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Original article

First report on reproductive features of the Flathead Sillago *Sillaginopsis panijus* (Hamilton 1822) from the Bay of Bengal (Southern Bangladesh) in relation to eco-climatic factors

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ABSTRACT

The Flathead Sillago, *Sillaginopsis panijus* is a prominent marine species in the Indian subcontinent. Our study describes the reproductive biology of *S. panijus* through monthly sampling of 511 female specimens from the Bay of Bengal (southern Bangladesh) during 2021. Further, our research observed the consequence of eco-climatic factors (dissolved oxygen, pH, water temperature and rainfall) on the reproductive behavior of *S. panijus*. For individual specimen, total length (TL) and body weight (BW) were measured. Gonads were separated cautiously from the specimens and weighed. In order to determine sexual maturity size (L_m) and spawning season; the gonadosomatic index (GSI %), modified gonadosomatic index (MGSI %) and Dobriyal index (DI) were calculated. On the basis of above indices, L_m was estimated 19.0 cm TL. Furthermore, the TL_{50} was documented by logistic model as 19.0 cm TL. In addition, *S. panijus* spawns throughout the year while peak spawning occurs in August and October. We found no significant correlation between GSI and different eco-climatic factors. The outcomes of the investigation would be crucial to apply suitable management strategy for *S. panijus* in the Bay of Bengal and adjoining ecosystem.

Introduction

Presently fish is considered the main source of protein for worldwide population (Roy et al. 2020). The widespread necessity of fish protein causes immense fishing pressure on their natural ecosystem (Panhwar et al. 2013), particularly in the open-water environment. Therefore, fisheries resources are now classified as inadequate renewable resource (Sabbir et al. 2021a). The flathead sillago *Sillaginopsis panijus* is a marine demersal fish species (Riede 2004) under the family Sillaginidae. Typically, this Sillaginid prefers shallow muddy bays and found abundantly in the marine water of Bangladesh (Sabbir et al. 2021b). Further, *S. panijus* is distributed in western Indian Ocean, Ganges delta, Myanmar and Malaysia (Talwar and Jhingran 1991). Locally *S. panijus* is called Tular Dandi. Besides, this is a commercially important fish species in the context of Bangladesh. This species is an important source of both protein and micronutrient which is essential to prevent malnutrition and vitamin deficiency for the vulnerable rural coastal community of Bangladesh. Due to lack of captive breeding, *S. panijus* is usually harvested from marine ecosystem. Therefore, overfishing is considered the main threat for the wild stock (Sabbir et al. 2020; Sabbir et al. 2021c; Sabbir et al. 2022). Moreover, *S. panijus* is an important earning source for both large-scale and subsistence fisherman in the coastal region of Bangladesh who use multiple local gears like gill net.

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The government of Bangladesh usually imposes a 65 days ban on marine fishing during 20 May to 23 July to boost up the reproduction of standing stocks of fish and crustaceans since 2019 (DoF 2019). But the spawning period of maximum fauna is not yet determined in the Bay of Bengal. On the other hand, marine fisher folks always protest against the time of banning period, as the monsoon fishing activities is typically occurs during June to September in Bay of Bengal ecosystem (Sabbir et al. 2021d) and fishing is the main source of their livelihood. Therefore, without additional income source, this obligatory ban period will definitely lead the coastal and marine fishermen into the poorest situation.

In order to apply appropriate fisheries management policy, information about reproductive biology of fish is primary concern. King (2007) specified that knowledge of reproduction is crucial to understand the population dynamics of fish in an open-water ecosystem and to formulate appropriate management policy. Further, suitable management of commercially significant fish species totally rely on the regenerative capability of a particular fish population together with their reproductive behavior (Tracey et al. 2007). Replenishment and conservation of commercially important fish species largely depend on successful reproduction (Hossain et al. 2017). Knowledge about the sexual maturity size of fish is important to determine minimum permissible capture size (Hossain et al. 2017). Besides, stock assessment models exclusively rely on the sexual maturity size to ensure suitable management of fish population in a particular ecosystem (Tracey et al. 2007), particularly in developing nations like Bangladesh, where fishers depend on first maturity size as well as the beginning and duration of spawning period for the management of commercially important fisheries resources (Hossain et al. 2013). In spite of the significance of fish reproductive biology, the scarcity of data in several nations not only leads to overfishing of the wild stock but also results management failure in many cases (Kinas 1996). Therefore, information on gonadosomatic index (GSI), sexual maturity size as well as spawning period are crucial for fish reproductive research (Khatun et al. 2019).

