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Original article

Factors influencing food composition, feeding habits and intensity of *Glossogobius giuris* caught from the vietnamese mekong delta

Quang Minh Dinh [a,*], Ngon Trong Truong [b], Gieo Hoang Phan [b,c], Nam Sy Tran [d], Ton Huu Duc Nguyen [a]

[a] Department of Biology, School of Education, Can Tho University, Can Tho, Viet Nam
[b] Biotechnology Research and Development Institute, Can Tho University, Xuan Khanh Ward, Can Tho, Viet Nam
[c] Kien Giang University, Minh Luong Town, Chau Thanh District, Kien Giang 920000, Viet Nam
[d] Department of Environmental Sciences, College of Environment and Natural Resources, Can Tho University, Can Tho, Viet Nam

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ABSTRACT

Objective: Knowledge of diet composition and feeding habits are essential to our understanding of fish ecological adaptation and aquaculture studies. This study aims to gain knowledge on diet composition, feeding intensity and habits for *Glossogobius giuris* – a commercial goby residing in brackish to freshwater regions of the Vietnamese Mekong Delta.
Methods: A collection of 1,291 samples (632 males and 659 females) were caught monthly from January 2020 to December 2020 at four sites using trawl nets. A combined analysis of prey occurrence and weight was used to calculate the diet composition of this fish.
Results: This fish displayed high feeding intensity, and its diet composition was seen to be comprised of small fish, *Acetes* spp., *Uca* spp., molluscs, and others (e.g., detritus and fish scales). Although males and females of two fish size groups, two seasons and at the four sites displayed the same feeding trends as Costello graphical analysis showed, the diet composition was seen to vary with season and site. It suggested that the difference in salinity between seasons and the four sites regulated food composition within this fish.
Conclusion: These findings advance the understanding of fish adaptation capacities and food flexibility.

1. Introduction

Fish diet and feeding ecology are crucial to understanding the roles of fish in a community (Wootton, 1996). Fish diet composition varies over seasons; e.g., *Neogobius melanostomus* in Canada ingests mainly ostracods in autumn, but fish eggs in spring (Brush et al., 2012). The fish diet composition is also related to food availability, e.g., *Parapocryptes serperaster* consumes mainly diatoms in Malaysia (Khaironizam & Norma-Rashid, 2000), but detritus in the Vietnamese Mekong Delta (VMD) (Dinh et al., 2017c). Diet and feeding ecology also were seen to improve fish adaptation to habitat, but limited to gobiid species in the VMD.

Glossogobius is a genus of the family Gobiidae with 29 species in the world documented by Hoese et al. (2015). In the VMD, this genus has three species: *G. aureus*, *G. giuris* and *G. sparsipapillus* (Tran et al., 2013). *Glossogobius giuris* is widely inhabited from marine to brackish and freshwater from Africa to Oceania (Riede, 2004), including the VMD (Dinh, 2008; Diep et al., 2014; Tran et al., 2020). This fish is a target is a carnivore ingesting mainly small fish and crustaceans in Bangladesh, reported by Hossain et al. (2016). In the VMD, *Glossogobius giuris* plays essential roles in the local food supply, but knowledge of its biology and ecology is fragmented and patchy at best, with some data on morphology, classification, environmental requirements, reproducing traits and growth patterns existing (Tran et al., 2013; Dinh & Ly, 2014; Nguyen & Dinh, 2021; Phan et al., 2021). Meanwhile, there is no data on its diet composition, feeding intensity and habits within the VMD, where its population is currently overfished (Dinh et al., 2017b). The study aims to provide data on the diet composition, feeding intensity and habits of *Glossogobius giuris* in order to increase our understanding of fish adaptation, food flexibility and aquaculture.

