Population structure of *Periophthalmodon schlosseri* (Perciformes: Gobiidae) in Soc Trang province, Vietnam

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Abstract. *Periophthalmodon schlosseri* is a species of goby and which is considered to be a commercial fish, yet little data on its population structure is known, especially in the Mekong Delta (Vietnam) where the fish is caught increasingly as a food source. This study, therefore, was conducted to document its population biological parameters. Specimens were caught monthly, from July 2017 to June 2019 using traps and hands along the muddy flats and the mangroves of the forest regions. The length-frequency analysis of 920 individuals, of which 497 were females and 423 males, shows that the von Bertalanffy growth curve of this fish was $L_t=29.4(1-e^{-0.95[t+0.19]})$ and six fish groups were determined. The average length at first capture was 16.0 cm, and the exploitation rate was 0.580. Its longevity and growth performance are 3.16 yr in and 2.91, respectively. The mortality rates of the fish population, including natural mortality, fishing mortality, and total mortality inferred from length-converted catch curve, were 1.81 yr^{-1}, 2.62 yr^{-1}, and 4.43 yr^{-1}, respectively. The values E_{max} = 0.715, $E_{0.1}$ = 0.609 and E_{50} = 0.380 are obtained from yield and biomass per recruit analysis. With a high growth rate of 0.95 yr^{-1}, the species is a potential aquaculture candidate. The goby stock is overfished since its exploitation rate was higher than E_{50}. For sustainable exploitation, fish caught should be over 16 cm in total length.
Key Words: exploitation rate, growth, mortality, overexploitation.

Introduction. Fisheries management is related to the exploitation rate that is estimated from the yield-per-recruit analysis documented by Beverton and Holt (1957). Ricker (1975) showed that growth and mortality parameters are used to assess the fish population. The sexual and spatial variations of fish growth rate have a strong relationship with a combination of growth and asymptotic length analysis (namely growth performance), as reported by Pauly and Munro (1984). In the Mekong Delta, the data on population parameter are presented for some gobiid species, which are diversified (Tran & Dinh 2020). Moreover, the population of some gobies like *Glossogobius giuris* (Dinh et al 2017) and *Boleophthalmus boddarti* (Dinh 2017) have been subjected to overfishing because of the fishing pressure with a variety of fishing tools (Trinh & Tran 2012; Diep et al 2014). Therefore, studies of the population dynamics of the gobiid species should be conducted because they are useful for fishery management.

There are three species in the genus *Periophthalmodon* (Larson 2005); nonetheless, only two species – *Periophthalmodon schlosseri* and *Periophthalmodon septemradiatus* – of this genus are recorded in the Mekong Delta, Vietnam (Tran et al 2013). *Periophthalmodon schlosseri* is an amphibious fish (Clayton 1993), belonging to the family Gobiidae (Larson 2005). In the Indo-Pacific region, it appears widely from brackish to marine waters, mainly in the mangrove swampland (Larson 2005; Tran et al 2013; Froese & Pauly 2019). This fish can use its skin for respiration (Zhang et al 2003). It is also a commercial fish (Ip et al 1990). *Periophthalmodon schlosseri*, during the spawning season, constructs burrows in the estuarine mudflats as a place of refuging, storing oxygen, and laying eggs (Ishimatsu et al 1998; Ishimatsu et al 1999; Ishimatsu et al 2009). Data on age structure, growth patterns and reproductive traits are documented by Mazlan and Rohaya (2008). The slope value (b) in the length-weight relationship of this goby is close to three in Malaysia and Vietnam, displaying isometric growth pattern (Khaironizam & Norma-Rashid 2002; Dinh 2016), but lower than three in Bangladesh, showing negative allometric growth pattern (Saha 2013).

In Vietnam, the species *P. schlosseri* is distributed from Can Gio to Mui Ca Mau (Tong et al 2012; Tran et al 2013). It plays an essential part as a food supply and is increasingly caught in the Mekong Delta (Tran et al 2019a; Tran et al 2019b); however, little is known about this fish, including growth pattern (Dinh 2016), feeding habit (Tran et al 2019a), and reproductive season (Tran et al 2019b) and burrow structure (Tran et al 2020). Yet, data on the population biology of this fish, especially in the Mekong Delta, where the population of this species is decreasing (Dinh 2016; Tran et al 2019a; Tran et al 2019b), are limited. Consequently, the present study was conducted to provide new data on biological features to understand fish stocks and their management.

