling area; 1: Vinh Hau, Hoa Binh, Bac Lieu; 2: Dien Hai, Dong Hai, Bac Lieu; 3: Tan Thuan, Dam Doi, Ca Mau).

Specimens' sex is determined by the genital spines' morphology (oval shape in female, triangle shape in male) (Dinh 2015). The weight (W) and length (TL) of the samples were determined, before removing the digestive tracts, (with a precision of 0.01 g and 0.1 cm, respectively). The length (L_g) and weight (Wg) of the tracts were also measured in order to determine the relative gut length (RGL) and the gastrosomatic index (GaSI). The RGL was estimated as the ratio L_g/TL (where L_g is the gut length and TL is the fish total length) in order to determine the feeding habit, according to the distinction between carnivores (RGL<1.0), omnivores (RGL=1.0-3.0) and herbivores (RGL>3.0) (Al-Hussaini 1947). The GaSI, calculated as (W_g/W)*100 (with W_g is the gut weight and W is the fish body weight), was used to determine the feeding intensity (Desai 1970).

Data analysis. A one-way ANOVA test ws used to quantify the variations of RGL and GaSI with sites and months. The changes in RGL and GaSI between genders and seasons were examined through a t-test. A General Linear Model was used to test the interaction of fish size, season and place effects on the RGL and GaSI changes. Significant differences from 1 in the RGL (of *G. sparsipapillus* males and females at different sizes, sites, seasons and months) were confirmed by using a t-test. Fish sizes were divided into two groups (immature and mature) based on the fish length at first maturity at each sampling site, by gender. In males, it was 6.8, 8.7 and 6.9 cm at HBBL DHBL and DDCM, respectively, while in females it was 6.1, 7.2 and 8.9 cm at HBBL DHBL and DDCM, respectively (Nguyen et al 2020a). The SPSS software v21 was used for data analyses. The significance level for all tests was set at $P<0.05$.

Results and Discussion

The relative gut length and feeding habit. A total of 661 fish specimens (331 males and 330 females) was collected from three sites during the dry and wet seasons and recorded in Table 1.

Table 1

The number of *Glossogobius sparsipapillus* caught from the three sampling sites

Sampling time	*Vinh Hau, Hoa Binh, Bac Lieu*		*Dien Hai, Dong Hai, Bac Lieu*		*Tan Thuan, Dam Doi, Ca Mau*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
Dec-19	16	8	7	2	13	2
Jan-20	3	5	5	11	8	5
Feb-20	10	12	26	18	14	16
Mar-20	15	7	8	6	6	1
Apr-20	6	4	15	11	18	6
May-20	4	11	6	18	10	11
Jun-20	5	3	10	10	11	13
Jul-20	3	6	10	10	12	10
Aug-20	7	5	15	15	10	17
Sep-20	9	8	5	8	7	9
Oct-20	5	13	7	16	3	8
Nov-20	10	9	10	6	2	10
Sum	93	91	124	131	114	108

Data analysis showed that the relative gut length index (RGL=0.43±0.00 SE) of the *G. sparsipapillus* was significantly lower than 1 (t-test, $P>0.05$). This also confirms that the species is carnivorous, like some other gobiid species in the Mekong Delta, e.g. *Eleotris melanosoma* (Dinh et al 2017a). There are also omnivore species living in the Mekong Delta, including the *Pseudapocryptes elongatus* (Tran et al 2008), *Parapocryptes serperaster* (Dinh et al 2017b), and *Stigmatogobius pleurostigma* (Dinh et al 2018).

Different patterns of the RGL of the *G. sparsipapillus* among two fish size groups (t-test, $P<0.05$) (Figure 2) suggest that this species' feeding habit shows an ontogenetic variation. The feeding habit of the *P. serperaster* living in the Mekong Delta changed with the fish size (Dinh et al 2017b). The feeding habit of *G. sparsipapillus* displayed a spatial variation, reaching the highest point in Dien Hai, Dong Hai, Bac Lieu (0.45±0.01 SE; ANOVA, $P<0.05$) (Figure 3). A temporal change of the feeding habit was also found in this mudskipper species, because the monthly values of the RGL displayed significant differences during the 12-month study, reaching the highest point in October (0.49±0.05 SE) and the lowest point in April (0.37±0.04 SE), as determined by the ANOVA test ($P<0.05$) and showed in Figure 4. The feeding habit of *G. sparsipapillus* changed with seasons, as the RGL in the dry season (0.40±0.00 SE) was lower than in the wet season (0.46±0.01 SE; t-test, $P<0.05$). However, both males and females fall into the carnivorous fish class, since the RGL was significantly lower than one (t-test, $P>0.05$ for