* Corresponding author.
E-mail address: dmquang@ctu.edu.vn (Q.M. Dinh).
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2. Materials and methods

2.1. Study site

Fish were sampled from two sites in Hau River at Cai Rang, Can Tho (CRCT; 10°00′42.6″N-105°48′42.4″E) and Long Phu, Soc Trang (LPST; 9°37′34.4″N-106°08′25.6″E) and two sites along the coast at Hoa Binh, Bac Lieu (HBBL; 9°12′02.5″N-105°43′01.2″E) and Dam Doi, Ca Mau (DDCM; 8°58′11.3″N-105°22′54.4″E) (Fig. 1). Fish were sampled every month between January 2020 to December 2020. The tide in these sites is semi-diurnal with range of ~ 1.2 m. The temperature and pH of these regions are ~ 27 °C and ~ 8, respectively. The salinity was ~ 12 ‰ in LPST and 0 ‰ in CRCT. It rains heavily with ~ 400 mm precipitation in the wet season (June to December) but roughly no rain in the dry season (January to May) (Le et al., 2006).

2.2. Fish collection and analysis

Trawl nets (with a cod-end mesh size of 1.5 cm) were used to catch fish. After setting up at high tide, nets were retrieved to collect specimens during the ebb tide at each site. Then fish was identified based on its external morphology (Tran et al., 2013) before sexing using urogenital papilla shape, e.g., oval in females and triangle in males documented by Dinh & Ly (2014). Fish were then anesthetised by Tricaine Methanesulfonate and stored in a 5 % formalin jar before transportation to the laboratory. Before removing the intestinal tract, the fish weight and total length were measured to the nearest 0.01 g and nearest 0.1 cm, respectively.

2.3. Food and feeding habits

A stereomicroscope was used to analyse food items, which were identified up to a suitable taxonomic level using the identification description provided by Nguyen et al. (2013). The stomach contents were then calculated by prey occurrence (%O_i = 100 × O_i/N, where O_i: number of fish consuming prey *i* and N: all examined fish) (Hynes, 1950) and prey weight (%W_i = 100 × W_i/W_{total}, W_i: weight of prey *i*, W_{total}: all prey weight) (Hyslop, 1980). The diet composition was quantified using a combined analysis of prey occurrence and weight (e.g., biovolume) as $\%V_i = \frac{100 \times O_i \times W_i}{\sum O_i \times W_i}$ (V_i: *i*-prey biovolume, O_i: *i*-prey occurrence, W_i: *i*-prey weight) (Natarajan & Jhingran, 1961; Hyslop, 1980).

All prey biovolume values were used to test if diet composition changed with sex, fish size, season, and site (Baeck et al., 2013). This test was performed using PRIMER v.6.1.11 with PERMANOVA + v.1.0.1 add-on package (Clarke & Gorley, 2006; Anderson et al., 2008). If diet composition was varied significantly between sexes or seasons or fish sizes, the Mann-Whitney *U* test was used to verify which prey contributed to the differences. The Kruskal-Wallis test was applied to prove which prey contributed to the spatial variation in diet composition (Dinh et al., 2017c). The difference in the number of fish with empty stomachs and fish with stomach contents between months was tested using the χ^2. These tests were performed by SPPS v.21. All tests were set at $p < 0.05$.

3. Results

3.1. Feeding intensity and habits

A collection of 1,291 fish specimens (659 females and 632 males) were presented in Table 1. Data analysis showed that the proportion of fish with an empty stomach (27.19 %) was significantly higher than that of the fish with stomach contents (~72.81 %, χ^2 = 6.33, p = 0.01). The Costello graphic illustrates that *G. giuris* was a generalist feeder, consuming mainly *Acetes* spp., followed by others and small fish (Fig. 2). Male and female *G. giuris* in