Material and Method

Study site, fish collection, and analysis. This study was carried out in Tran De District, Soc Trang Province, Vietnam, for two years from July 2017 to June 2019. There were two seasons in the studied site, including the dry season (January-May) with little rain and the wet season (June-November) with average monthly precipitations of ~400 mm. The average annual temperature in the studied region is ~27°C. These characteristics represent the natural environment in the Mekong Delta (Le et al 2006).

Fish specimens were collected monthly using traps and hands along the mudflats and mangroves from 9°26'28.0"N 106°11'03.0"E to 9°28'59.1"N 106°12'25.7"E. After visual identification based on external fish morphology (Tran et al 2013), fish specimens were stored in 4% formalin fluid and carried to the laboratory. In the laboratory, *P. schlosseri* specimens were sexed according to its genital papilla morphology, which is round in females and triangular in males (Dinh 2016). The morphometry criteria of fish, including total length (0.1 cm) and weight (0.01 g) were measured.

Data analysis. The fish length frequency data was analyzed using FiSAT II to estimate the population biological parameters (Gayanilo et al 2005). The asymptotic fish length ($L\infty$) and the growth parameter (K) were calculated using ELEFAN I (Pauly & David 1981; Pauly 1982; Pauly 1987). To estimate the fish total mortality rate (Z), the length-converted catch curve was applied (Beverton & Holt 1957; Ricker 1975). According to Pauly (1979) and Pauly (1980), the theoretical age parameter (t0) when the fish was zero in length is calculated from the equation

$$log_{10}(-t_0) = -0.3922 - 0.2752\, log_{10} L_\infty - 1.038\, log_{10} K$$

and M is estimated from the empirical formula

$$\text{Log}M = -0.0066 - 0.279\text{Log}L_\infty + 0.6543\text{Log}K + 0.463\text{Log}T$$

(T was the average yearly water temperature (°C)). In the studied region, the above equation was obtained to estimate the natural mortality rate (M). Consequently, according to Ricker (1975), the fishing mortality (F) was calculated as F = Z – M, and the exploitation rate (E) was determined as E = F/Z.

The cumulative probability of capture was used to calculate the fish length at first capture (L50). In order to estimate the fish stock and yield, the yield-per-recruit model of Beverton and Holt (1957) was applied according to Sparre and Venema (1992). Beverton and Holt (1966) stated that the knife-edge selection E_{max} (the maximum exploitation rate), $E_{0.1}$ (the 10% minimal increase of exploitation rate of Y'/R), and $E_{0.5}$ (the reduction of stock to 50%) were estimated based on the knife-edge selection. Pauly and Soriano (1986) stated that the combined analysis of E and isopleth ratio ($Lc/L\infty$) was used to determine the fishing status. The *P. schlosseri*'s von Bertalanffy growth parameters were referenced to other fishes who live in and out of the Mekong Delta based on the growth performance ($\Phi' = LogK + 2LogL\infty$) (Pauly & Munro 1984). The longevity (tmax) of P. schlosseri was calculated using the following formula (Taylor 1958; Pauly 1980):

$$t_{max} = \frac{3}{K}$$

Results

The fish length ranged from 8.0 cm to 29.0 cm, with most fish lengths being between 16.0-22.0 cm (83.26%). Fish weight ranged from 6.95 to 219.07 g, with most fish weights ranging between 30.00 to 90.00 g (73,69%). The average length and weight of P. schlosseri fluctuated by month, ranging from 16.0±0.2 cm and 41.74±1.56 g to 22.4±0.3 cm and 113.77±6.14g (Table 1). There were six groups categorized by sizes (e.g., six growth curves or blue lines in Figure 1) in the population of P. schlosseri based on the length-frequency analysis of 920 individuals (497 females and 423 males, Table 2). As the growth curve of the bigger fish group was slighter than that in the smaller ones, the smaller fish grew slightly faster than the bigger fish group. The von Bertalanffy growth curve of P. schlosseri was $L_t=29.4(1-e^{-0.95[t+0.19]})$ based on the analysis of the growth increment data.