all cases). The RGL was not influenced by the interactions of fish size and place or fish size and season (ANOVA, P>0.05 for all cases), showing that these combinations of factors did not influence the variation of the studied specimens' feeding habit. However, the RGL was influenced by the interaction between place and season (ANOVA, P<0.05), showing that this combination of factors influenced the studied specimens' feeding habit.

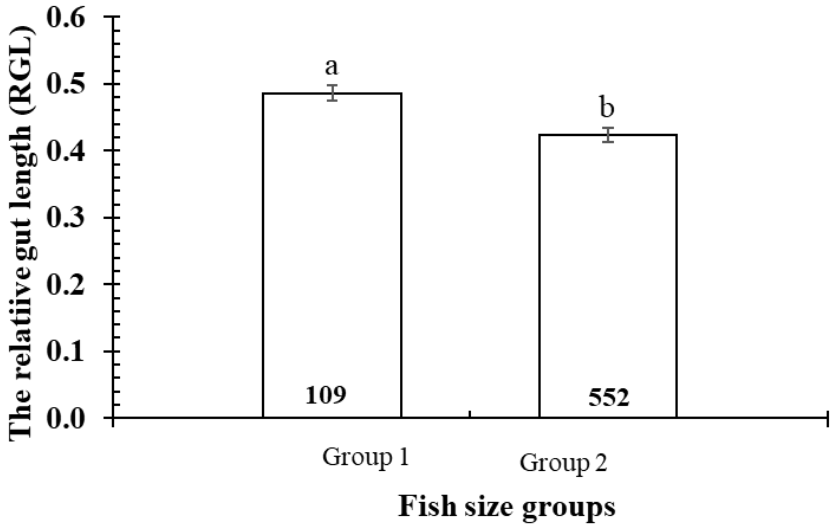

Figure 1. The variation in RGL of *Glossogobius sparsipapillus* among the two fish size groups (group 1: immature, group 2: mature; the numbers in each column represent the specimens in each fish size group; the vertical bar is the standard error of the group mean; the different letters (a and b) represent the significant differences of RGL between two fish sizes).

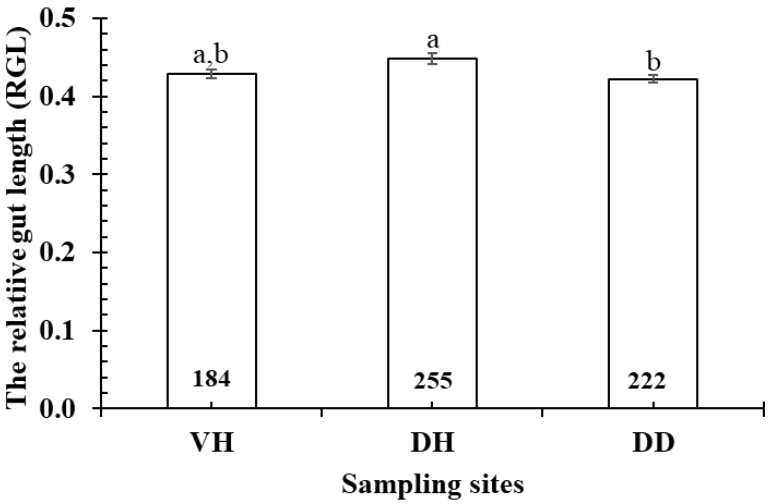

Figure 2. The variation in RGL of *Glossogobius sparsipapillus* among the three sampling sites (VH: Vinh Hau, Hoa Binh, Bac Lieu; DH: Dien Hai, Dong Hai, Bac Lieu; TT: Tan Thuan, Dam Doi, Ca Mau; the numbers in each column represent the number of specimens in each site; the vertical bar is the standard error of mean; the different letters (a and b) represent the significant differences of RGL among the three sampling sites).