Assessment of biological and environmental parameters influencing the reproductive biology of fish population is notably important to identify the susceptibility of a wild stock in the context of climate change (Sabbir et al. 2021d). Fluctuations of temperature exclusively influence the spawning timing of various fish population (Pankhurst and Munday 2011). Similarly, rainfall influences the spawning behavior of fish population by reducing the water temperature (Ahamed et al. 2018). Besides, fish reproduction in a specific ecosystem is influenced by a number of ecological factors *i.e.*, dissolved oxygen (DO), photoperiod, salinity and pH (Sabbir et al. 2021d). To maintain sound metabolic activities of fish it is essential to maintain an optimum DO level. Additionally, pH is responsible for acidic/alkaline nature of an aquatic ecosystem. Higher pH level (> 9) not only denature the cell membrane of fish but also alter various water quality parameters (Brown and Sadler 1989) that may affect fish reproduction.

Nevertheless, a good number of researches were carried out about morphometric relationship (Sabbir et al. 2021a) and biometry of *S. panijus* (Islam et al. 2012; Hossain et al. 2015; Pradhan et al. 2020; Siddik et al. 2015; Sabbir et al. 2022). Demographic information about reproductive biology with year round data is absent in literature. Therefore, our study described first-time the reproductive behavior of *S. panijus* in the Bay of Bengal (southern Bangladesh) in relation to eco-climatic factor.

Materials and methods

Fish identification and sampling

A total of 511 female individuals of *S. panijus* were harvested through monthly basis from the Bay of Bengal (southern Bangladesh) during 2021 (Fig. 1). The specimens were instantly kept in 5% formalin solution to prevent spoilage and decomposition. Thereafter, females were identified by microscopic observation of gonad.

Fish measurement

Specimens were washed carefully and excess moisture was removed with blotting paper to ensure the exact body weight. For individual specimen, total length (TL) and body weight (BW) were measured. Similarly, gonads were separated cautiously from the specimens and weighed.

First sexual maturity size (L_m) and spawning period

Multiple reproductive indices were used to determine L_m as (i) gonadosomatic index (GSI) *vs.* TL; (ii) modified gonadosomatic index (MGSI) *vs.* TL; and (iii) Dobriyal index (DI) *vs.* TL. The GSI was

calculated following the equation of Nikolsky (1963) as GSI (%) = (GW/BW) x 100. MGSI was determined using the formula of Nikolsky (1963) as MGSI = (GW/BW-GW) x 100. Besides, DI was determined with the equation of Dobriyal et al. (1999) as DI $=\sqrt[3]{GW}$. Additionally, TL_{50} was calculated following the logistic curve of King (2007) as PMI = 100/[1+ exp{$-f$ (TL_m -TL_{50})}] where, f is the growth coefficient and TL_m is the median of each TL class. Nevertheless, all mature fish do not spawn at a time. Therefore, PMI never exceeded 100% even in the largest TL class. Similarly, spawning and peak spawning period were determined with higher values of GSI, MGSI, and DI.

Eco-climatic factors

Water quality parameters were collected monthly basis following APHA (2005) procedure to observe the effect of eco-climatic factors on GSI of female *S. panijus* from the sampling site.The parameters were DO (mg/l), pH and water temperature (°C). An accurate time was maintained (8.00 am to 9.00 am) while recording water quality parameters. Further, rainfall data were documented monthly basis from the meteorological department of Khulna, southern Bangladesh.

