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# Population and age structure of the goby *Stigmatogobius pleurostigma* (Perciformes: Gobiidae) from the Mekong Delta

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**Abstract:** This study was conducted in the Mekong Delta to provide new knowledge on the population and age structure of *Stigmatogobius pleurostigma*, a commercial target fish for catching. The von Bertalanffy growth parameters were $L_\infty$ = 8.6 cm, $K$ = 0.83 yr$^{-1}$, and $t_0$ = -0.07 yr$^{-1}$ basing on length frequency data analysis of 607 individuals. The species displayed 3.8 cm in the length at first capture, 3.61 yr in the longevity and 1.79 in the growth performance. The natural, fishing and total mortalities of the fish population were 2.31 yr$^{-1}$, 1.17 yr$^{-1}$ and 3.48 yr$^{-1}$ respectively basing on the length-converted catch curve analysis. One recruitment peak was recorded in June in the study region, and the analyses of relative yield-per-recruit and biomass-per-recruit gave $E_{max}$ = 0.704, $E_{0.1}$ = 0.555 and $E_{50}$ = 0.335. Four fish age groups were recorded in the present study (0.5$^+$, 1.0$^+$, 1.5$^+$ and 2.0$^+$). The species is a potential aquaculture candidate because of its high growth rate. The goby stock was overfishing since its exploitation rate ($E$=0.34) was higher than $E_{50}$, suggesting that the mesh size of gillnets should be increased and avoid catching fish during the recruitment period for future sustainable fishery management.

**Keywords**: *Stigmatogobius pleurostigma*; mortality; growth; exploitation rate; age

## Introduction

Beverton and Holt (1957) reported that fisheries management and the exploitation rate, which was estimated from the analysis of the yield-per-recruit, have a strong relationship. The fish population assessment depends on the growth and mortality parameters, according to Ricker (1975). Pauly and Munro (1984) indicated that the growth performance, which is estimated from a combined analysis of growth and asymptotic length relationship, is related to the variations of fish growth rate between genders and locations. The fish age is estimated from length frequency data (Devries and Frie, 1996; Cardinale and Arrhenius, 2004) and helpful for fishery management (Beatriz, 1992; Cardinale *et al*., 2000). In the Mekong Delta, the gobies diversify with 58 species but data on population and age structure limited to two elongated gobiid species such as *Pseudapocryptes elongatus* (Tran *et al*., 2007) and *Parapcryptes serperaster* (Dinh *et al*., 2015b). The overexploitation with various fishing gears (Trinh and Tran, 2012) lead the reduction of fish species in the Mekong Delta including gobies (Diep *et al*., 2014). For example, the stocks of *Glossogobius giuris* (Dinh *et al*., 2017a), *Glossogobius aureus* (Dinh *et al*., 2017b) and *Boleophthalmus boddarti* (Dinh, 2017a) have been subjected to overfishing. There is a need to study on fishing status and age structure of other fishes, especially gobiid species.

The goby *Stigmatogobius pleurostigma* (Bleeker, 1849) is a small and elongated body shaped fish belonging to the family Gobiidae, according to Larson (2005). The species distributes widely from the brackish to freshwater in Thailand, Singapore, Malaysia, Indonesia and Vietnam (Larson, 2005; Tran *et al*., 2013; Froese and Pauly, 2017). There are seven species in the *Stigmatogobius* genus (Larson, 2005) but only *S. pleurostigma* is recorded in the Mekong Delta, Vietnam (Tran *et al*., 2013). The species shows negative allometric growth and does not vary with gender and season (Dinh, 2017b). It plays an important role for food supply in the Mekong Delta especially in the estuarine regions from Bac Lieu to Soc Trang, but data on its population and age structure are unknown. This study, therefore, aims to provide new data on biological features to understand its stock and management.

## Materials and Methods

### Study site, fish collection and analysis

The present study was conducted in the mudflat and mangrove forests from Ganh Hao and Nha Mat (Bac Lieu Province) to Tran De (Soc Trang Province, Fig.

