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HABITAT SEGREGATION OF *Gerres japonicus* AND *G. limbatus* IN EARLY STAGES IN THE TIEN YEN ESTUARY, NORTHERN VIETNAM

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ABSTRACT

Silver-biddy (Gerreidae: *Gerres*) are commercially important euryhaline fishes in coastal waters; however, information about their distribution during early stages in estuarine environments is poorly known. The present study aims to elucidate the habitat utilization of two species of the family, *Gerres japonicus* and *G. limbatus* as larvae and juveniles based on monthly collections from 2013 to 2015 in the Tien Yen estuary, northern Vietnam. They occurred from April to June for *G. japonicus* and in April and May for *G. limbatus* with a peak in May for both the species. Both *G. japonicus* and *G. limbatus* used the Tien Yen estuary as a nursery ground; however, the former species that colonized the shallows along the banks of the estuary extended to near freshwater habitat, whereas the latter was found at the end of the upper reach and the middle reach. The different habitat uses between the two species in the early life history may be related to their specific salinity preference as *G. japonicus* prefer lower salinities than *G. limbatus*.

Keywords: Gerres, Northern Vietnamese estuary, Nursery ground, Salinity, Spatio-temporal occurrence.

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INTRODUCTION

Twenty-eight species of *Gerres* (Perciformes: Gerreidae) are commercially important euryhaline fishes in coastal waters of the Indo-Pacific region (Nelson et al., 2016). *Gerres japonicus* and *G. limbatus* are closely related species distributed along coasts from Japan to the Philippines for the former, and from India and Sri Lanka to the southeast Asia and the South China Sea and Iran for the latter (Iwatsuki et al., 2001; Hatooka, 2002; Nguyen, 2005).

Understanding of early life history of fish is a key in conservative management (Ellis et al., 2012); however, few studies were carried out for the early stages of two given species (Mito, 1963; Jeyaseelan, 1998; Kinoshita, 2014; Tran et al., 2014). These studies have focused on descriptions of early stages and little is conducted to understand ecological characteristics in the early life stages of both the species.

Recently, we found that larvae and juveniles of *G. japonicus* and *G. limbatus* occurred in the same season and their longitudinal distributions were cross-sectional in the bank waters of the Tien Yen estuary, northern Vietnam. Therefore, this paper attempts to elucidate the distribution of larvae and juveniles of the given species relative to time and space within the Tien Yen estuary and discuss some aspects of their early stages, which are ecologically valuable for further conservation actions in such an environment.

MATERIALS AND METHODS

The investigations were conducted in the bank waters near the shore of the Tien Yen estuary, northern Vietnam (Fig. 1). Fish larval and juvenile collections were monthly made at 7 stations (TS5–8, TS10 and TS12) from March 2013 to February 2014 and 5 stations (TS8–12) from October 2014 to September 2015 by a small seine net (1 × 4 m, 1 mm mesh-aperture) (Kinoshita et al., 1988) (Fig. 1; Table 1). Division of the estuary into zones is in accordance with Kaiser et al. (2005). In this study, the estuary was divided into the head (stations TS9–12, salinity generally < 5‰), upper (stations TS6', TS7 and TS8, salinity usually 5–18), and middle (stations TS5 and TS6, salinity usually 18–25) reaches (Fig. 1).