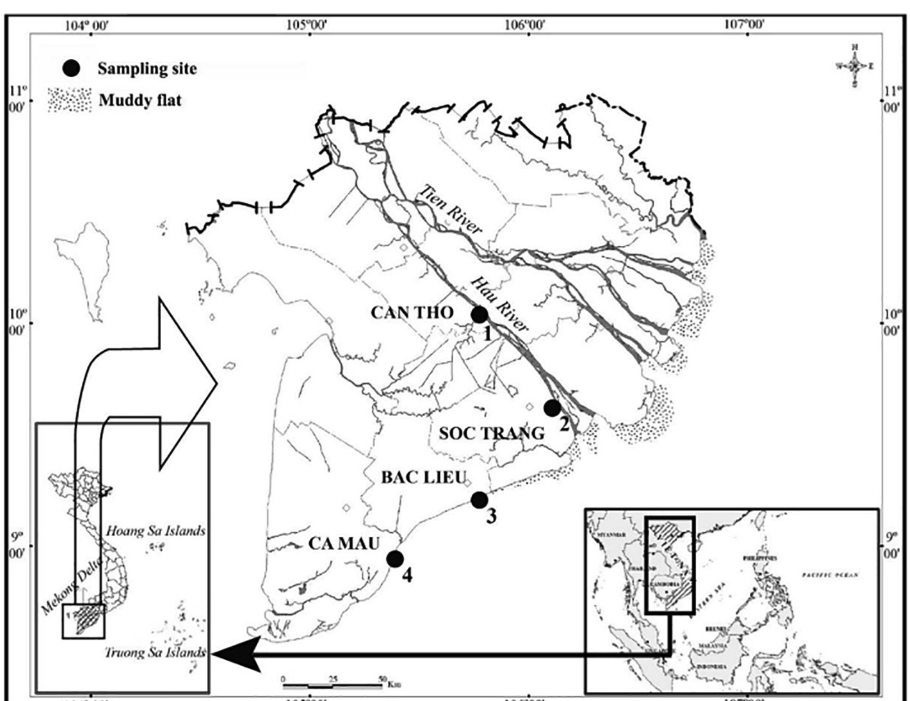

Fig. 1. The sampling map modified from Fig. 1 of Dinh (2018) (1: Cai Rang, Can Tho; 2: Long Phu, Soc Trang; 3: Hoa Binh, Bac Lieu; 4: Dam Doi, Ca Mau).

Table 1
The number of *Glossogobius giuris* individuals.

Sampling time	Cai Rang, Can Tho				Long Phu, Soc Trang				Hoa Binh, Bac Lieu				Dam Doi, Ca Mau			
	Total		No. of fish with empty stomach		Total		No. of fish with empty stomach		Total		No. of fish with empty stomach		Total		No. of fish with empty stomach	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Jan-20	7	6	4	4	11	19	10	16	14	11	11	7	18	9	11	5
Feb-20	7	13	5	11	19	16	10	7	11	14	11	11	32	33	21	18
Mar-20	19	11	11	6	14	10	8	5	8	19	8	17	13	17	8	9
Apr-20	11	12	9	11	17	15	6	11	23	14	16	12	18	11	6	4
May-20	16	15	10	12	17	15	8	8	18	7	16	6	25	5	18	4
Jun-20	19	11	12	5	10	6	9	5	14	12	8	10	17	10	13	6
Jul-20	9	21	0	8	21	6	20	6	11	18	8	9	10	19	7	17
Aug-20	8	23	8	23	9	12	7	10	9	12	7	10	13	13	13	13
Sep-20	11	19	11	19	7	21	5	19	11	13	9	10	15	15	15	15
Oct-20	9	12	7	10	6	7	6	7	12	8	7	7	11	18	9	17
Nov-20	9	12	7	10	13	14	9	12	12	14	10	12	9	20	3	17
Dec-20	9	21	8	11	4	11	3	10	13	8	6	5	13	11	10	9
Sum	134	176	92	130	148	152	101	116	156	150	117	116	194	181	134	134

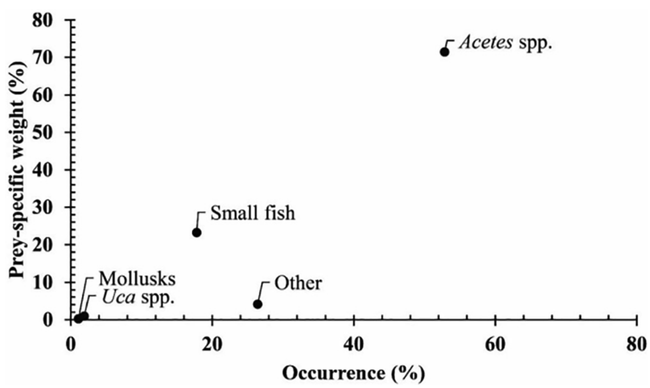

Fig. 2. The modified Costello graphic of *Glossogobius giuris*.

different fish groups and seasons (Fig. 3) and sites (Fig. 4) fed predominantly on *Acetes* spp., others and small fish.

