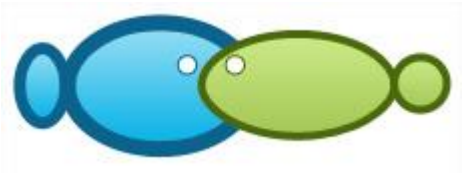

Factors affecting relative gut length and fullness index of *Glossogobius giuris* living along Hau River, Vietnam

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Abstract. *Glossogobius* is one of the largest genera of the family Gobiidae with 29 species. Of them, three species including *G. giuris*, *G. aureus,* and *G. sparsipapillus* have been considered important species in the Mekong Delta, Vietnam. Until now, the systematic study of these species has been limited. This study aims to provide new knowledge on relative gut length (RGL) and fullness index (FI), and on the variation of these two indexes with sex, size, site and season. The experiment was carried out from January to December 2020 at four provinces in the Mekong Delta: Can Tho, Soc Trang, Bac Lieu, and Ca Mau. 1291 specimens (659 females and 632 males) were captured. Data analyses show that the goby belongs to the carnivorous category as the RGL is lower than 1. There is a variation of RGL and FI between two biometric indexes and saturation coefficient of *G. giuris*. This variation depends not only on the genotype of the fish but also on environmental conditions such as season and site. There are no differences of RGL and FI between females and males, and immature and mature fish, except for FI, where differences are observed between immature and mature individuals. There are significant differences in RGL and FI between seasons. The RGL had a maximum value in the wet season, while the FI had a high value in the wet season. The RGL varies from one site to another. The maximum value is at Dam Doi, Ca Mau province and lower values are observed for fish from Cai Rang, Can Tho and Hoa Binh, Bac Lieu province. The FI value varies from the maximum value in Cai rang, Can Tho to a minimum value in Long Phu, Soc Trang province. The variations of RGL and FI of this fish are regulated by sex x site, and season x site interactions. The findings help better understand the fish feeding habitat and intensity, being used to evaluate the fish adaption.
Key Words: Bac Lieu, Ca Mau, Can Tho, carnivores, Mekong Delta, Soc Trang.

Introduction. *Glossogobius*, according to Hoese et al (2015), is one of the largest genera of the family Gobiidae with 29 species. Only three species, *G. giuris*, *G. aureus,* and *G. sparsipapillus* have been recorded in the Mekong Delta, Vietnam (Tran et al 2013; Tran et al 2020a; Tran et al 2021). The species *G. giuris* is widely distributed from brackish waters to freshwaters in the Indo-Pacific regions (Talwar & Jhingran 1991; Riede 2004; fishbase.org) including the Mekong Delta (Dinh 2008; Dinh et al 2009; Dinh 2011; Tran et al 2013; Tran et al 2020b). The eco-biology of *G. giuris* in Bangladesh is documented by Islam (2004). The species spawns twice a year (in March and from June to October) in Mithamoin Haor, Bangladesh, as demonstrated by Hossain (2014), but only once a year in October in the middle of Hau River catchment, Vietnam, as reported by Pham & Tran (2013). Likely, this goby spawns once yearly in September in the Payra River, Bangladesh (Roy et al 2014) and in March in Pakistan (Qambrani et al 2016). The goby is carnivorous, ingesting primarily small fish and crustaceans in Mithamain Haor, Bangladesh (Hossain et al 2016). It is a target candidate for fishing (Hossain & Sultana 2014; Qambrani et al 2016). This species plays an important role in the food supply in the Mekong Delta, leading to overfishing in the area (Dinh et al 2017a; Nguyen & Dinh

2021; Phan et al 2021; Dinh et al 2021a). However, its feeding habits and intensity are still fragmented.

The relative gut length (RGL) is helpful for feeding habits determination (Al-Hussaini 1947), and the fullness index (FI) is used to examine the feeding intensity (Desai 1970). Therefore, this study aimed to provide new knowledge on RGL, FI and the variation of these two indexes of *G. giuris* according to sex, size, site and season. The results will help better understand the fish feeding habitat and intensity, being used to evaluate the fish adaption.