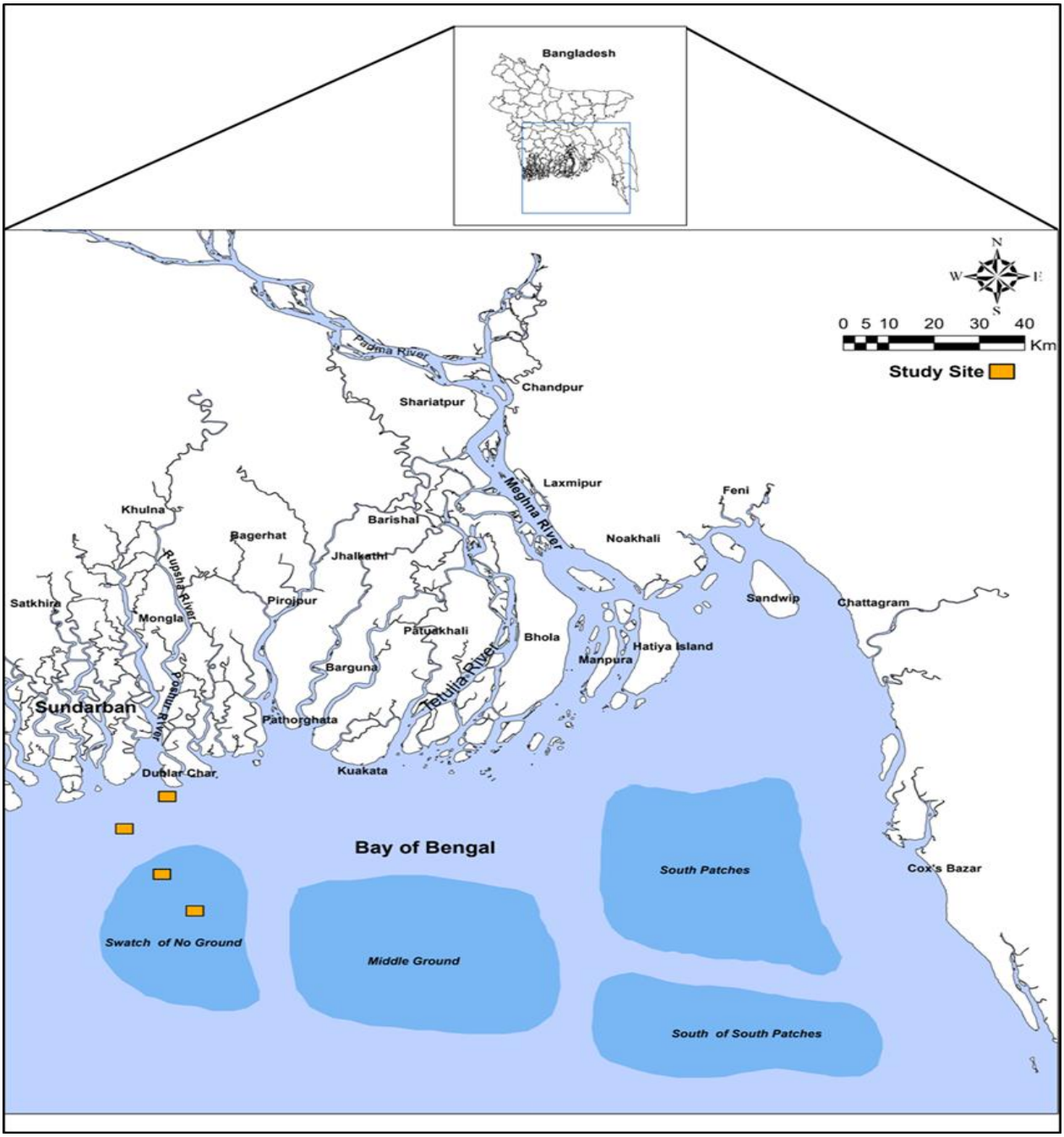

Fig. 1 The study site in the Bay of Bengal, Bangladesh (Rectangle shapes indicate the sampling sites)

Statistical analyses

GraphPad Prism and Microsoft Excel software were used to analyze the data. Moreover, Spearman rank test was applied to identify the influence of eco-climatic factors on GSI. Statistical analyses were conducted with 5% significance level.