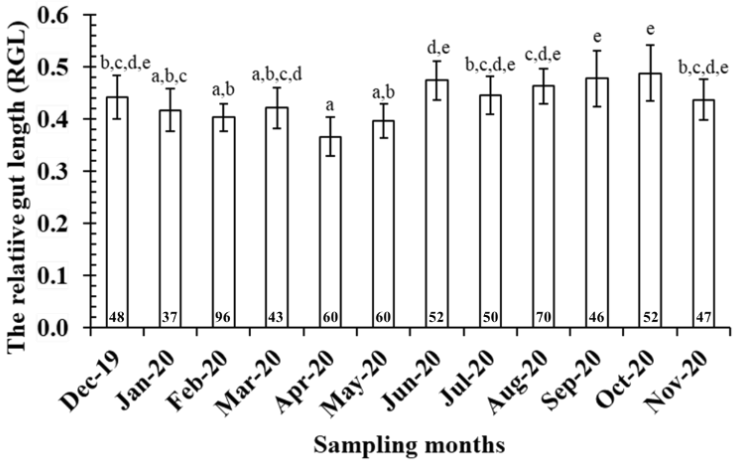

Figure 3. The variation in RGL of *Glossogobius sparsipapillus* among the 12 months (the numbers in each column represent the number of specimens in each fish size group; the vertical bar is the standard error of the group mean; the different letters (a, b, c, d, and e) represent the significant differences of RGL among 12 months).

The gastrosomatic index and feeding intensity. The *G. sparsipapillus* displayed a low feeding intensity level as the gastro-somatic index (GaSI) was 0.02±0.00 SE. The highest feeding intensity was found in *P. serperaster* (Dinh et al 2017b) and *E. melanosoma* (Dinh et al 2017a).

This species' feeding intensity shows ontogenetic variation, as the GaSI was significantly different among the two fish size groups (t-test, $P<0.05$) (Figure 4). The feeding intensity of *P. serperaster* living in the Mekong Delta did not change with the fish size (Dinh et al 2017b). The feeding intensity of *G. sparsipapillus* displayed a spatial variation, reaching the highest point in Vinh Hau, Hoa Binh, Bac Lieu (0.02±0.00 SE) and the lowest point in Dien Hai, Dong Hai, Bac Lieu (0.01±0.00 SE; ANOVA, $P<0.05$) as shown in Figure 5. It seems that the feeding intensity of *G. sparsipapillus* was related to environmental conditions.

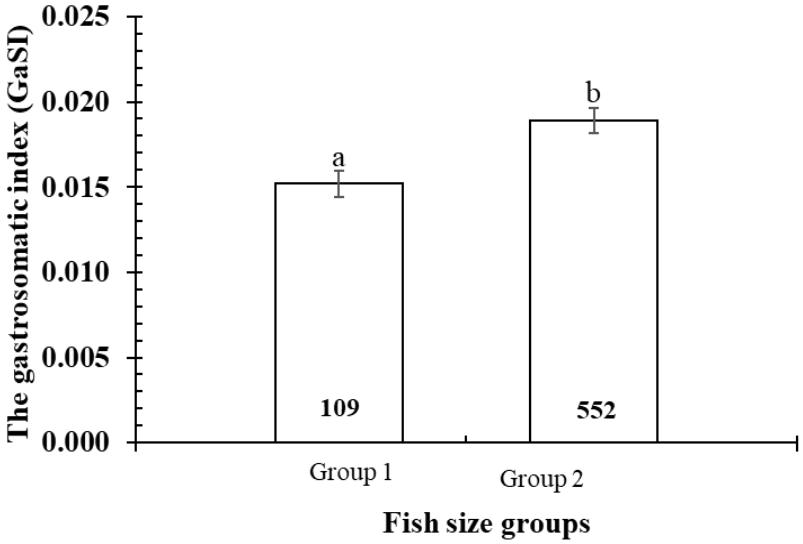

Figure 4. The GaSI variation in *Glossogobius sparsipapillus*, among the two fish size groups (group 1: immature, group 2: mature); the numbers in each column represent the specimens in each fish size group; the vertical bars are the standard error of the group mean; the different letters (a and b) represent the significant differences of GaSI between two fish sizes).