Material and Method

Study sites. This study was conducted along the Hau River in Mekong Delta from Cai Rang, Can Tho (CRCT) to Long Phu, Soc Trang (LPST), Hoa Binh, Bac Lieu (HBBL), and Dam Doi, Ca Mau (DDCM) (Figure 1), from January 2020 to December 2020. These regions are represented by a semi-diurnal tide range of ~1.2 m, temperature of ~27°C, and pH of ~8. The salinity was ~12 ‰ in LPST and zero in CRCT. It rarely rains in the dry season (January–May), while heavy rainfalls occur in the wet season (June–December), with monthly precipitation of 400 mm, typical for the natural environment of the Mekong Delta (Le et al 2006; Tran et al 2020b; Dinh et al 2021b).

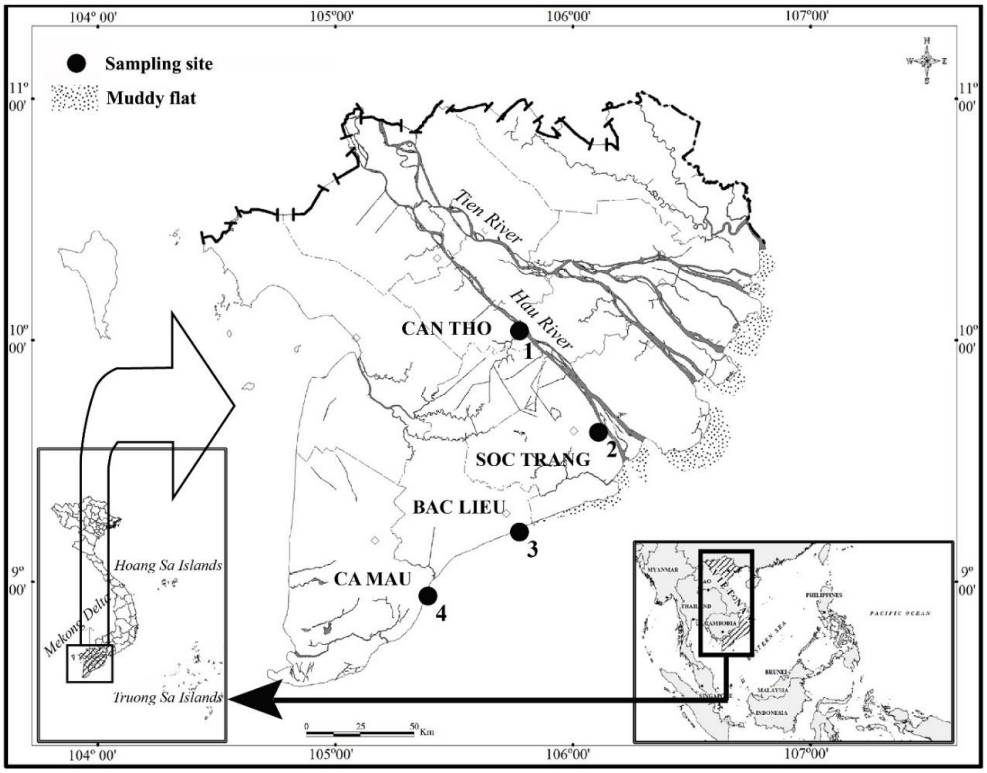

Figure 1. The sampling site in the Mekong Delta (1 - Cai Rang, Can Tho; 2 - Long Phu, Soc Trang; 3 - Hoa Binh, Bac Lieu; 4 - Dam Doi, Ca Mau). This figure was modified from Dinh (2018) with permission.

Fish collection and analysis. Fish specimens were collected monthly using trawl nets with 1.5 cm mesh aperture in the cod-end. In each study site, the nets were set at the highest tide along the mudflat and mangrove forest and retrieved after 2–3 h during an ebb to collect fish specimens based on the method described by Dinh et al (2015). After identification based on the external description (Tran et al 2013), fish were sexed using the external morphology of the urogenital papilla, which has an oval shape in females and a triangle shape in males (Dinh 2014; Dinh & Ly 2014). The fish were stored in 5% formalin and transported to the laboratory. In the laboratory, the total length (TL) and

weight (W) were measured with a precision of 0.1 cm and 0.01 g, respectively, before removing the intestinal tract.

Feeding habit and intensity. The RGL was used to estimate the feeding habit of fish, herbivores having a RGL higher than 3, while the RGL is lower than 1 for carnivores, or between 1 and 3 for omnivores (Al-Hussaini 1947). According to this method, the length of the intestinal tract of 1291 *G. giuris* (Table 1) was measured (0.1 cm accuracy) in order to calculate the RGL as the ratio of the gut length to the fish TL. The alimentary tracts of 689 *G. giuris* with stomach contents (Table 1) were weighed (0.01 mg accuracy) to calculate the gut fullness index as:

$FI=100\times W_i/W$

Where: FI is gut fullness index, W_i is the weight of stomach and W is fish body weight (Bakhoum & Faltas 2003).