3.2. General food composition of Glossogobius giuris

The diet composition of this goby comprised of small fish, *Acetes* spp., *Uca* spp., molluscs and others (e.g., detritus and fish scales). Frequency analysis showed that the goby fed primarily on *Acetes* spp (52.83 %), followed by others (26.42 %) and small fish (17.79 %), but ingested randomly *Uca* spp (1.89 %) and molluscs (1.08 %). Meanwhile, the weight and biovolume analyses showed this goby primarily consumed *Acetes* spp. (71.47 %) and secondarily small fish (23.23 %), but randomly fed on other prey (Table 2).

3.3. Food composition of males and females, fish sizes, two seasons, and four sites

The diet composition of male and female *G. giuris* over fish size, season and sites consisted of small fish, *Acetes* spp., *Uca* spp., molluscs and others (Table 2). The fish fed primarily on *Acetes* spp (52.83 %), followed by other (26.42 %) and small fish (17.79 %). This species could randomly ingest *Uca* spp. (1.89 %) and molluscs (1.08 %) based on the prey occurrence. Meanwhile, prey weight analysis showed that this species fed predominantly *Acetes* spp. (71.47 %), followed by small fish (23.23 %) and other prey (~5.30 %). The biovolume prey analysis indicated that this goby fed primarily on *Acetes* spp., followed by small fish (Table 2). Likewise, males and females of different sizes in the dry-wet season pattern ingested mainly *Acetes* spp, followed by small fish and others based on the occurrence frequency analysis. However, the fish predominantly ingested *Uca* spp., followed by others and small fish according to prey weight and biovolume analyses (Table 2). Diet composition was seen not vary with sex (PERMANOVA, Pseudo-F = 0.26, p = 0.80), fish sizes (Pseudo-F = 2.58, p = 0.07), but varied over season (Pseudo-F = 4.96, p < 0.001), and site (Pseudo-F = 5.58, p < 0.001). The variations in the diet between males and females was not dependant on fish size (Pseudo-F = 1.74, p = 0.19), season (Pseudo-F = 1.09, p = 0.34) and site (Pseudo-F = 1.18, p = 0.32). Other preys regulated variation in food composition between two seasons as their biovolume changed with season (Mann-Whitney, U = -3.40, p < 0.001). Similarly, the difference in food composition among the four sites was regulated by *Acetes* spp. and other prey, reaching the highest values in CRCT (Kruskal-Wallis, $\chi^2_{Acetes\ spp.} = 23.55$, $\chi^2_{other} = 18.55$, $p_{Acetes\ spp} < 0.001$, $p_{other} < 0.001$).

4. Discussion

The goby *G. giuris* displayed high feeding intensity due to its high proportion of fish with an empty stomach. Similar results have been found in other gobies living in VMD, such as *Boleophthalmus boddarti* (Dinh, 2015), *Eleotris melanosoma* (Dinh et al., 2017a), *P. serperaster* (Dinh et al., 2017c), and *Periophthalmodon schlosseri* (Tran et al., 2019) and *G. sparsipapillus* (Tran et al., 2021).

Glossogobius giuris in various fish sizes, seasons, and sites was a generalist feeder as different food types were found in its stomach, enabling the species to sufficiently adapt to various environmental conditions. A generalist feeding habits were also found for *Pomatoschistus minutus* and *P. microps* (Salgado et al., 2004; Leitão et al., 2006), *Periophthalmus barbarus* (Udo, 2002), *P. argentilineatus* (Kruitwagen et al., 2007), *Pseudapocryptes elongatus* (Tran, 2008), *B. boddarti* (Dinh, 2015), *P. serperaster* (Dinh et al., 2017c), *P. schlosseri* (Zulkifli et al., 2012; Tran et al., 2019) and *G. sparsipapillus* (Tran et al., 2021). By contrast, *Economidichthys pygmaeus* was found to be a specialist feeder, ingesting copepods and chironomids (Gkenas et al., 2012). The difference in feeding habits of these gobies indicates that the feeding strategy was species-specific.