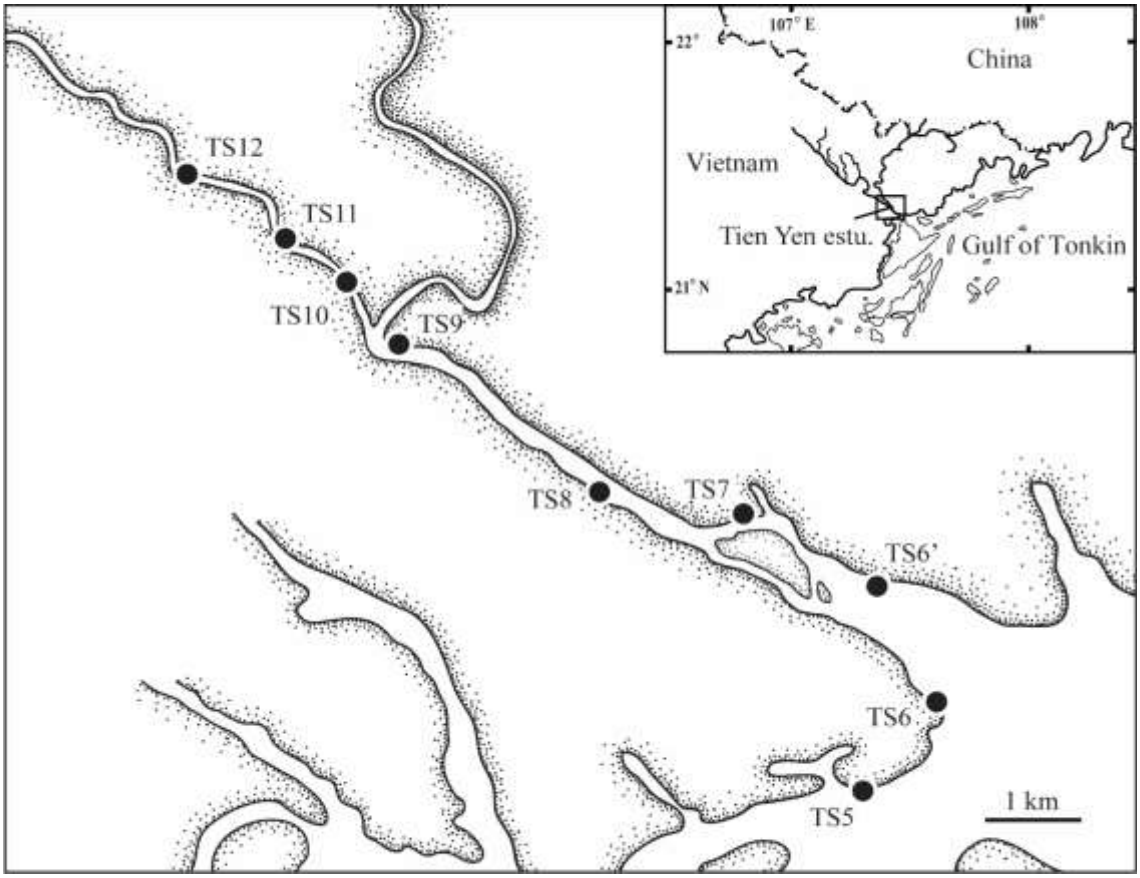

Figure 1. Chart showing stations (solid circles) where samples were collected in the bank waters of the Tien Yen estuary, northern Vietnam

The water temperature (°C), salinity (‰) and turbidity (NTU) were measured at each station using a Water Quality Checker (WQC-22A, TOA DDK). All samples were initially fixed in 10% formalin solution. Fishes were sorted from the samples and transferred to

80% ethanol. Specimens were measured for size by development stages (Kendall et al., 1984).

In *G. japonicus*, juveniles were identified to species based on dorsal fin ray count of X, 9, which is unique to this species within the region (Nguyen, 2005; Tran & Ta, 2014). Identification of the larvae was verified by melanophore pattern traced back from the juveniles. Furthermore, a series of development was completely conformable to the description of Kinoshita (2014). Identification of the *G. limbatus* larvae and juveniles is available in Tran et al. (2014).

RESULTS AND DISCUSSION

Size and developmental stages

A total of 266 individuals (5 flexion, 86 postflexion larvae and 175 juveniles) of *G. japonicus* and 103 individuals (3 flexion, 91 postflexion larvae and 9 juveniles) of *G. limbatus* were collected in the bank waters of the Tien Yen estuary during the study period (Table 1).