Data analysis. The variations of RGL and FI within sites were qualified by one-way ANOVA, and the changes of RGL and FI according to sex and season were examined by t-test. A General Linear Model was used to test the interaction of fish size, season and site effects on the RGL and FI changes. The t-test was also used to verify if RGL of sex, size, season, and site were close to 1. The fish size was divided into two groups (immature and mature) based on the fish length at first maturity at each sampling site, by gender. The males were the first to mature, at 7.24, 7.18, 7.43, and 6.57 cm TL in CRCT, LPST, HBBL, and DDCM, respectively (Dinh et al 2021c). Female length at first maturity was 6.14, 4.82, 5.59, and 5.85 cm TL in CRCT, LPST, HBBL, and DDCM, respectively (unpublished data). The SPSS software v21 was used for data analyses. The significance level for all tests was set at $p<0.05$.

Results and Discussion

Feeding habit. Data analysis of 1,291 individuals (Table 1) showed that *G. giuris* fell into the carnivorous category as the RGL was 0.4±0.00 SE (<1, t-test, $p<0.001$).

Table 1

The number of *Glossogobius giuris* individuals caught from the four sites

Months	*Number of fish*	*Number of individuals without food in the digestive tract*	*Number of individuals with food in the digestive tract*	*Percentage of the digestive tract that did not contain food*
Jan-20	95	68	27	71.58
Feb-20	145	58	87	40.00
Mar-20	111	41	70	36.94
Apr-20	121	48	73	39.67
May-20	118	64	54	54.24
Jun-20	99	47	52	47.47
Jul-20	115	43	72	37.39
Aug-20	99	58	41	58.59
Sep-20	112	59	53	52.68
Oct-20	83	39	44	46.99
Nov-20	103	39	64	37.86
Dec-20	90	38	52	42.22

The RGLs of females *G. giuris* (0.41±0.01, n=659) was not significantly different from that of males (0.40±0.01, n=632) (t-test, t=1.64, p=0.10, Figure 2). Likewise, the RGL of the immature fish group (0.41±0.01, n=406) was not significantly different from the mature fish group (0.40±0.01, n=885) (t=0.79, p=0.43, Figure 3), but the value in the wet season (0.41±0.01, n=701) was higher than in the dry season (0.39±0.01, n=590)

(t=-4.79, p<0.001, Figure 4). At DDCM, the RGL had the highest value (0.43±0.01, n=375), followed closely by LPST (0.41±0.01, n=300), while the lowest values were observed in HBBL (0.39±0.01, n=306) and CRCT (0.38±0.01, n=310) (one-way ANOVA, F=22.79, p<0.001, Figure 5). The RGL of *G. giuris* was regulated by interactions: sex × site, season × site (General Linear Model, p<0.01 for two cases), but not sex × season (p=0.09). In general, RGL of males and females in two fish groups, seasons and sites were significantly lower than a threshold of 1 (t-test, p<0.001 for all cases), showing that this goby belonged to a carnivorous fish group. The RGL index can classify the feeding habits of fish (Xie et al 2001; Hernaman et al 2009). In the present study, *G. giuris* fell into the carnivorous fish category. Another study in Mithamain Haor, Bangladesh, also found that *G. giuris* is a carnivorous fish (Hossain et al 2016). Some other gobies living in the Mekong Delta are also carnivores, like *G. aureus* (Nguyen & Tran 2018), *P. septemradiatus* (Dinh et al 2018), *B. koilomatodon* (Nguyen et al 2020), and *G. sparsipapillus* (Tran et al 2021). Conversely, some other fish species with omnivorous habits also live in this area, like *P. elongatus* (Tran 2008) and *P. serperaster* (Khaironizam & Norma-Rashid 2000; Dinh et al 2017b).