Glossogobius giuris was a carnivore, feeding primarily *Acetes* spp., secondarily small fish, and rarely molluscs, *Uca* spp. and other prey, as demonstrated by the greatest and lowest percentage of these prey items in the fish diet. Yet, in Mithamain Haor, Bangladesh, this species was a carnivore consuming mainly small fish and crustacean (Hossain et al., 2016). Similarly, *G. sparsipapillus* liv-

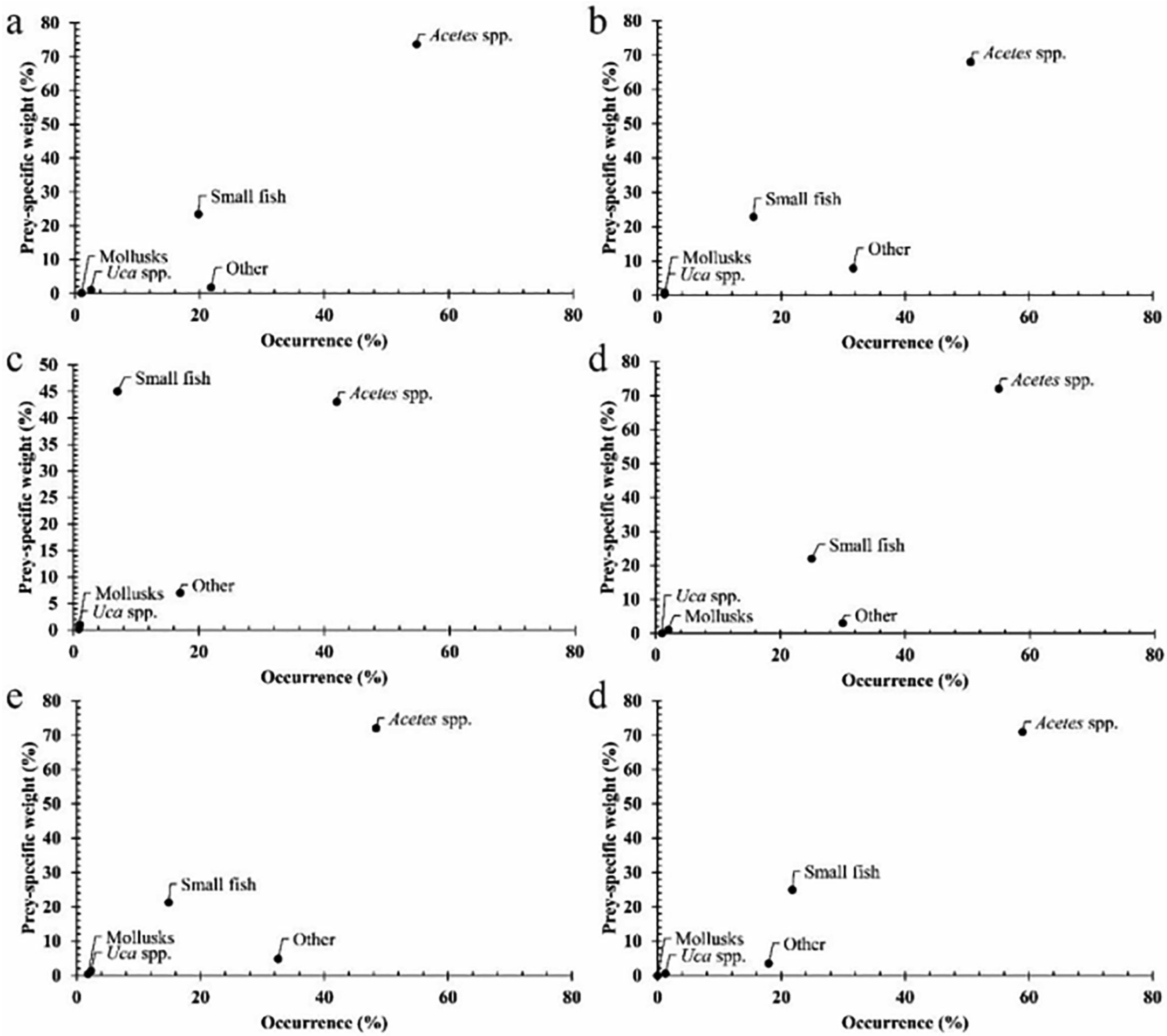

Fig. 3. The modified Costello graphics of *Glossogobius giuris* in sex, fish sizes and seasons (a: male, n = 632; b: female, n = 659; c: immaturity, n = 406; d: maturity, n = 885; e: dry, n = 590 and d: wet, n = 701).