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1), Vietnam. These two provinces are fringed by large *Avicenna marina* and *Sonneratia caseolaris* mangrove forests with long coastlines and vast mudflats. Like other provinces in the Mekong Delta, the natural conditions of Soc Trang and Bac Lieu are represented by semi-diurnal tide with a range of ~1.2 m, a mean annual temperature of ~27 °C and two seasons (dry season from January to May with little rain and wet season from June to December with monthly precipitation of 400 mm) (Le *et al*., 2006).

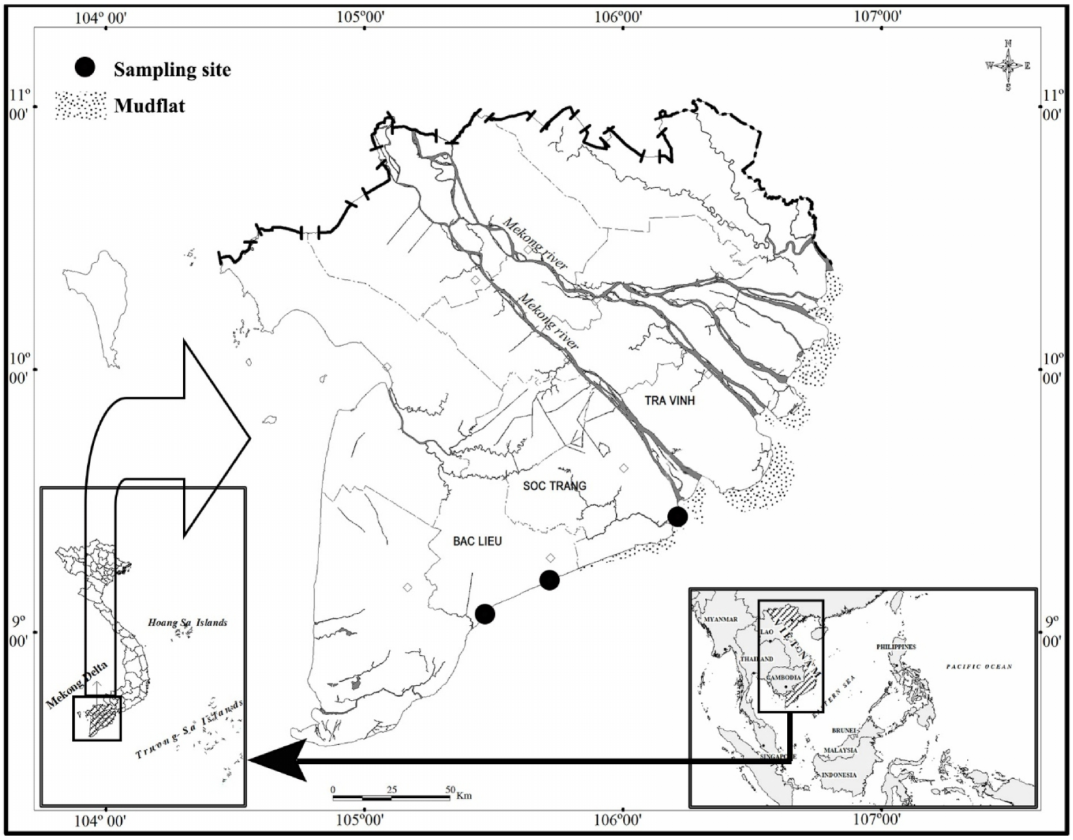


**Fig. 1: The sampling map in the Mekong Delta (●: Sampling sites).**

Fish specimens were monthly collected by bottom gill nets with 1.5 cm mesh size in the cod-end. According to Dinh *et al*. (2015a), a group of three gill nets was set at along the mudflat and mangrove forest in each study site at the highest tide and retrieved after 2–3 h during an ebb to collect fish specimens. After identification based on the external description given by Larson (2005), fish was sexed according to the morphology of urogenital papilla shape described by Dinh (2014) and anaesthetized with benzocaine before storing in 5% formalin and transporting to the laboratory. Fish was then measured to the nearest 0.1 cm in total length and weighed to the nearest 0.01 g in fish body weight.