Results

All together 511 female individuals were collected from commercial fishermen during January to December 2021. TL varied from 11.5 to 37.0 cm, BW 10.57 to 368.49 g and GW 0.01 to 11.08 g (Table 1).

Eco-climatic factor

During the study period four eco-climatic parameters (dissolve oxygen, pH, temperature and rainfall) were recorded to observe their impact on gonadal development of *S. panijus*. But no significant relation was found between the environmental factors and GSI (Table 2; Fig. 5).

Discussion

Information about fish maturity is essential to manage an exploited wild stock (Rahman et al. 2018). Moreover, it is important to have sufficient knowledge

Table 1. Descriptive statistics on the total length (cm), body weight (g), and gonad weight (g) measurements of *Sillaginopsis panijus* in the Bay of Bengal (southern Bangladesh)

Characters	*n*	Min	Max	Mean ± SD	95% CL
Total length (cm)	511	11.50	37.00	21.80 ± 5.04	21.36 - 22.24
Body weight (g)		10.57	368.49	69.43 ± 56.16	64.55 - 74.30
Gonad weight (g)		0.01	11.08	0.39 ± 1.08	0.30 - 0.49

n, sample size; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit

Sexual maturity size (L_m)

Correlation between TL *vs.* GSI, MGSI and DI of female *S. panijus* were revealed in Fig. 2. GSI, MGSI and DI index were found lower (< 0.91, < 0.96 and < 0.65) for female population smaller than19.0 cm TL. Nevertheless, these reproductive indices rose sharply at around 19 cm TL. Additionally, the correlation between TL and the percentage of mature female specimens were specified with the logistic model (Fig. 3). According to logistic model, 50% fishes were matured at the length 19.0 cm (TL). Therefore, based on the above four models, the anticipated size at sexual maturity was around 19.0 cm TL.

Spawning season

Monthly changes of reproductive indices for *S. panijus* were shown in Fig. 4. According to these indices the species usually spawns throughout the year. The minimum value of the GSI, MGSI and DI were documented during January to July. Furthermore, the maximum values were observed from August to December. Moreover, the highest value of the reproductive indices were noted in August and October which indicated the peak breeding seasons for *S. panijus*.

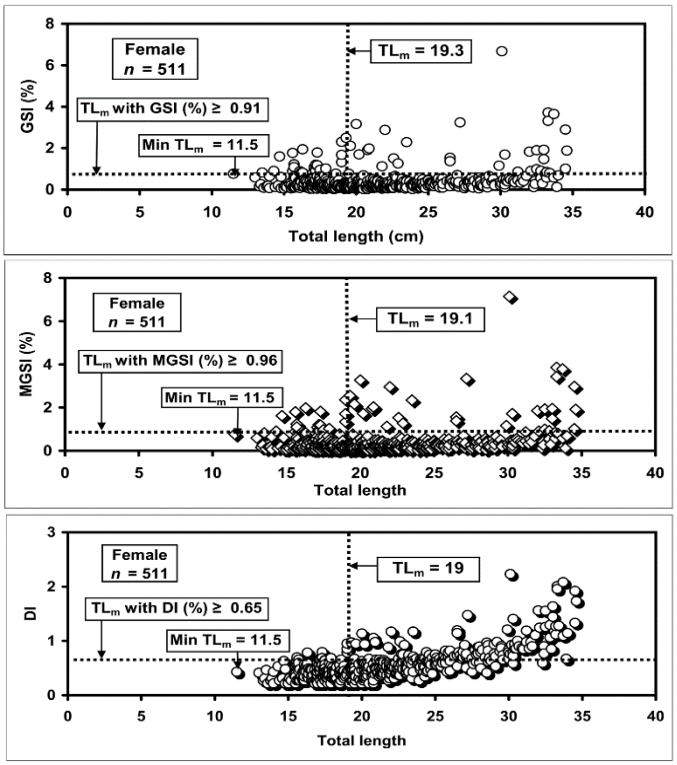

Fig. 2 Relationship between gonadosomatic index (GSI), modified gonadosomatic index (MGSI) and Dobriyal index (DI) with total length of female *Sillaginopsis panijus* in the Bay of Bengal (southern Bangladesh)

