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 fishing. The von Bertalanffy growth parameters were \( L_\infty = 8.6 \text{ cm}, K = 0.83 \text{ yr}^{-1}, \) and \( t_0 = -0.07 \text{ yr}^{-1} \) 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 \( E_{\text{max}} = 0.704, E_{\text{cr}} = 0.555 \) and \( E_{\text{so}} = 0.335 \). Four fish age groups were recorded in the present study (0.5\(^\circ\), 1.0\(^\circ\), 1.5\(^\circ\) and 2.0\(^\circ\)). 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 \( E_{\text{so}} \), 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

Bezvort 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 (De Vries 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 *Paracryptes serperaster* (Dinh et al., 2015b). The overexploitation with various fishing gears (Trinh and Tran, 2012) lead to 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.
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).

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 (°C). 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 ($E_{\text{max}}$), 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 ($\Phi' = \log K + 2 \log L_\infty$, 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 $t_{\text{max}} = 3/K$ 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 $S$. pleurostigma 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 $L_t = 8.6 (1 - e^{-0.83 (t+0.07)})$ based on the analysis of the growth increment data performed by using the Bahtachaya procedure (Fig. 3).

**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* ($E_{\text{max}} = 0.704$, $E_{0.1} = 0.555$ 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 gobid species.

<table>
<thead>
<tr>
<th>Species</th>
<th>L∞</th>
<th>K</th>
<th>tmax</th>
<th>Z</th>
<th>F</th>
<th>M</th>
<th>Lc</th>
<th>E</th>
<th>Φ'</th>
<th>Fishing gears</th>
<th>Study site</th>
<th>Ref.</th>
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</thead>
<tbody>
<tr>
<td><em>Periophthalmus barbarus</em></td>
<td>21.60</td>
<td>0.55</td>
<td>5.45</td>
<td>4.21</td>
<td>2.86</td>
<td>1.35</td>
<td>10.2</td>
<td>0.68</td>
<td>2.41</td>
<td>Non-return valved basket traps</td>
<td>Nigeria</td>
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<tr>
<td><em>Pseudocryptops elongatus</em></td>
<td>26.00</td>
<td>0.65</td>
<td>4.35</td>
<td>2.91</td>
<td>1.47</td>
<td>1.44</td>
<td>11.75</td>
<td>0.51</td>
<td>2.64</td>
<td>Fixed-bag nets</td>
<td>Mekong Delta</td>
<td>2</td>
</tr>
<tr>
<td><em>Periophthalmodon schlosseri</em></td>
<td>29.00</td>
<td>1.40</td>
<td>2.14</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3.10</td>
<td>Hook, cast net and traps</td>
<td>Malaysia</td>
<td>3</td>
<td></td>
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<tr>
<td><em>Parapocryptops serperaster</em></td>
<td>25.52</td>
<td>0.74</td>
<td>4.05</td>
<td>3.07</td>
<td>1.57</td>
<td>1.51</td>
<td>14.6</td>
<td>0.49</td>
<td>2.67</td>
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<td>Mekong Delta</td>
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<tr>
<td><em>Boleophthalmus boddarti</em></td>
<td>16.80</td>
<td>0.79</td>
<td>3.55</td>
<td>2.13</td>
<td>0.30</td>
<td>1.83</td>
<td>12.97</td>
<td>0.14</td>
<td>2.35</td>
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<td>Mekong Delta</td>
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<tr>
<td><em>Glossogobius giuris</em></td>
<td>20.53</td>
<td>0.56</td>
<td>5.36</td>
<td>3.17</td>
<td>1.77</td>
<td>1.40</td>
<td>7.41</td>
<td>0.56</td>
<td>2.37</td>
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<td>Mekong Delta</td>
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<tr>
<td><em>Glossogobius aureus</em></td>
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<td>0.72</td>
<td>4.17</td>
<td>4.25</td>
<td>2.73</td>
<td>1.52</td>
<td>6.77</td>
<td>0.64</td>
<td>2.75</td>
<td>Gill nets</td>
<td>Mekong Delta</td>
<td>7</td>
</tr>
<tr>
<td><em>Stigmatogobius pleurostigma</em></td>
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<td>3.48</td>
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<td>0.34</td>
<td>1.79</td>
<td>Gill nets, hands, traps</td>
<td>Mekong Delta</td>
<td>8</td>
</tr>
</tbody>
</table>


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∞) varies with some gobid species when studying the age and population structure of *P. serperaster*. Similarly, Φ' of *S. pleurostigma* was lower than that of other gobid species living in the same or different habitat such as *P. schlosseri* in Malaysia (Mazlan and Rohaya, 2008), *P. barbarus* in Nigeria (Etim et al., 2002), *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) in the Mekong Delta (Tab. 2). It could be resulted from the lower of L∞ of *S. pleurostigma* compared to these six gobid species (Tab. 2).

Like *B. arerus*, the goby *S. pleurostigma* had one recruitment peak, but the former gobey reaches a peak in July (Dinh et al., 2017b) whereas the later fish displayed in June. By contrast, some other co-occurring gobid 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 gobid species (Tab. 2).

The stock of *S. pleurostigma* was subjected to overexploitation since its E was higher than E∞. 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∞ and Lc 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.*


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