## Data analysis

The population and age structure of fish were estimated from length frequency data inputted into the FiSAT II software (Gayanilo *et al*., 2005). After decomposing composite length-frequency distributions using the method of Bhattacharya (1967), the linking of the mean procedure was applied to obtain the length-at-age data that was used to estimate the asymptotic length ($L_\infty$), the growth parameter ($K$) and the age when the egg was fertilised ($t_0$). After that, these parameters were fitted to ELEFAN I procedure to obtain the von Bertalanffy curve (Pauly and David, 1981; Pauly, 1982) and the length-converted capture curve method was applied to determine the rate of total mortality ($Z$) (Beverton and Holt, 1957; Ricker, 1975). The function $LogM = -0.0066 - 0.279LogL_\infty + 0.6543LogK + 0.463LogT$ of Pauly (1980) was used to estimate the natural mortality rate ($M$), where $L_\infty$ and $K$ were two parameters of the von Bertalanffy curve and $T$ was the mean annual water temperature ($^oC$). According to Ricker (1975), the fishing mortality was calculated as $F = Z – M$ and the exploitation rate was calculated from the function $E = F/Z$.

Both the fish length at first capture and recruitment time were estimated from the length-converted catch and the recruitment pattern procedures respectively (Pauly, 1987). The fish stock and yield were estimated from the yield-per-recruit model of Beverton and Holt (1957), according to Sparre and Venema (1992). The knife-edge selection procedure was performed to obtain the maximum exploitation rate ($E_{max}$), optimum exploitation rate ($E_{0.1}$) and the exploitation rate when the stock reduced to 50% ($E_{0.5}$) (Beverton and Holt, 1966). The growth performance ($\Phi' = LogK + 2LogL_\infty$, where $K$ and $L_\infty$ are two parameters of the von Bertalanffy curve), according to Pauly and Munro (1984), was used to compare the von Bertalanffy growth parameters between *S. pleurostigma* and other gobiid species in or different genus dwelling in the same or different habitat. The longevity was calculated as $t_{max} = 3/K$ where $K$ was the growth constant of the von Bertalanffy curve (Taylor, 1958).

## Results

There were three size groups (e.g., three growth curves or blue lines, Fig. 2) in the population of *S. plerostigma* basing on the length-frequency analysis of 607 individuals (375 females and 232 males, Tab. 1, 2.3–7.0 cm in TL). The smaller fish grew slightly faster than the bigger fish because of a slight slope in the larger fish group. This species displayed the von Bertalanffy growth curve as $L_t = 8.6\ (1\text{-}e^{-0.83\ (t+0.07)})$ based on the analysis of the growth increment data performed by using the Bahtachaya procedure (Fig. 3).

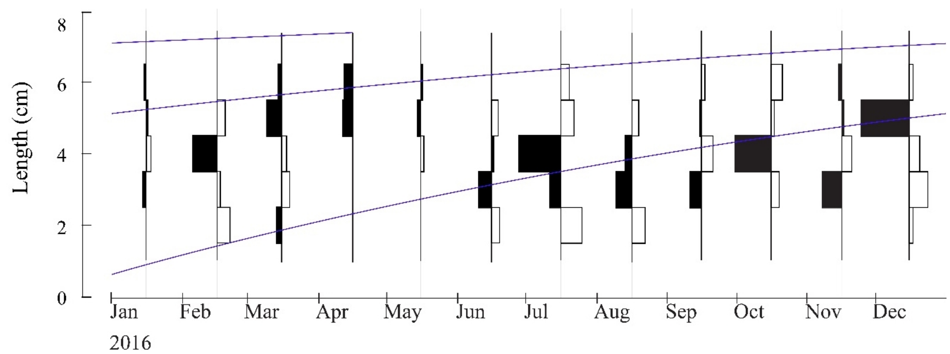


**Fig. 2: Length-frequency distribution of *Stigmatogobius pleurostigma* (n = 607, the curves show the increase of fish length over time).**