about fish reproductive behavior to evaluate the life cycle of a particular fish stock (Hossain et al. 2017). Stock assessment models are significantly reliant on reproductive biology of fish (Tracey et al. 2007). In order to determine the maturation status of fish, microscopic and biological procedures are considered easier and cost-effective when histological observation techniques are inadequate (Khatun et al. 2019). Further, biological indices including reproductive behavior commonly denote the pathway through which fish exploit the ecological and energetic resources from its surrounding environment (Khatun et al. 2019). The GSI observation method is applied quite frequently by several researchers to determine the maturity size of fish (Hossain et al. 2012; Khatun et al. 2019; Sabbir et al. 2021d; Rahman et al. 2018). Data about the reproductive behavior of *S. panijus* is inadequate in literature. Consequently, our study highlights the sexual maturity size and spawning period of *S. panijus* along with different eco-climatic factors harvested from marine water of Bangladesh.

Knowledge about maturity size (L_m) of fish is essential simultaneously for distinguishing among various stocks of a particular fish species (Sabbir et al. 2021d) as well as for anticipating a basis that ultimate changes in length at first maturity are due to fisheries pressure or other reasons (Templeman 1987). Such information is crucial for fisheries managers to conserve a specific wild fish stock (Lucifora et al. 1999). According to GSI based reproductive indices, the L_m for female *S. panijus* was 19.0 cm TL. The logistic curve (King 2007) also revealed that L_m was 19.0 cm for the female population of *S. panijus*. However, the L_m may vary due to habitat characteristics accompanied by different environmental parameters (Sinovcic and Zorica 2006). Absence of information on the maturity status of *S. panijus* prohibits substantial comparisons with our findings. Further, our study indicates first extensive evidence on sexual maturity size about *S. panijus* which could be supportive for adjusting the mesh size of the fishing gears in the Bay of Bengal to avoid catching mature smaller individuals.

It was noted before that the government of Bangladesh imposes a 65 days ban on marine fishing during 20 May to 23 July to boost up the spawning of marine fauna (DoF 2019). But the actual spawning and peak spawning season of our marine fisheries resource is still unknown. Instead, the prolonged banned imposed by Bangladesh government on marine fishing has an adverse effect to the livelihood of the poor fishers. Consequently, intensive research is needed to determine the actual spawning period of the marine fauna in Bangladesh. Information about appropriate spawning period is crucial to determine the spawning time as well as migration of a particular fish stock for the purpose of spawning (Vadas 2000). Female *S. panijus* shows prolonged spawning periods throughout the year, but peak spawning occurs in August and October. Therefore, ban should be imposed on all types of fishing during the peak spawning period, considering the peak reproduction of other fish stocks in the Bay of Bengal.

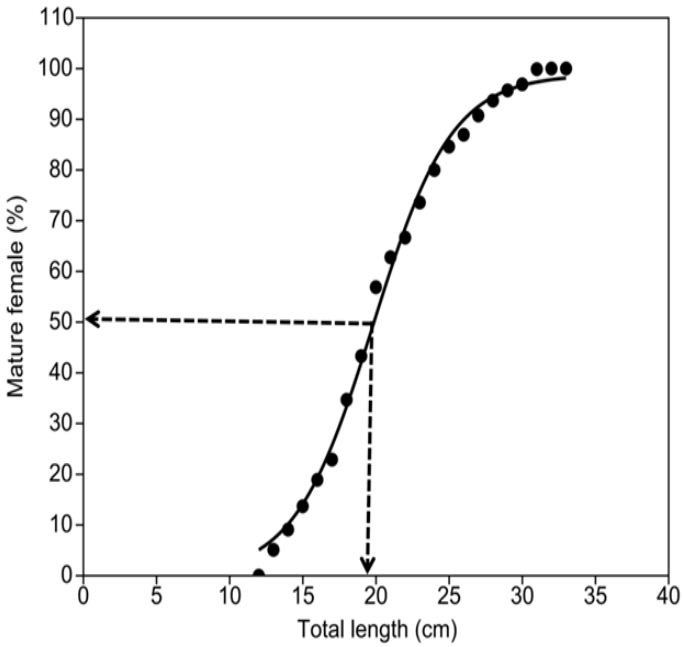

Fig. 3 Adjusted percentage of mature females of *Sillaginopsis panijus* versus total length showing the logistic curve fitted to the data