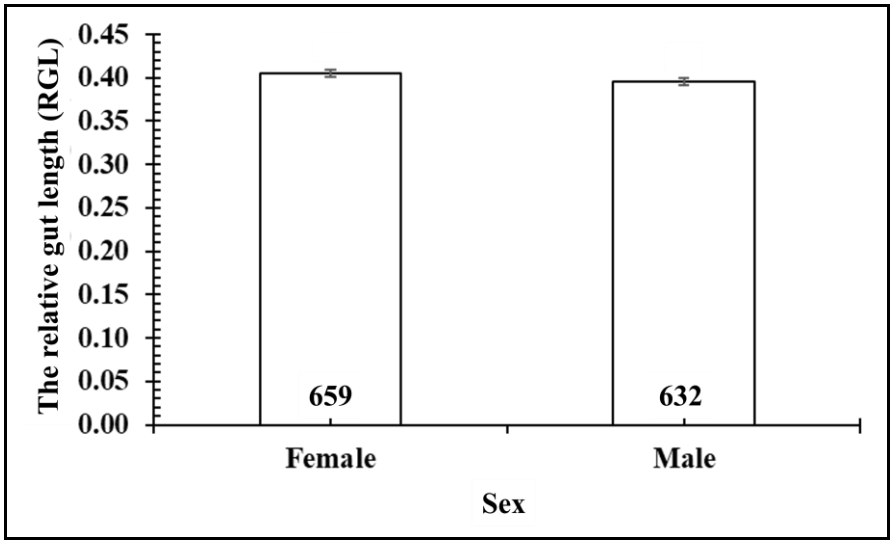

Figure 2. The variation in the relative gut length of *Glossogobius giuris* based on sex; the vertical bars represent the standard error of the group mean.

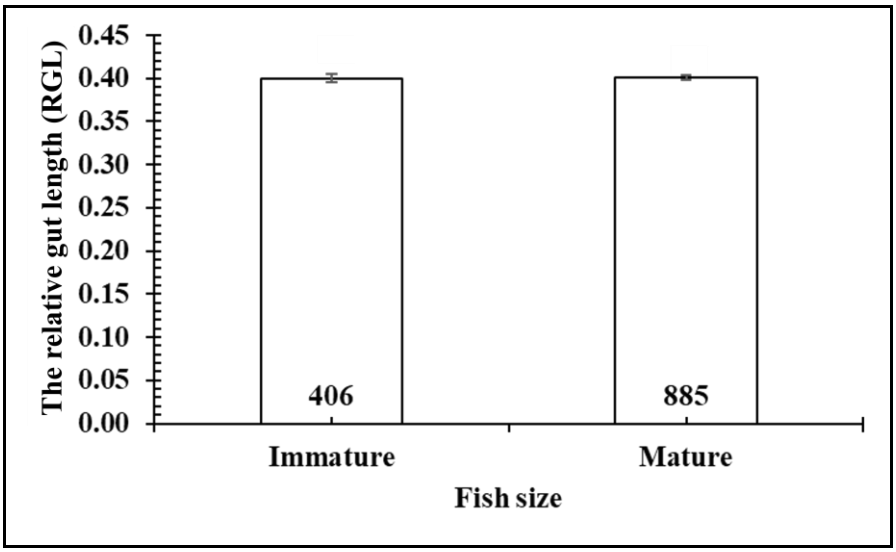

Figure 3. The variation in the relative gut length of *Glossogobius giuris* between the two sizes; the vertical bars represent the standard error of the group mean.