Table 1. Collection records of *G. japonicus* and *G. limbatus* in the bank waters of the Tien Yen estuary, northern Vietnam

Date	Stn	Total fish No.		CPUE		Range of BL (mm)		Physical parameters		
		J	L	J	L	J	L	Tem	Sal	Tur
16 Apr 2013	TS5	0	37	0	24.7		4.2-6.5	22.2	21.0	10
	TS6	0	14	0	14.0		5.0-7.4	22.3	12.2	2
	TS6'	0	9	0	9.0		3.9-6.6	21.7	12.1	22
	TS7	0	2	0	1.1		4.7-4.8	21.8	12.0	5
10 May 2013	TS5	0	32	0	32.0		4.9-10.9	27.3	18.6	2
	TS6	0	9	0	8.0		5.4-10.5	28.6	2.5	82
	TS6'	5	0	6.7	0	6.4-11.9		26.6	1.3	108
	TS7	18	0	12.0	0	7.4-12.2		26.3	0.3	150
	TS8	3	0	3.0	0	9.5-11.3		27.8	0.2	115
06 Apr 2015	TS8	11	0	22.0	0	5.0-6.0		24.2	16.6	17
	TS9	51	0	25.5	0	4.6-8.8		23.6	11.3	2
	TS10	6	0	24.0	0	5.0-6.0		24.7	10.0	4
	TS11	17	0	17.0	0	5.0-7.2		23.8	8.8	5
	TS12	8	0	16.0	0	5.2-8.2		24.1	1.3	8
17 May 2015	TS8	8	0	32.0	0	6.2-12.2		29.1	0.5	48
	TS9	30	0	40.0	0	7.5-11.8		29.5	0.2	53
	TS10	6	0	12.0	0	7.1-14.0		27.2	1.0	135
	TS11	87	0	174.0	0	6.1-19.5		27.0	0.6	128
	TS12	11	0	44.0	0	7.8-23.8		26.1	0.2	76
15 Jun 2015	TS8	1	0	4.0	0	12.7		30.1	0.9	12
	TS9	1	0	1.0	0	13.0		31.1	0.3	30
	TS11	3	0	4.0	0	11.7-13.5		29.1	0.0	8

CPUE [*n* $haul^{-1}$ (ca. 50 m distance)]; J: *G. japonicus*; L: *G. limbatus*; Sal: Salinity (‰); Stn: Station in Fig. 1; Tem: Temperature (°C); Tur: Turbidity (NTU)

Size and developmental stage composition of monthly collections from the bank waters of the Tien Yen estuary were shown in the Figs. 2 and 4. *G. japonicus* was larger in size than *G. limbatus* in the estuary (Fig. 2). The monthly mode of *G. japonicus* shifted from 4.6–8.8 mm BL in April, through 6.1–23.8 mm BL in May, to 11.7–13.5 mm BL in June. Size ranges widened in May and were relatively narrow in the other months (Fig. 4). In 2015, the averages of the body sizes monthly increased from 5.6 mm in April, through 10.2 mm in May, to 12.7 mm in June. The monthly length mode of *G. limbatus* larvae and juveniles shifted from 3.9–7.4 mm BL in April to 4.9–10.9 mm BL in May (Fig. 4). The averages of fish sizes monthly increased from 5.3 in April to 6.9 mm BL in May.