At present, fluctuations of eco-climatic factors are the leading pressures to the wild fish stocks along with other risks like overfishing and pollution (Rose 2005). Eco-climatic factors are responsible to control species abundance, population density and reproductive success of aquatic animals (Ceneviva-Bastos et al. 2014). However, we observed the effect of four eco-climatic factors (DO, pH, water temperature and rainfall) on the gonadal development of *S. panijus*. We found no significant relation between eco-climatic factors and GSI of *S. panijus*. During the study period, the peak water temperature was documented 28°C

Table 2 Relationship between eco-climatic parameters with GSI of *Sillaginopsis panijus* in the Bay of Bengal (southern Bangladesh)

Relationships	r_s value	95% CL of r_s value	*p* value	Significant
DO *vs.* GSI	-0.4135	-0.8049 to 0.2287	0.1816	*ns*
pH *vs.* GSI	0.1678	-0.4646 to 0.6869	0.6039	*ns*
TDS *vs.* GSI	0.4755	-0.1542 to 0.8305	0.1215	*ns*
Salinity *vs.* GSI	0.1818	-0.4532 to 0.6944	0.5731	*ns*
Water Temp. *vs.* GSI	-0.3328	-0.7693 to 0.3156	0.2886	*ns*
Rainfall *vs.* GSI	-0.2587	-0.7340 to 0.3867	0.4169	*ns*

GSI, gonadosomatic index; DO, dissolved oxygen; TDS, total dissolved solids; r_s, Spearman rank correlation values; CL, confidence limit; *p*, the level of significance; *ns*, not significant

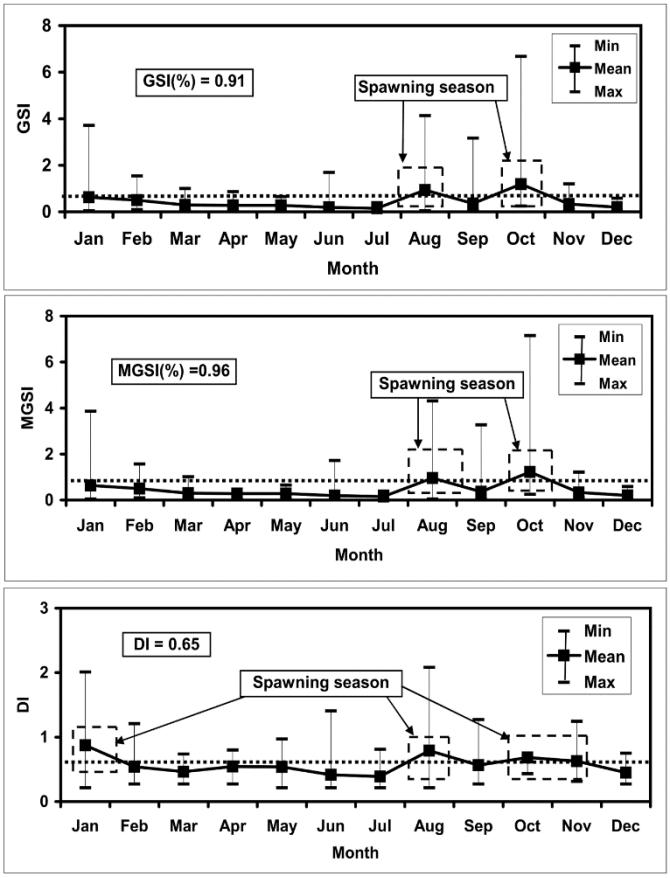

Fig. 4 Spawning season through gonadosomatic index (GSI), modified gonadosomatic index (MGSI) and Dobriyal index (DI) of female *Sillaginopsis panijus* in the Bay of Bengal (southern Bangladesh)