**Tab. 1: The number of the goby Stigmatogobius pleurostigma collected from the study site, from January to December 2016.**

| Fish total length (cm) | Jan | Feb | Mar | Apr | May | Jun | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <3.0 | - | 1 | 2 | - | - | 2 | 1 | - | - | - | 5 |
| 3.0-4.9 | 6 | 14 | 1 | - | - | 10 | 62 | 22 | 12 | 22 | 7 |
| 4.0-5.9 | 4 | 52 | 2 | - | 2 | 5 | 42 | 4 | 38 | 3 | 14 |
| 5.0-5.9 | 6 | 8 | 4 | 7 | 3 | 3 | 14 | 16 | 15 | 10 | 60 |
| 6.0-6.9 | 7 | - | 3 | 8 | 2 | 3 | - | 5 | 2 | 7 | 16 |
| >7.0 | - | - | 1 | 1 | - | - | - | - | - | 1 | 9 |

The length-converted catch curve analysis showed that the total, natural and fishing mortalities were 3.48, 2.31 and 1.17 respectively (Fig. 4). This goby displayed a high exploitation rate of 0.64 and a recruitment peak in June (Fig. 5). The species was firstly caught ($L_c$ or $L_{50}$) at 3.8 cm in the total length obtained from the capture probability procedure (Fig. 6).

The goby *S. pleurostigma* showed $E_{0.1}$ = 0.555, $E_{0.5}$ = 0.335 and $E_{max}$ = 0.704 basing on the analyses of the yield-per-recruit and biomass-per-recruit procedure (Fig. 7). The species displayed 1.79 in the growth performance and 3.61 yrs in the longevity respectively. Four fish age groups ($0.5^+$, $1.0^+$, $1.5^+$, and $2.0^+$) were recorded in the present study (Fig. 8).

## Discussion

Dinh *et al*. (2015b) indicated that the growth

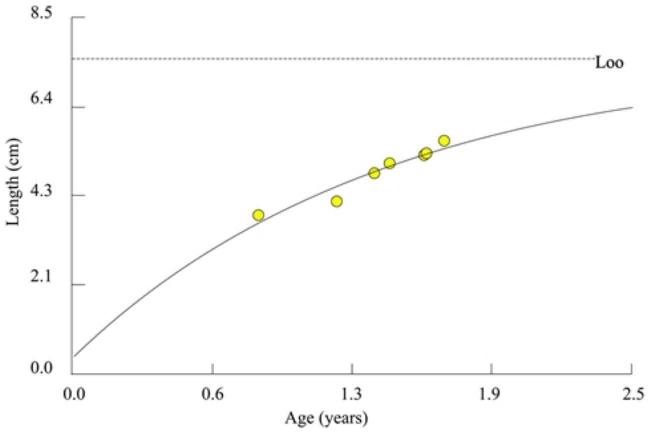


Fig. 3: The von Bertalanffy growth curve of *Stigmatogobius pleurostigma* based on growth increment analysis ($L_\infty$ = 8.6 cm, $t_0$ = –0.07 yr$^{-1}$, $K$ = 0.83 yr$^{-1}$).

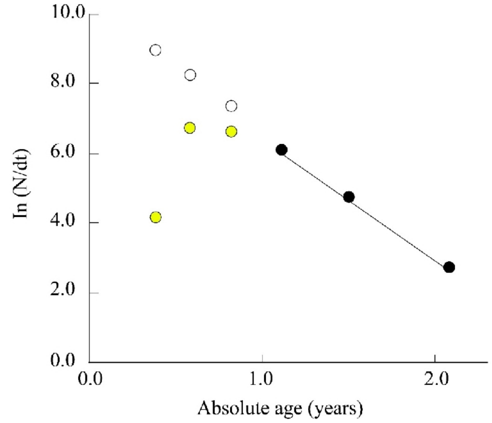


Fig. 4: The length converted catch curve of *Stigmatogobius pleurostigma* ($Z$=3.48, $M$ = 2.31, $F$ = 1.17 and $E$ = 0.34).