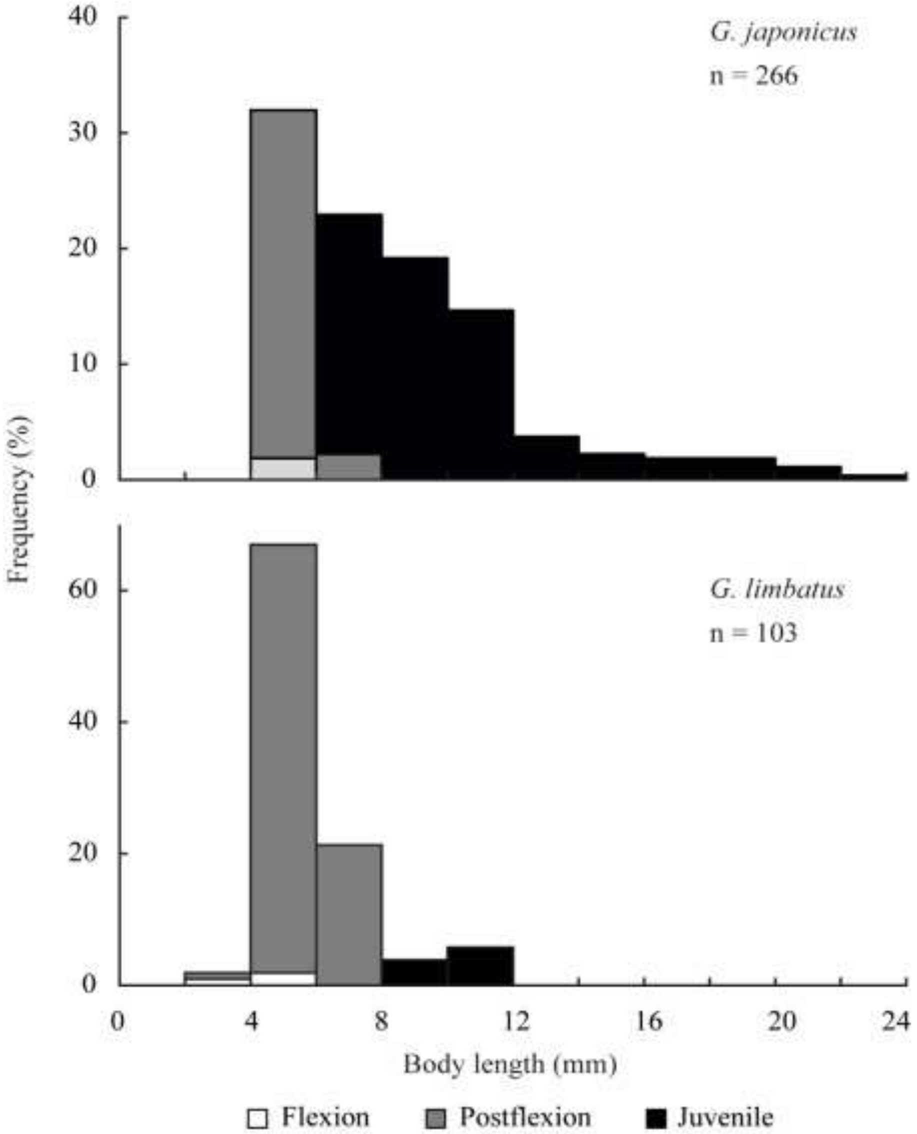

Figure 2. Body length frequencies of *G. japonicus* and *G. limbatus* collected in the bank waters of the Tien Yen estuary, northern Vietnam

Both the species are categorized as the resident fishes in the Tien Yen estuary since their relative increase in length during the periods in which they were collected (Moddle, 1980). *G. japonicus* and *G. limbatus* occurred as the same developmental stage, being significantly larger in size in the former in the bank waters of northern Vietnam. Hence, it seems that their development than growth were more regular in the inhabitation such as bank waters.

Temporal distribution

Temporal distribution of *G. japonicus* and *G. limbatus* was shown in Fig. 3. Larvae and juveniles of the former species occurred in May 2013 and from April to June 2015, and the latter occurred from April to May 2013 with a peak in May for both the species.

Larvae and juveniles of *G. japonicus* occurred from April to June in the estuary of northern Vietnam, and although in August, when it was almost same temperature ranging from ca. 24 to 31°C in the Shimanto estuary facing to Tosa Bay in southern Japan (Fujita et al., 2002). The occurrence of *G. japonicus* indicates that their settlement in coastal nursery areas is temperature dependent, thus the temporal distribution of larvae and juveniles of this fish would have been shifted by different oceanography.