Table 1

Length and weight of *P. schlosseri*

Month	*No. of fish*	*Weight (Mean±SE g)*	*Total length (Mean±SE cm)*
7/2017	19	52.41±1.47	17.3±0.2
8/2017	22	58.51±1.34	18.1±0.1
9/2017	16	64.08±3.64	19.4±0.4
10/2017	31	107.17±4.14	22.4±0.3
11/2017	35	76.01±2.37	19.8±0.3
12/2017	51	56.53±5.34	17.0±0.6
1/2018	32	61.10±4.32	18.1±0.4
2/2018	19	66.60±3.18	19.0±0.3
3/2018	29	72.61±2.37	19.6±0.2
4/2018	31	63.54±3.30	18.5±0.4
5/2018	42	75.80±3.50	20.0±0.3
6/2018	38	74.15±4.38	20.1±0.6
7/2018	31	113.77±6.14	22.4±0.3
8/2018	62	44.14±3.48	15.7±0.3
9/2018	74	41.74±1.56	16.0±0.2
10/2018	44	48.80±2.82	17.0±0.3
11/2018	42	59.24±3.00	18.3±0.3
12/2018	42	60.29±3.71	18.2±0.4
01/2019	40	75.98±4.20	19.6±0.4
02/2019	36	61.85±4.44	18.3±0.5
3/2019	47	69.82±3.11	19.4±0.3
4/2019	45	52.95±3.37	17.5±0.4
5/2019	37	47.37±2.51	17.2±0.3
6/2019	55	45.40±2.10	17.0±0.3

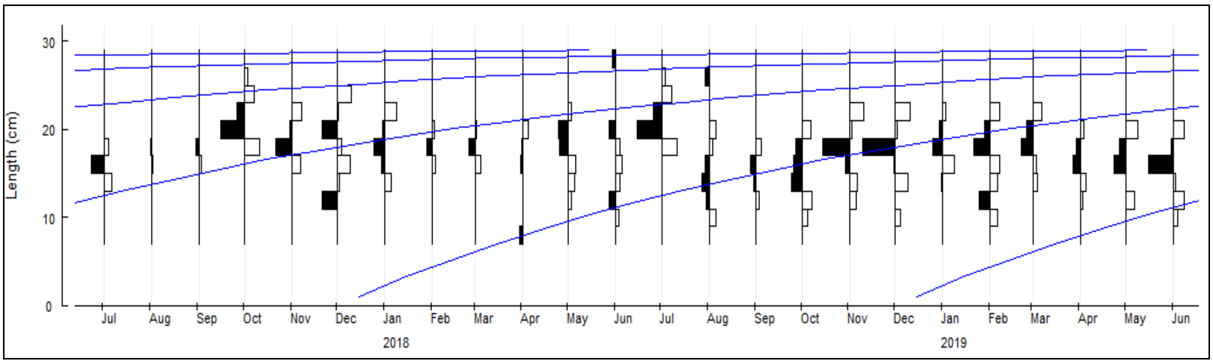

Figure 1. Length-frequency distribution of *P. schlosseri* (n=920, the curves show the increase of fish length over time).

Table 2

The number of *P. schlosseri* collected from the study site from July 2017 to June 2019

TL(cm) / *Month*	*8-10*	*10-12*	*12-14*	*14-16*	*16-18*	*18-20*	*20-22*	*22-24*	*24-26*	*26-28*	*28-30*	*Total*
07/2017				1	15	3						19
08/2017					9	13						22
09/2017					4	7	5					16
10/2017						1	15	10	3	2		31
11/2017					4	17	11	3				35
12/2017		6	12	7	3	6	11	5	1			51
01/2018			3		8	10	7	1				29
02/2018				3	4	10	5					22
03/2018					4	16	9					29
04/2018	1				12	11	7					31
05/2018			1	2	3	13	17	6				42
06/2018		1	3	2	2	5	15	9			1	38
07/2018						1	15	10	3	2		31
08/2018		2	15	20	17	6	1			1		62
09/2018			12	22	31	9						74
10/2018		2	2	13	12	13	2					44
11/2018			2	4	10	19	6	1				42
12/2018	1	1	3	2	8	20	6	1				42
01/2019				6	2	15	11	6				40
02/2019		1	4	3	3	13	10	2				36
03/2019				4	7	17	16	3				47
04/2019			5	5	15	14	6					45
05/2019			2	8	13	13	1					37
06/2019		2	3	9	25	13	3					55
Total	2	15	67	111	211	265	179	57	7	5	1	920

The total, natural, and fishing mortalities obtained from the analysis of length-converted catch curve and Pauly's empirical formula were 4.43, 1.81, and 2.62, respectively (Figure 2). The capture probability procedure analysis showed that the fish species' exploitation rate was 0.580, and length at first capture was 16.0 cm (Figure 3).