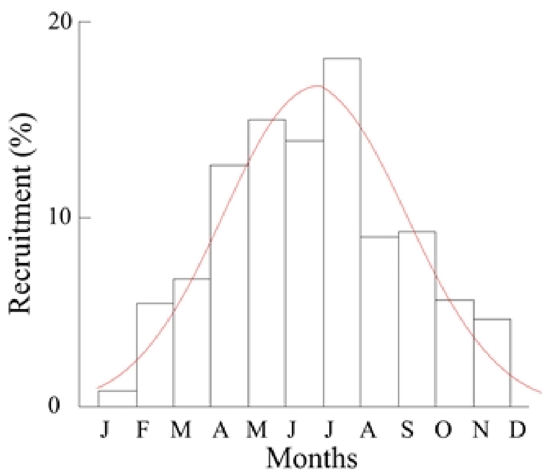


Fig. 5: The recruitment pattern of *Stigmatogobius pleurostigma*.

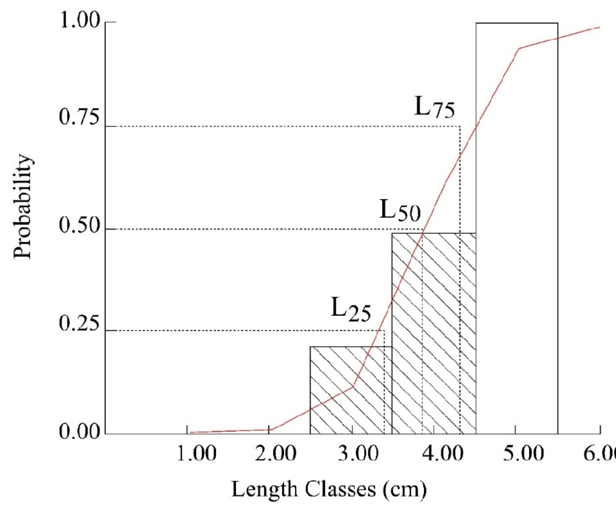


Fig. 6: The probability of capture of *Stigmatogobius pleurostigma* ($L_{25}$ = 3.40, $L_{50}$ = 3.86 and $L_{75}$ = 4.33 cm which was estimated from the logistic transform curve, e.g., red line).

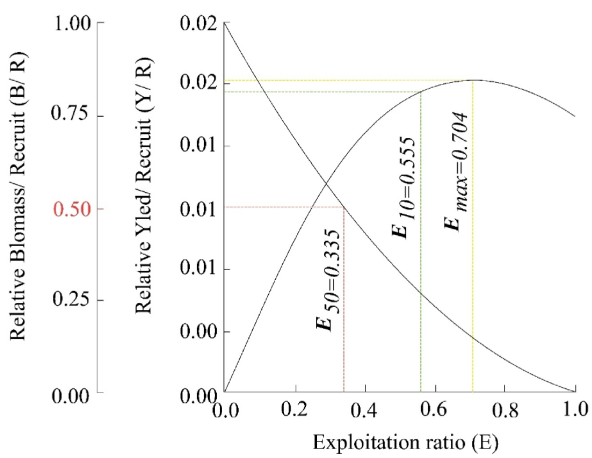


Fig. 7: The relative yield-per-recruit and relative biomass-per-recruit of *Stigmatogobius pleurostigma* ($E_{max}$ = 0.704, $E_{0.1}$ = 0.555 and $E_{0.5}$ = 0.335).