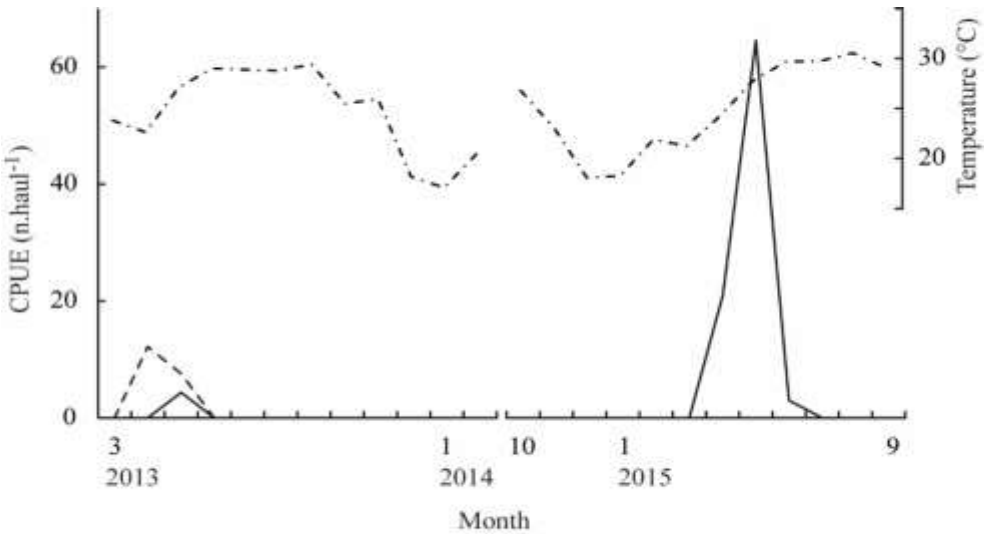

Figure 3. Seasonal occurrences of the two *Gerres* species in the bank waters of the Tien Yen estuary. Solid and dashed lines indicate *G. japonicus* and *G. limbatus*, respectively. Average water temperatures are shown by a dot-dashed line

Seasonal occurrence is one of the most commonly used information in identification of the early life history of fishes. This ecological trait is useful to identify *Gerres* larvae and juveniles because they easily confuse in larval morphology and pigmentation within the genus. Larvae of *G. limbatus* and *G. erythrourus* were little different in external morphology (Kinoshita, 2014; Tran et al., 2014); however, recent survey of fish larvae and juveniles in the Tien Yen and Kalong estuaries in northern Vietnam showed that the two species are distinctly separate from each other in seasonal occurrences, in which the former occurred from ca. April to June, but the latter from ca. July to November.

Spatial distribution

Gerres japonicus was almost distributed along the entire banks waters of the Tien Yen estuary, except for stations TS5 and TS6 (Fig. 5). The most abundance was found at station TS11. Temperatures, salinities and turbidities of the waters where they were collected ranged from 23.6 to 31.2°C, 0–16.6‰ (mostly < 2), 2–150 NTU, respectively (Table 1). *G. limbatus* only occurred from TS5 to TS7, with a peak at station TS7 (Fig. 5). Temperatures, salinities and turbidities of the waters where they were collected ranged from 21.7 to 28.6°C, 2.5–21.0‰ (mostly > 10), 2–150 NTU, respectively (Table 1).