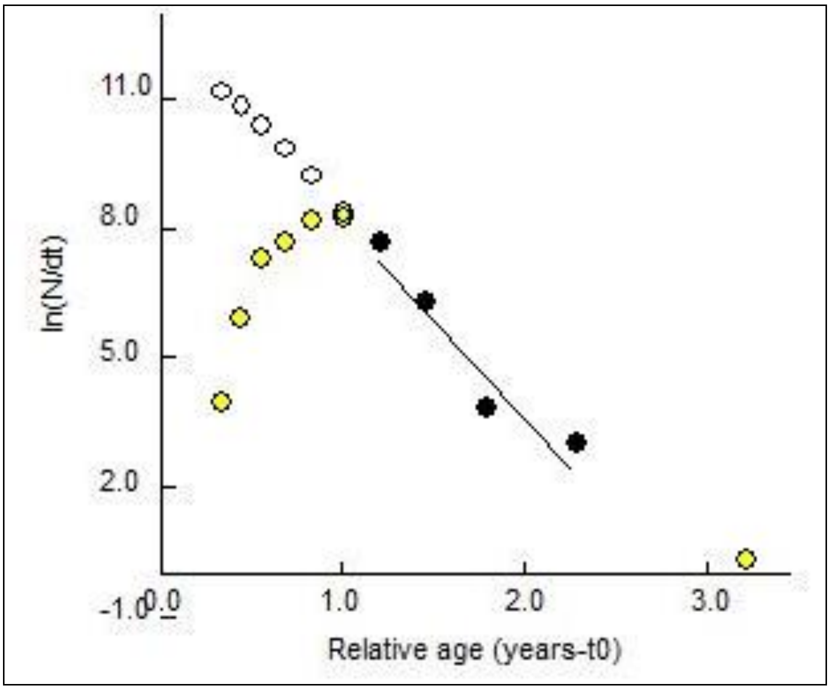

Figure 2. The length converted catch curve of *P. schlosseri* (Z=4.43, M=1.81, F=2.62).

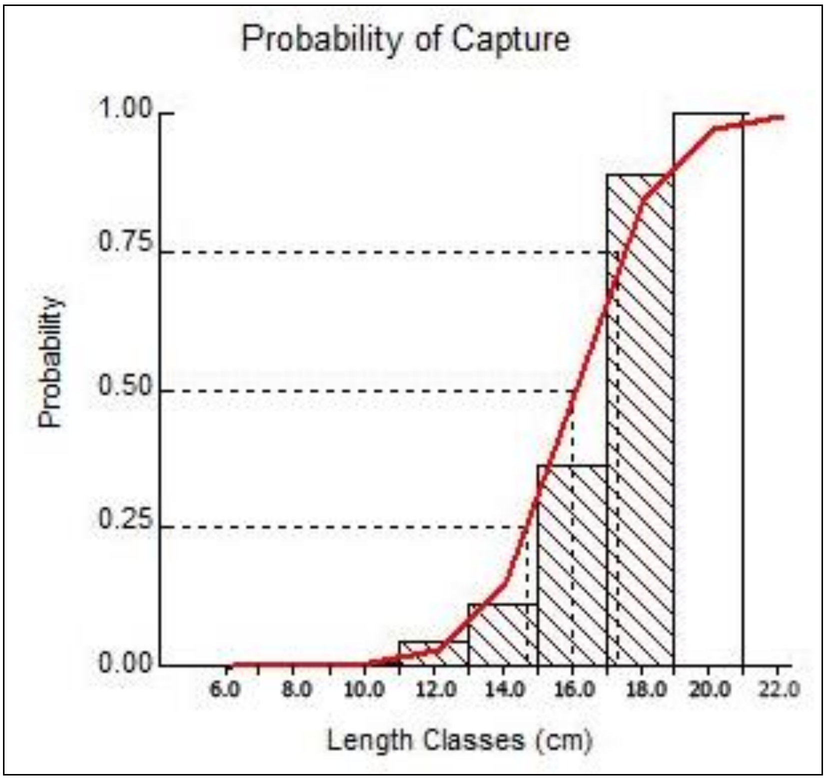

Figure 3. The probability of capture of *P. schlosseri* (L_{25} = 14.7, L_{50} = 16.0 and L_{75} = 17.3).