ing in VMD fed mostly on *Acetes* spp. and small fish (Tran et al., 2021). Meanwhile, *P. elongatus* (Tran, 2008) and *P. serperaster* (Dinh et al., 2017c) in VMD ingested primarily detritus and diatoms, whereas *Boleophthalmus pectinirostris* (Yang et al., 2003) and *Boleophthalmus boddarti* (Ravi, 2013; Dinh, 2015) were seen to feed mainly diatoms. It is therefore suggestive that the fish diet is species-specific and regulated by food availability. For example, *P. serperaster* ingested mostly diatoms in Malaysia (Khaironizam & Norma-Rashid, 2000), but detritus in the VMD (Dinh et al., 2017c). The stomach of *P. microps* contented Mysidacea in the upper Tagus estuary (Salgado et al., 2004), but not in fish found in the Mondego estuary (Leitão et al., 2006).

Some gobies like *P. serperaster* (Dinh et al., 2017c) show the intraspecific variation of dietary composition. But, in this study, the diet composition of immature *G. giuris* was not significantly different from the mature group, which was found in *G. sparsipapillus* (Tran et al., 2021). The intraspecific change in diet composition was also found in *P. waltoni* in Iraq (Barak, 1994), *P. barbarus* in the Imo River estuary (Udo, 2002) and Rumuolumeni Creek of Nigeria (Bob-Manuel, 2011), *P. argentilineatus* in Japan (Nanjo et al., 2008) in East Africa (Kruitwagen et al., 2010), *P. schlosseri* in Malaysia (Zulkifli et al., 2012) and *B. boddarti* in India (Ravi, 2013).

The detritus input regulated from high rainfall in the wet season affected the diet composition of *G. giuris* in this study, but corresponding results were not found for *G. sparsipapillus* (Tran et al., 2021). The seasonal variations in diet composition were found in *B. boddarti* in India (Ravi, 2013) and *P. septemradiatus* in VMD (Dinh et al., 2020).

5. Conclusion

Glossogobius giuris was carnivorous fish, consuming mainly small *Acetes* spp, small fish, and others. The diet of this goby did not change with sex, size but varied with season and site. The present study contributes important biological data of this goby spe-