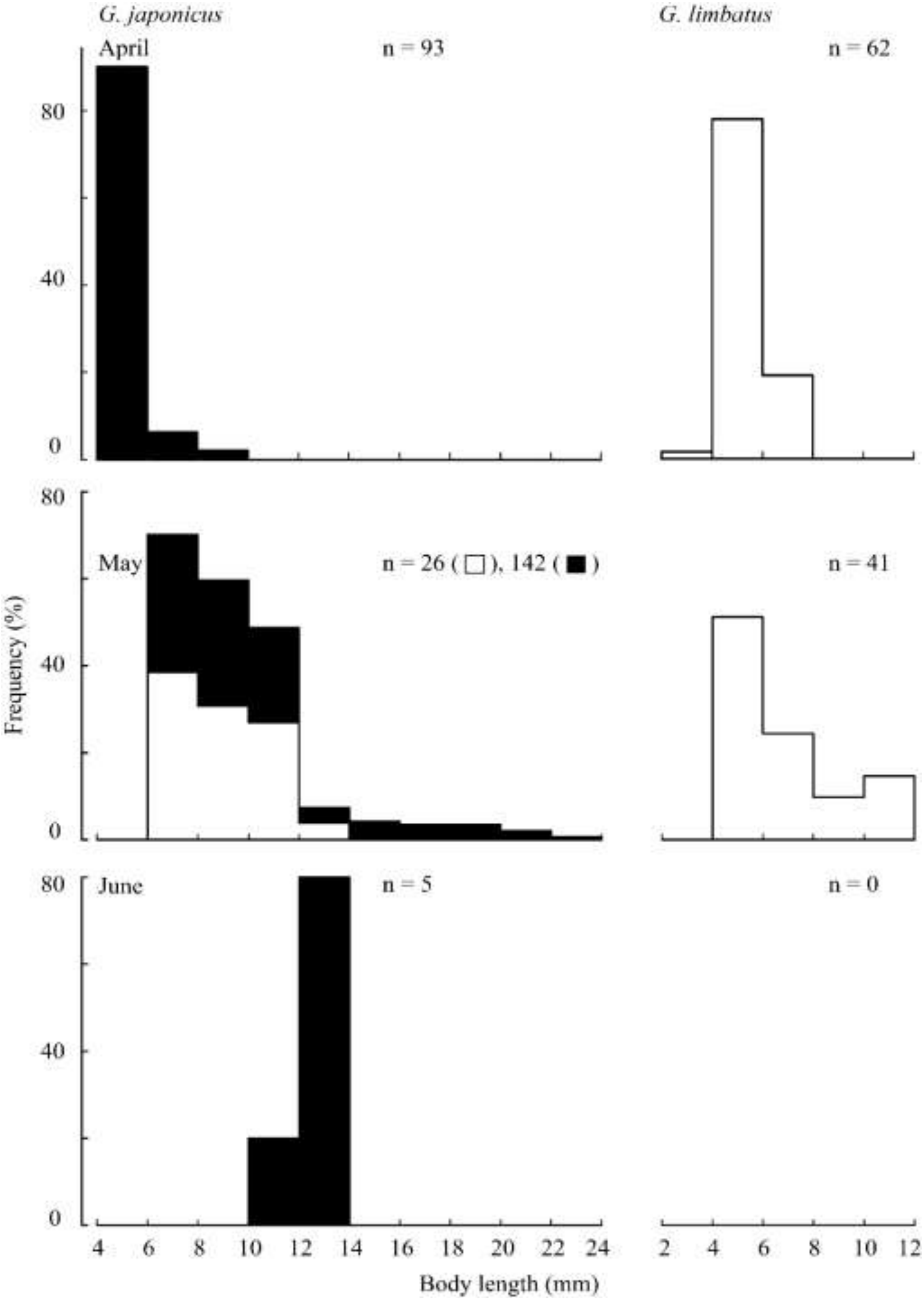

Figure 4. Seasonal changes in body length distribution of the *G. japonicus* and *G. limbatus*. Open and solid bars indicate fishes collected in 2013 and 2015, respectively