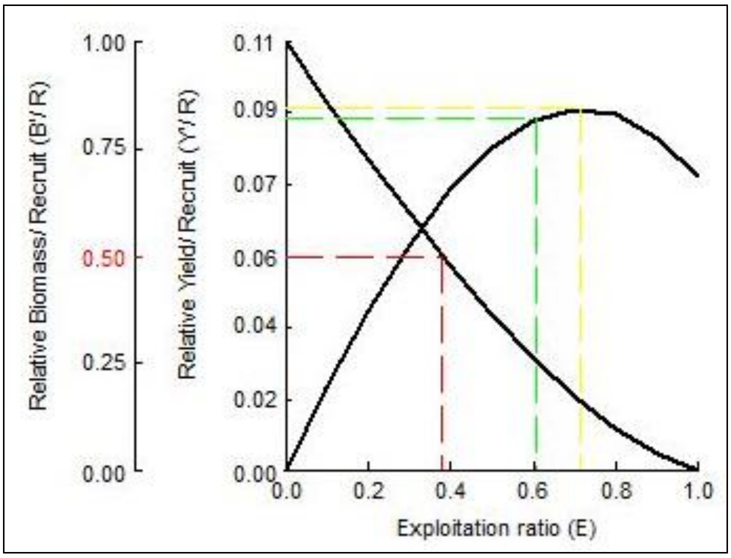

Figure 4. The Y'/R and B'/R of *P. schlosseri* (E_{max} = 0.715, $E_{0.1}$ = 0.609 and $E_{0.5}$ = 0.380).

Combined analysis of the Y'/R and B'/R procedure of goby P. schlosseri showed $E_{0.1}$ = 0.609, $E_{0.5}$ = 0.380 and E_{max} = 0.715 (Figure 4). The species displayed 2.91 in the growth performance and 3.16 yr in the longevity, respectively.

Discussion

Pauly and Munro (1984) reported that growth performance (Φ') of fish varies between locations. Indeed, Φ' of *P. schlosseri* was lower than that of a gobiid species living in Malaysia (Mazlan & Rohaya 2008) (Table 3). The Φ' of *P. schlosseri* differed from those of some other gobies occurring in and out of the Mekong Delta. For example, this value was higher than that of *P. septemradiatus* (Tran & Dinh 2020), *Parapocryptes serperaster* (Dinh et al 2015), *Boleophthalmus boddarti* (Dinh 2017), *Glossogobius giruris* (Dinh et al 2017), *Butis butis* (Dinh 2018) and *Stigmatogobius pleurostigma* (Dinh & Nguyen 2018) in the Mekong Delta (Table 3). It could result from the higher L_∞ of *P. schlosseri* compared to these gobiid species (Table 3).

The longevity of *P. schlosseri* in the present study was higher than that of *P. schlosseri* in Malaysia (Mazlan & Rohaya 2008), but lower than that of other species in the Gobiidae family (Table 3). Specifically, this value was lower than that of *P. septemradiatus* (Tran & Dinh 2020), *P. serperaster* (Dinh et al 2015), *B. boddarti* (Dinh 2017), *G. giruris* (Dinh et al 2017), *B. butis* (Dinh 2018) and *S. pleurostigma* (Dinh & Nguyen 2018) in the Mekong Delta (Table 3). However, the growth constant (K) of *P. schlosseri* was lower than that of this species in Malaysia, but higher than that of other gobies shown in Table 3. This suggests that the growth constant could be oppositely related to fish longevity.

P. schlosseri has a high economic value, so it is heavily exploited, and the death rate due to exploitation (F=2.62) is higher than the natural death rate (M=1.81). The natural mortality is species-specific as this value changes with fish species, e. g., natural mortality of *P. schlosseri* in the present study is higher than co-habitant gobies such as *P. serperaster* (Dinh et al 2015), *G. giuris* (Dinh et al 2017), *B. butis* (Dinh 2018), and *S. pleurostigma* (Dinh & Nguyen 2018) (Table 3). The variety of fishing gear might lead to the differences in the fishing mortality and length at first capture of *P. schlosseri* and other gobiid species (Table 3).