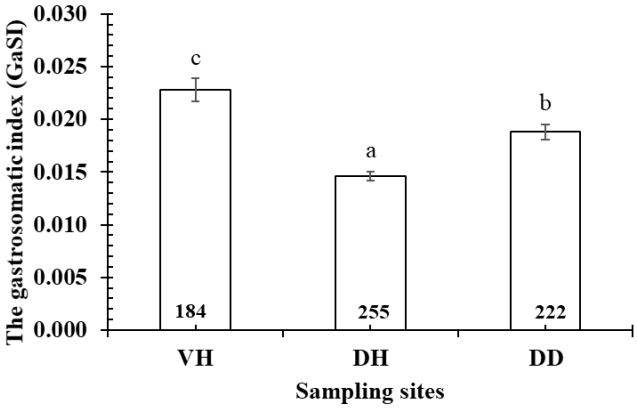

Figure 5. The variation in GaSI of *Glossogobius sparsipapillus* among the three sampling sites (VH: Vinh Hau, Hoa Binh, Bac Lieu; DH: Dien Hai, Dong Hai, Bac Lieu; TT: Tan Thuan, Dam Doi, Ca Mau); the numbers in each column represent the specimens of fish in each site; the vertical bars are the standard error of the group mean; the different letters (a and b) represent the significant differences of GaSI among the three sampling sites.

A monthly change in the feeding intensity was found in *G. sparsipapillus* (significant differences in the GaSI during the 12-month study), reaching the highest point in December (0.03±0.00 SE) and the lowest point in April (0.01±0.00 SE; ANOVA, $P<0.05$), as shown in Figure 6. Similarly, a feeding intensity change with the month was also found in *P. serperaster* in the Mekong Delta (Dinh et al 2017b). The GaSI of *G. sparsipapillus* in the dry season (0.01±0.00 SE) was lower than in the wet season (0.02±0.00 SE, t-test, $P<0.05$), suggesting that the feeding intensity of this goby changed with the season. It seems that the difference in the precipitation patterns between the dry and wet seasons regulated the feeding intensity of *G. sparsipapillus* and the rainy season has a higher concentration of prey, due to a higher diversity than in the dry season, which influenced the feed rate. This assumption was also verified for *P. serperaster* in the Mekong Delta (Dinh et al 2017b), but not in *E. melanosoma* (Dinh et al 2017a) and *S. pleurostigma* (Dinh & Tran 2018). The change of feeding habit of this fish species was not influenced by the interaction of fish size × place, fish size × season and site × season, since the GaSI did not change with these combinations of factors (ANOVA, $P>0.05$ for all cases).

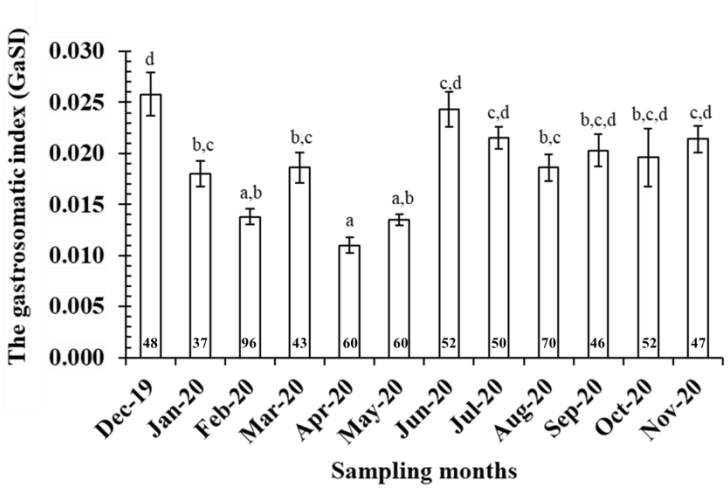

Figure 6. The GaSI variation in *Glossogobius sparsipapillus* among the 12 months; the numbers in each column represent the fish specimens in each month; the vertical bars are the standard error of the group means; the different letters (a, b, c and d) represent the significant differences of GaSI among 12 months).

Conclusions. The study showed that the feeding habit of *G. sparsipapillus* did not change with the sex, but varied according to the place, month, size and season. Both males and females, no matter the sizes, location, month and season, fall into the carnivorous class. This species' feeding intensity did not change with the sex, but displayed intraspecific and spatio-temporal variations. The feeding intensity was not regulated by the interactions: fish size × place, fish size × season and site × season. The feeding habits changes were not regulated by the combinations fish size × place and fish size × season, but only by the combination place × season. These results bring new evidence for understanding fish adaption and conservation in the study region.

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

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