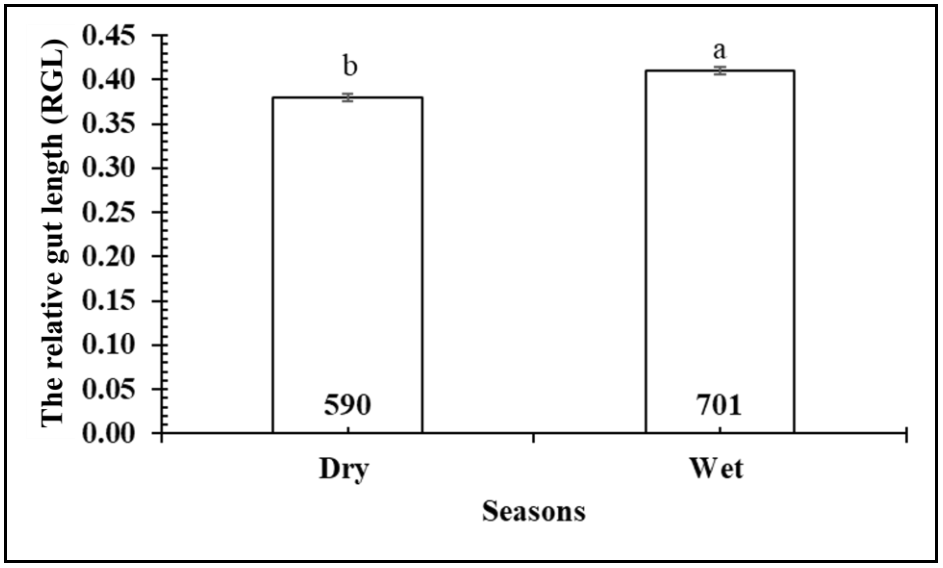

Figure 4. The variation in the relative gut length of *Glossogobius giuris* among the two seasons; the vertical bars represent the standard error of the group mean; different letters show significant differences ($p<0.05$).

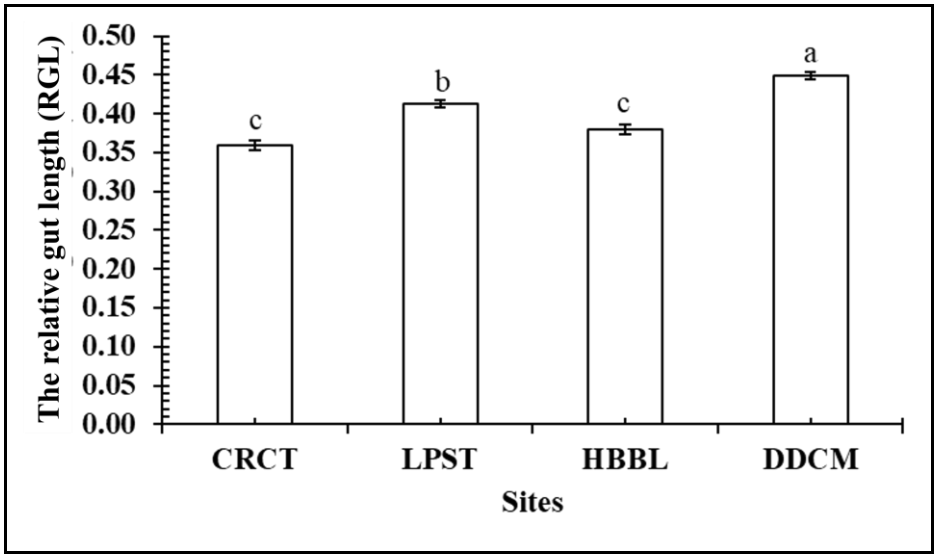

Figure 5. The variation in the relative gut length *Glossogobius giuris* among four sites; the vertical bars represent the standard error of the group mean; different letters show significant differences ($p<0.05$); CRCT - Cai Rang, Can Tho; LPST - Long Phu, Soc Trang; HBBL - Hoa Binh, Bac Lieu; DDCM - Dam Doi, Ca Mau.

Feeding intensity. This species displayed high feeding intensity, since the proportion of fish with an empty stomach was significantly different from fish with stomach contents. The FI of females (2.58±0.08) was similar to that of males (2.57±0.07) (t-test, t=0.09, p=0.10, Figure 6), showing that both males and females shared a similar pattern in feeding intensity. By contrast, the FI of the mature fish group (2.73±0.06) was significantly higher than that of the immature fish group (2.24±0.13) (t=-4.01, p<0.001, Figure 7), seeming that mature fish showed a higher feeding intensity than immature fish. This goby displayed a higher feeding intensity in the wet season compared to the dry season, as FI in the wet season (2.81±0.08) was significantly higher than in the dry season (2.30±0.08) (t=-4.47, p<0.001, Figure 8). In terms of site, the FI of this fish reached a higher value in the freshwater region in CRCT (3.21±0.14) and a lower one in the brackish water in LPST (2.20±0.11), HBBL (2.42±0.12) and DDCM (2.34±0.08) (one-

way ANOVA, F=13.08, p<0.001, Figure 9), displaying that the fish fed more intensively in freshwater than in the brackish region. The FI of this goby varied with the interactions: sex × site, season × site (General Linear Model, p<0.01 for two cases), but not sex × season (p=0.07). Likewise, the feeding intensity of *P. serperaster* was not regulated by fish size, but this goby fed more actively in the wet season (Dinh et al 2017b) due to a great abundance of food available at that time (Nedeco 1993). The seasonal change in feeding habits was also found in the naked goby *Gobiosoma bosc* (D'Aguillo et al 2014), *B. boddarti* (Dinh 2015), and *P. schlosseri* (Tran et al 2019).