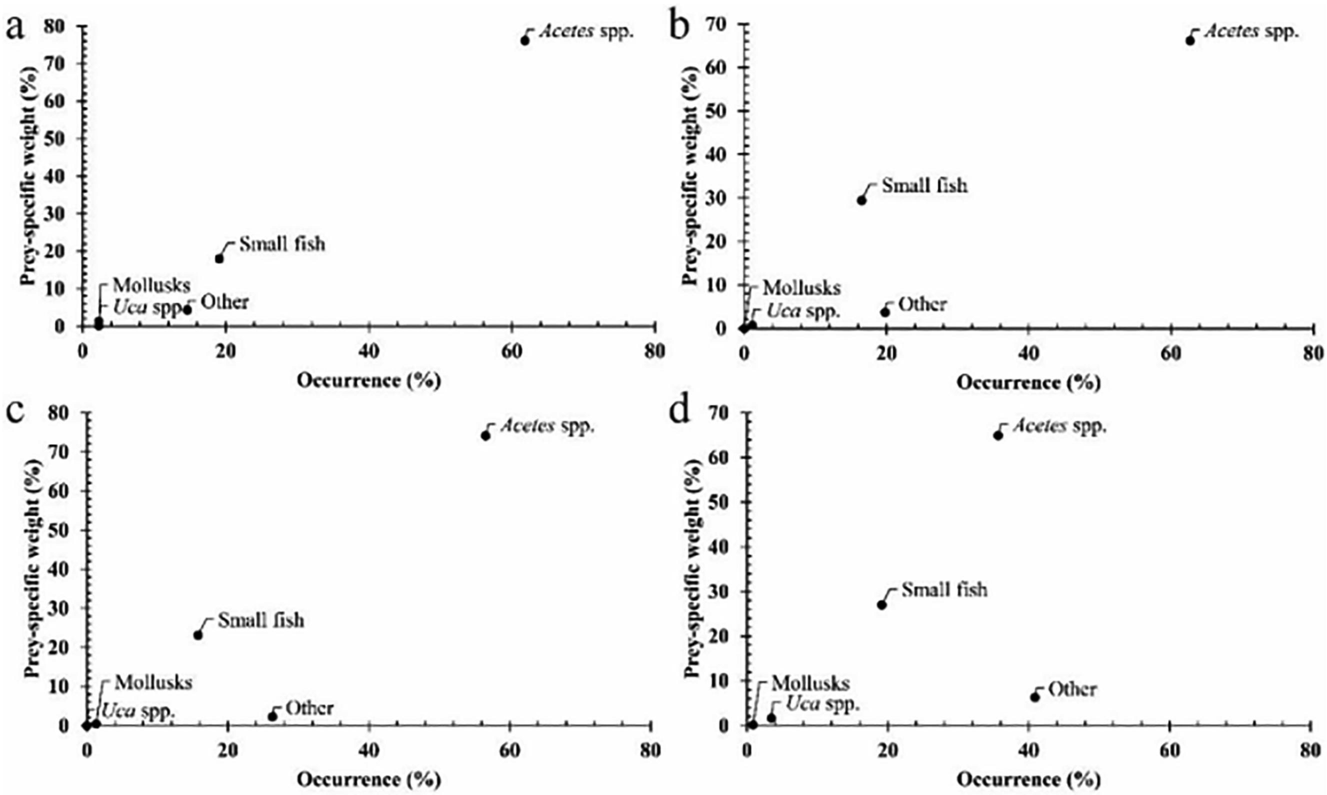

Fig. 4. The modified Costello graphics of *Glossogobius giuris* in four sites (a: CRCT, n = 310; b: LPST, n = 300; c: HBBL, n = 306; d: DDCM, n = 375).

Table 2
The food composition of *Glossogobius giuris* by sex, size and season.

		Food items				
Frequency	Category	*Acetes* spp.	Small fish	Mollusks	*Uca* spp.	Others
Occurrence	Male	54.82	19.80	1.02	2.54	21.83
	Female	50.57	15.52	1.15	1.15	31.61
Weight	Male	73.68	23.45	0.12	0.99	1.76
	Female	67.96	22.88	0.34	0.91	7.91
Biovolume	Male	73.68	23.45	0.12	0.99	1.76
	Female	67.96	22.88	0.34	0.91	7.91
Occurrence	Dry season	48.37	14.88	1.86	2.33	32.56
	Wet season	58.97	21.79	–	1.28	17.95
Weight	Dry season	72.06	21.28	0.43	1.38	4.86
	Wet season	70.95	24.95	–	0.59	3.51
Biovolume	Dry season	72.06	21.28	0.43	1.38	4.86
	Wet season	70.95	24.95	–	0.59	3.51
Occurrence	CRCT	50.57	15.52	1.15	1.15	31.61
	LPST	62.64	16.48	–	1.10	19.78
	HBBL	56.58	15.79	1.32	–	26.32
	DDCM	35.65	19.13	0.87	3.48	40.87
Weight	CRCT	67.96	22.88	0.34	0.91	7.91
	LPST	66.14	29.44	–	0.72	3.70
	HBBL	74.14	23.12	0.45	–	2.29
	DDCM	64.33	30.68	0.19	–	4.80
Occurrence	CRCT	67.96	22.88	0.34	0.91	7.91
	LPST	66.14	29.44	–	0.72	3.70
	HBBL	78.26	17.08	–	0.61	4.05
	DDCM	64.89	26.99	0.19	1.65	6.28

(CRCT: Cai Rang, Can Tho; LPST: Long Phu, Soc Trang; HBBL: Hoa Binh, Bac Lieu; DDCM: Dam Doi, Ca Mau).

cies, which can be used to advance sustainable fish management and aquaculture.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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