The stock of *P. schlosseri* was subjected to over-exploitation since its E value was higher than E50. Likewise, some goby species are also overexploited, such as *G. giuris* (Dinh et al 2017), *B. butis* (Dinh 2018), and *S. pleurostigma* (Dinh & Nguyen 2018). Contrary, the stock of other goby species living in the Mekong Delta comprising *P.*

septemradiatus (Tran & Dinh 2020), *P. serperaster* (Dinh et al 2015), and *B. boddarti* (Dinh 2017) are not subjected to overexploitation. The dissimilarity of the fishing status of these gobies could be related to the variations in fishing preferences and their economic value of L∞ and Lc shown in Table 3.

Table 3

Population parameters of some gobiid species

Species	*L∞*	*K*	*tmax*	*F*	*M*	*Z*	*Lc*	*Lc/L∞*	*E*	*Φ'*	*Gears*	*Place*	*Authors*
Periophthalmodon schlosseri	29.0	1.40	2.14	-	-	-	-	-	-	3.10	Hook, cast net and traps	Malaysia	Mazlan and Rohaya (2008)
Parapocryptes serperaster	25.5	0.74	4.05	1.57	1.51	3.07	14.6	0.57	0.49	2.67	Gill nets	Mekong Delta	Dinh et al. (2015)
Boleophthalmus boddarti	16.8	0.79	3.55	0.30	1.83	2.13	13.0	0.77	0.14	2.35	Gill nets	Mekong Delta	Dinh (2017)
Glossogobius giuris	20.5	0.56	5.36	1.77	1.40	3.17	7.4	0.36	0.56	2.37	Gill nets	Mekong Delta	Dinh et al. (2017)
Butis butis	24.0	0.61	4.92	1.98	1.42	3.40	10.5	0.44	0.58	2.55	Gill nets	Mekong Delta	Dinh (2018)
Stigmatogobius pleurostigma	8.6	0.83	3.61	1.17	2.31	3.48	3.8	0.44	0.34	1.79	Gill nets, hands, traps	Mekong Delta	Dinh and Nguyen (2018)
Periophthalmodon septemradiatus	12.6	0.68	4.41	0.39	1.82	2.21	7.0	0.55	0.18	2.03	Traps, hands	Mekong Delta	Tran and Dinh (2020)
	12.6	0.55	5.46	1.27	1.59	2.86	8.0	0.64	0.44	1.94			
	12.6	0.49	6.12	0.22	1.46	1.68	7.7	0.61	0.13	1.89			
	12.6	1.10	2.73	1.58	2.47	4.05	9.5	0.76	0.39	2.24			
	12.6	1.60	1.88	0.97	3.14	4.11	9.2	0.73	0.24	2.41			
Periophthalmodon schlosseri	29.4	0.95	3.16	2.62	1.81	4.43	16.0	0.54	0.59	2.91	Traps, hands	Mekong Delta	The present study

Fish were firstly caught at 16.0 cm total length that was shorter than the length at first maturity (Lm), which was 19.3 cm for females and 21.1 cm for males reported by Tran et al (2019b). Additionally, the majority of fish were collected during the wet season, which is the main spawning season (Tran et al 2019b), at a length that was lower than Lm. Thus, to sustainably manage this fishery resource in the future, it is necessary to increase the mesh size of fishing gear and limit fishing during the spawning period.

Conclusions. The von Bertalanffy growth parameters of *P. schlosseri* were L∞ = 29,4 cm, K = 0.95 yr^{-1}, and t_0 = -0.19yr^{-1}. The average length at first capture was 16.0 cm, and the exploitation rate was 0.580. Its longevity was 3.16 yr and its growth performance was 2.91. The natural, fishing, and total mortalities of *P. schlosseri* population were 1.81 yr^{-1}, 2.62 yr^{-1}, and 4.43 yr^{-1}, respectively. With a high growth rate, this species has potential for future aquaculture studies. This species population has been subjected to overexploitation as its exploitation rate was higher than E_{50}, suggesting that fishing gear mesh size should be increased, and fishing should not be conducted in the spawning period.

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