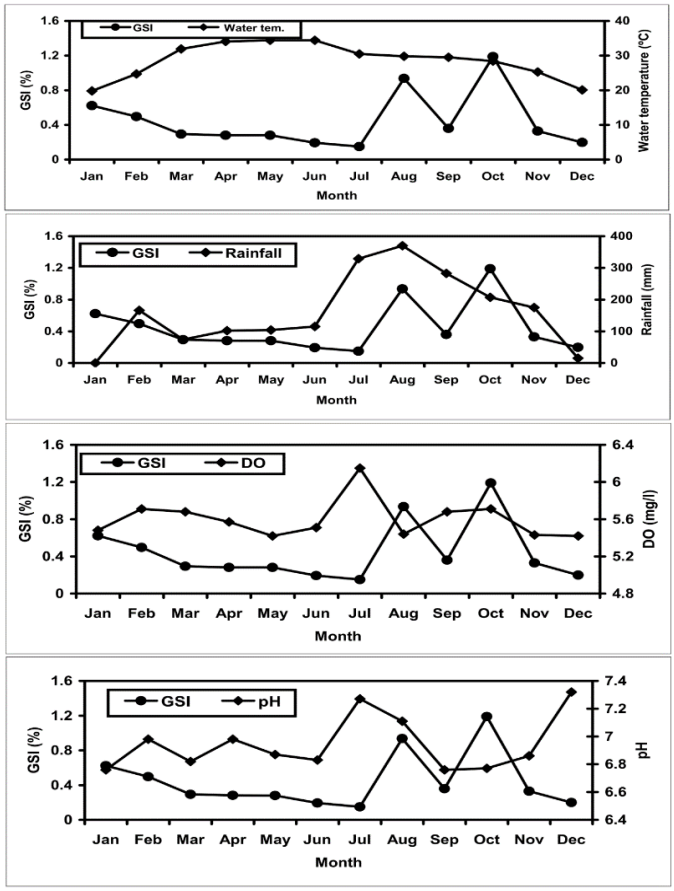

Fig. 5 Relationship between gonadosomatic index (GSI) with eco-climatic factors of female *Sillaginopsis panijus* in the Bay of Bengal (southern Bangladesh)

(May-June) and the minimum temperature was recorded 19.8ºC (January). The highest rainfall was documented 370 mm in August while in January no precipitation was occurred. However, DO plays a significant role in fish aerobic metabolism (Sabbir et al. 2021d) and the recommended level of DO for marine fauna must be above 3.5 mg/l (EPA 2000). The maximum DO level was found in May (6.2 mg/l) and the minimum DO level was recorded in February (4.5 mg/l). Likewise, pH denotes whether an aquatic ecosystem is acidic or alkaline. Prolonged acidic (pH < 4.5) or alkaline (pH > 9.5) condition is responsible to diminish fish growth and reproduction (Ndubuisi et al. 2015). During the study period, pH level ranged from 6.8 (September) to 7.8 (February). Therefore, our investigation revealed that all the eco-climatic factors were within suitable range for fish reproduction in the Bay of Bengal. However, it is recommended that more intensive research should be conducted in order to clarify the effect of eco-climatic factors on reproductive behavior of fisheries resource in the marine water of Bangladesh.

Conclusion

The size at first sexual maturity was recorded 19.0 cm TL for *S. panijus* in the Bay of Bengal (southern Bangladesh). Information about sexual maturity size helps to fix appropriate mesh size of the fishing gears to let the mature individuals to escape, thus providing them opportunity to spawn. Besides, the species spawns throughout the year while peak spawning occurs in August and October. Consequently, it is suggested that matured fish should be conserved during peak breeding season to maintain the sustainability of the exploited stock. Besides, GSI did not show any significant correlation with the eco-climatic factors. Our findings would be valuable for fishery managers to conserve the wild stock of *S. panijus* in the Bay of Bengal and connected ecosystem.

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