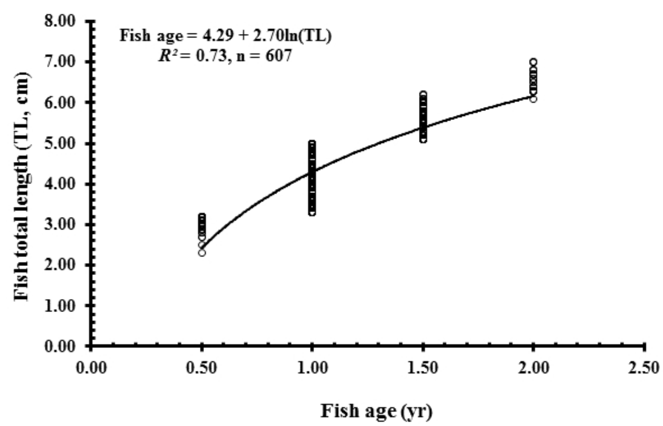


Fig. 8: The relationship between fish total length and age obtained from the length frequency analysis of *Stigmatogobius pleurostigma*.

Tab. 2: Population parameters of some gobiid species.

| Species | $L_\infty$ | K | $t_{max}$ | Z | F | M | $L_c$ | E | Φ' | Fishing gears | Study site | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Periophthalmus barbarus* | 21.60 | 0.55 | 5.45 | 4.21 | 2.86 | 1.35 | 10.2 | 0.68 | 2.41 | Non-return valved basket traps | Nigeria | 1 |
| *Pseudapocryptes elongatus* | 26.00 | 0.65 | 4.35 | 2.91 | 1.47 | 1.44 | 11.75 | 0.51 | 2.64 | Fixed-bag nets | Mekong Delta | 2 |
| *Periophthalmodon schlosseri* | 29.00 | 1.40 | 2.14 | - | - | - | - | - | 3.10 | Hook, cast net and traps | Malaysia | 3 |
| *Parapocryptes serperaster* | 25.52 | 0.74 | 4.05 | 3.07 | 1.57 | 1.51 | 14.6 | 0.49 | 2.67 | Gill nets | Mekong Delta | 4 |
| *Boleophthalmus boddarti* | 16.80 | 0.79 | 3.55 | 2.13 | 0.30 | 1.83 | 12.97 | 0.14 | 2.35 | Gill nets | Mekong Delta | 5 |
| *Glossogobius giuris* | 20. 53 | 0.56 | 5.36 | 3.17 | 1.77 | 1.40 | 7.41 | 0.56 | 2.37 | Gill nets | Mekong Delta | 6 |
| *Glossogobius aureus* | 27.97 | 0.72 | 4.17 | 4.25 | 2.73 | 1.52 | 6.77 | 0.64 | 2.75 | Gill nets | Mekong Delta | 7 |
| *Stigmatogobius pleurostigma* | 8.6 | 0.83 | 3.61 | 3.48 | 1.17 | 2.31 | 3.80 | 0.34 | 1.79 | Gill nets, hands, traps | Mekong Delta | 8 |

$L_\infty$: asymptotic length, *K*: growth parameter, $t_{max}$: maximum age; *Z*: total mortality, *F*: fishing mortality, *M*: natural mortality, $L_c$: length at first capture, *E*: exploitation rate and *Φ'*: growth performance

**Ref: 1)** Etim *et al*., 2002; 2) Tran *et al*., 2007; 3) Mazlan and Rohaya, 2008; 4) Dinh *et al*., 2015b; 5) Dinh *et al*., 2017a; 6) Dinh, 2017a; 7) Dinh *et al*. (2017b); 8) The present study

performance (*Φ'*) obtained from the growth parameter (*K*) and asymptotic length ($L_\infty$) varies with some gobiid species when studying the age and population structure of *P. serperaster*. Similarly, *Φ'* of *S. pleurostigma* was lower than that of other gobiid species living in the same or different habitat such as *P. schlosseri* in Malaysia (Mazlan and Rohaya, 2008), *P. barbarrus* in Nigeria (Etim et al., 2002), *P. elongatus* (Tran *et al*., 2007), *P. serperaster* (Dinh *et al*., 2015b), *G. giruris* (Dinh et al., 2017a), *G. aureus* (Dinh et al., 2017b) and *B. boddarti* (Dinh, 2017a) in the Mekong Delta (Tab. 2). It could be resulted from the lower of $L_\infty$ of *S. pleurostigma* compared to these six gobiid species (Tab. 2).