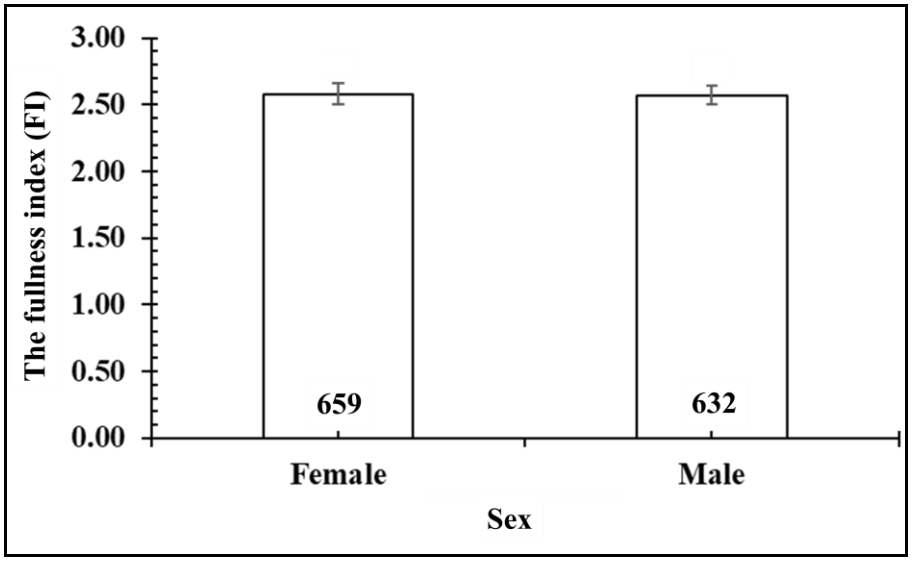

Figure 6. The variation of fullness index of *Glossogobius giuris* among the two sexes; the vertical bars represent the standard error of the group mean.

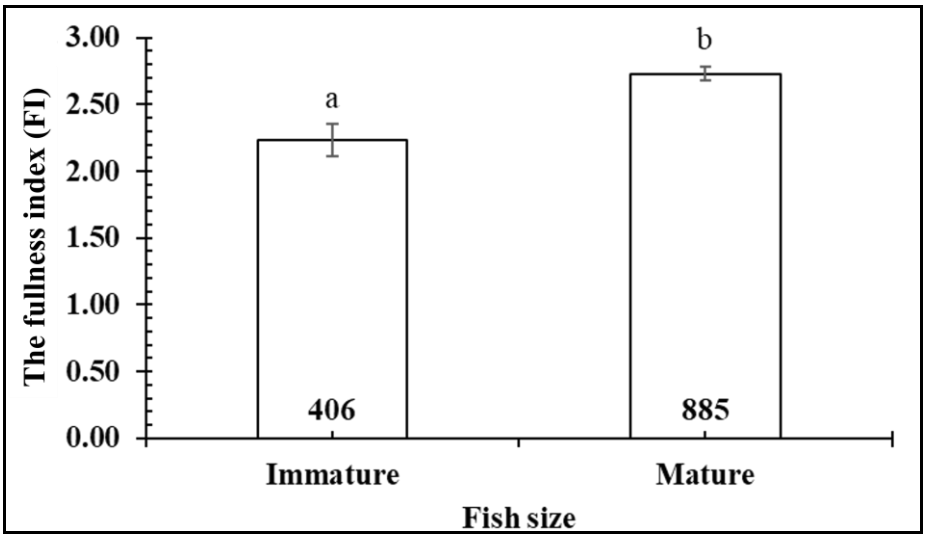

Figure 7. The variation of fullness index of *Glossogobius giuris* between the sizes; the vertical bars represent the standard error of the group mean; different letters show significant differences (p<0.05).