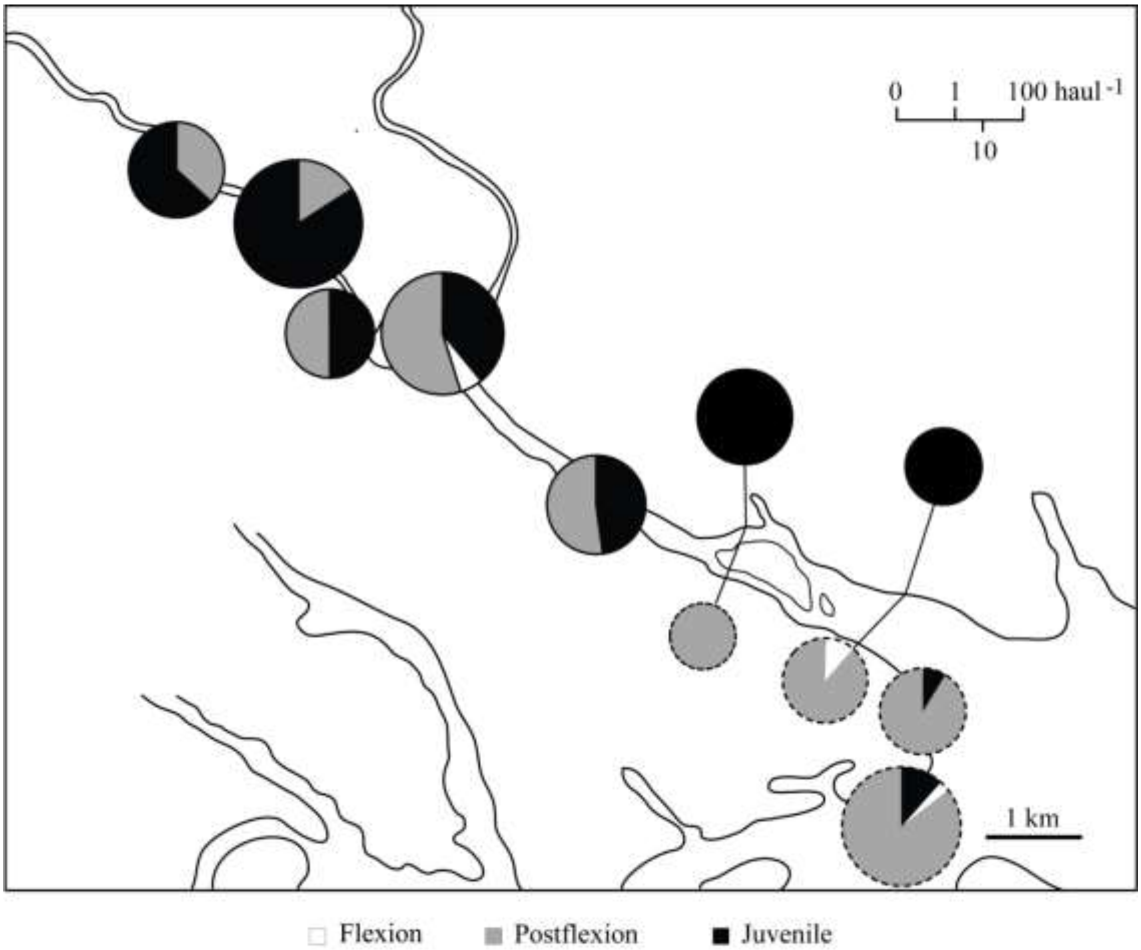

Figure 5. Distribution pattern of larvae and juveniles of the two *Gerres* species based on the collected data of the estuary sites. The circles with solid and dashed borders indicate the dominance of *G. japonicus* and *G. limbatus*, respectively. The diameter of each circle is drawn in proportion to the cube root of a total of the fishes

The difference of longitudinal distributions between *G. japonicus* and *G. limbatus* was revealed in Fig. 5. The larvae and juveniles of *G. japonicus* distributed almost in the head of the estuary (salinity < 2‰). Conversely, those of *G. limbatus* occurred chiefly in the end of the upper reach and the middle reach of the estuary with salinity usually over 10‰ (Table 1). The differences in the spatial distribution patterns indicate the distinction of the roles as nursery grounds (Beck et al., 2003; Ellis et al., 2012) for the two *Gerres* species between various zones of the estuary. Whereby, the head and upper reaches played for *G. japonicus* and the zones of over the end of the upper reach seemed for *G. limbatus*. These results support the hypothesis that these related species segregate their habitats on the reach scale in the larval and juvenile stages.

On the local scale, the two species exhibited some differences in cross-sectional habitat use. There are two possible explanations for the observed pattern. First, between different zones of an estuary, salinity may be the most different environmental parameter. The habitat separation of the two species may be related to their specific salinity preference: *G. japonicus* prefer lower salinities than *G. limbatus*. Second, interspecific competition seems to play a role in differentiating nursery habitat. The difference of habitats and food habits among closely related species has been mostly attributed to interspecific coaction (Mizuno et al., 1958; Saishu, 1963; Omori, 1975; Fujita et al., 1988). This case suggests that exploitive and/or interference compaction can have an influence on their habitat selection since the two species share food resources.

This study emphasizes the importance of considering spatial factors to better understand habitat segregation among related species in the early life history. The fact that ecological differences have already occurred during the larval and juvenile stages would be valuable information in analyzing the speciation of the present two species. To approach the problem, a further detailed ontogenetic comparison of ecology must be made together with food habit, morphology and physiology throughout their early stages.

CONCLUSION

Larvae and juveniles of *G. japonicus* and *G. limbatus* simultaneously occurred in the bank waters of the Tien Yen estuary, northern Vietnam, in the period of April to June, with a peak in May for both the species. Spatially, they were separated in the habitat use, in which *G. japonicus* was present in the head and upper reaches, whereas *G. limbatus* was found at the end of the upper reach and the middle reach. The fact suggests the bank waters of the estuary play an important role as nursery grounds for the two species.

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