Like *G. arerus*, the goby *S. pleurostigma* had one recruitment peak, but the former goby reaches a peak in July (Dinh et al., 2017b) whereas the later fish displayed in June. By contrast, some other co-occurring gobiid species show two recruitment peaks such as *P. elongatus* (Tran *et al*., 2007) *P. serperaster* (Dinh *et al*., 2015b), *G. giuris* (Dinh *et al*., 2017a) and *B. boddarti* (Dinh, 2017a). The fish recruitment times could be varied with geographical regions, e.g., *G. aureus* displayed one spawning period in Ben Tre from September to December (Nguyen et al., 2014) but in July in the coastline from Bac Lieu to Soc Trang (Dinh et al., 2017b). The goby *G. giuris*, additionally, spawns twice a year in Mithamoin Haor, Bangladesh (Hossain, 2014) and in the coastline from Bac Lieu to Soc Trang (Dinh *et al*., 2017a) but once in September in the Payra River, Bangladesh (Roy *et al*., 2014), in March in Pakistan (Qambrani *et al*., 2016) and in September in Can Tho City, Vietnam (Pham and Tran, 2013). The longevity of *S. pleurostigma* was higher than that of *P. schlosseri* in Malaysia (Mazlan and Rohaya, 2008) and *B. boddarti* in the Mekong Delta (Dinh, 2017a), but lower than that of other species in the Gobiidae family (Tab. 2). Inversely, the growth constant (*K*) of *S. pleurostigma* was lower than that of *P. schlosseri* in Malaysia (Mazlan and Rohaya, 2008) but higher than that of other gobies in the Gobiidae family (Tab. 2), suggesting that the growth constant could be positively related to the fish longevity.

The environmental conditions at the study site may influence the natural mortality of *S. pleurostigma* more than some co-occurring gobies including *P. elongatus* (Tran et al., 2007), *P. serperaster* (Dinh *et al*., 2015b), *G. giuris* (Dinh *et al*., 2017a), *G. aureus* (Dinh *et al*., 2017b) and *B. boddarti* (Dinh, 2017a) since the natural mortality of *S. pleurostigma* displayed the highest value among them (Tab. 2). Moreover, the difference in fishing gears may lead to the difference in the fishing mortality and length at first capture of *S. pleurostigma* and other gobiid species (Tab. 2).

The stock of *S. pleurostigma* was subjected to overexploitation since its *E* was higher than $E_{50}$. Like this goby species, the stock of two co-occurring goby *G. giuris* and *G. aureus* are overexploited (Dinh *et al*., 2017a; Dinh *et al*., 2017b). The stock of *P. elongatus* (Tran *et al*., 2007), *P. serperaster* (Dinh *et al*., 2015b) and *B. boddarti* (Dinh, 2017a) living in the same habitat, by contrast, have not been overfished. The difference in fishing status among these gobies could be caused by the differences in fishing status, economic value, $L_\infty$ and $L_c$ among them (Tab. 2).

Most of *S. pleurostigma* was caught at the young age (e.g., <1 yr), suggesting the mesh size of fishing gears should be increased for sustainable exploitation. Moreover, the derivation of goby age from the length frequency distributions suggested that length frequency analysis can be used as an alternative for fish age determination. Likewise, the age of two other co-occurring gobies such as *P.*

*elongatus* (Tran, 2008) and *P. serperaster* (Dinh *et al*., 2015b) are also estimated successfully from the length frequency data.

## Conclusion

This species displayed high growth constant and medium longevity, suggesting that it had a potential aquaculture resource. The fish stock was overexploited, and fish age could be estimated from the length frequency distributions in the study region. The fishing gear mesh size should be increased and avoid catching fish during the recruitment period for future sustainable management.

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