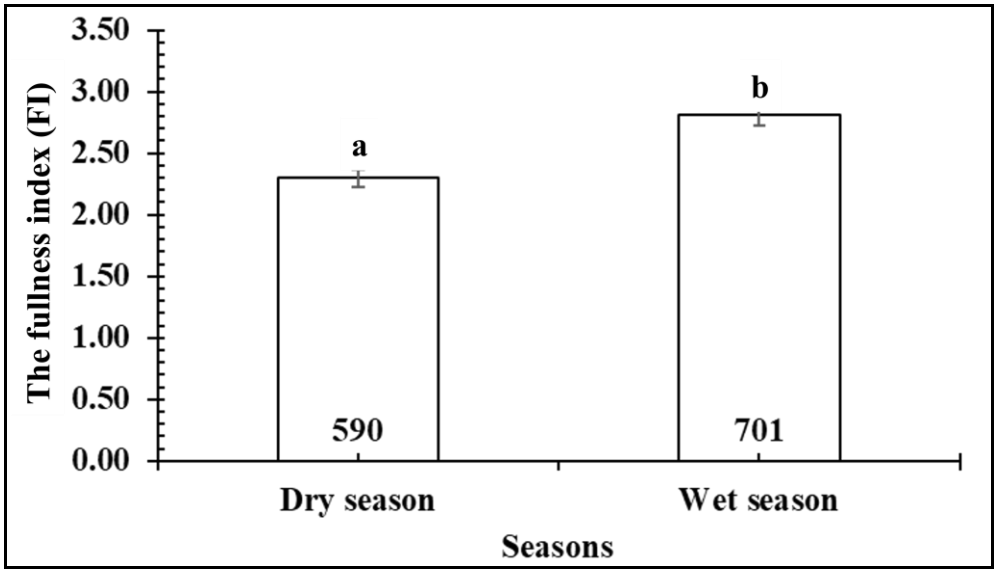

Figure 8. The variation of fullness index of *Glossogobius giuris* between the two seasons; the vertical bars represent the standard error of the group mean; different letters show significant differences ($p<0.05$).

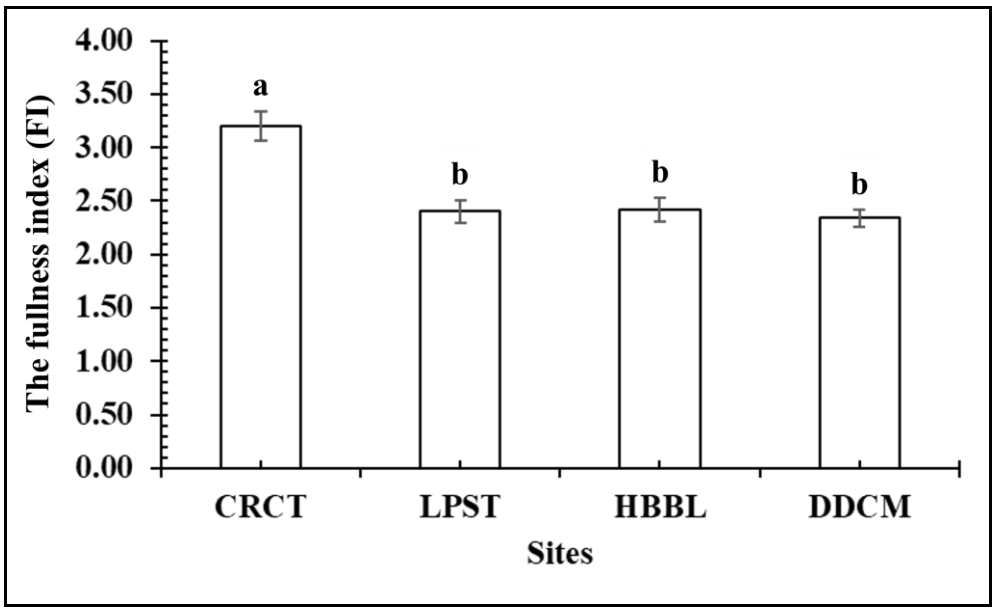

Figure 9. The variation of fullness index of *Glossogobius giuris* among the four sites; the vertical bars represent the standard error of the group mean; different letters show significant differences ($p<0.05$); CRCT - Cai Rang, Can Tho; LPST - Long Phu, Soc Trang; HBBL - Hoa Binh, Bac Lieu; DDCM - Dam Doi, Ca Mau.

Conclusions. *G. giuris* is a carnivorous goby that displays high feeding intensity. The RGL varied with season and site, and the FI of this fish varies with fish size, season and site. This goby showed a similar feeding intensity pattern between sexes, but not fish size, season and site. The variations of RGL and FI of this fish were regulated by sex × site, season × site. The results help better understand the fish feeding habitat and intensity, being used to evaluate the fish adaption.

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

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