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ORIGINAL ARTICLES

# Population size structure and breeding biology of *Puntius sophore* in the old Brahmaputra river, Bangladesh

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ABSTRACT

The pool barb (*Puntius sophore*) is an indigenous freshwater species of Bangladesh. The population size structure, sex ratio, condition factor, gonadosomatic index, and fecundity of *P. sophore* were estimated as biological parameters in the present study. A total of 480 specimens were collected in 12 months from the River Brahmaputra between July 2019 and June 2020. Length-frequency data revealed that the length of the maximum number (155) of individuals in catch sample was in 9-11cm intervals. The average male: female ratio was 1.0:1.4 indicating female dominance in the population throughout the year though there was no significant difference between the sex ratio ($\chi^2$=0.34, $P$>0.05). Mean condition factor ($K$) was different in different months. Both sexes experienced the highest condition factor ($K$) in June, and the lowest in February and January, respectively. The GSI in both sexes fluctuated significantly in different months and showed one peak in June. Total fecundity varied from 960 to 5680 (3116±1411). The arithmetic equations of fecundity against TL, BW, and OW were $F$=3409.33+615.35 $TL$, $F$=462.47+40.20 $BW$, and $F$=2932.9+2839.32 $OW$ respectively. The scatter diagram between fecundity with TL, BW, and OW demonstrated a linear relation and positive association between the three variables. The findings of this investigation offer baseline information on a few biological characteristics of *P. sophore*, information that will help forecast the reactions of *P. sophore* populations in the Old Brahmaputra River.

## Introduction

The pool barb (*Puntius sophore*) is an indigenous freshwater fish species of Bangladesh. The population size structure, sex ratio, condition factor, gonadosomatic index, and fecundity of *P. sophore* were estimated as biological parameters in the present study. The development of effective management and conservation plans for fish requires a thorough understanding of their biology. Fish have a wide range of reproductive tactics, and within a genus, the tactics typically reflect environmental stability,

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habitat specificity, and reproductive opportunity. The quantitative aspects of fish like size distribution, sex ratio, condition factor, fecundity, and gonadosomatic index (GSI) are important tools for studying fish physiology (Barman *et al.,* 2023). A fish population size structure can be thought of as a "snapshot" that depicts the interplay between the dynamic rates of recruitment, growth, and mortality (Guy and Brown, 2007; Sultana *et al.,* 2023). Investigations of fish ecological and life-history characteristics are revealed through size structure and length frequency distribution. The sex ratio gives fundamental data to determine stock size and evaluate the reproductive capacity of fish populations (Oliveira *et al*., 2012; Mazumder *et al*., 2022). The condition factor is commonly used to analyses the wellbeing of fishes in natural environment (Daliri *et al*., 2012). The condition factor of ≥ 1 indicates the good condition of fish while the ≤ 1 show bad condition (Abobi, 2015). Based on the idea that bigger fish are in better condition than lighter fish, condition factor (K) is an evaluation of fishes' overall health (Mon *et al*., 2020; *Mazumder et al., 2021*). The Gonado-somatic index (GSI) is a method for observing seasonal changes in gonad weight to body weight during the spawning season which is frequently used to determine a fish's reproductive cycle (Kokokiris *et al*., 2014). Additionally, determining fish fecundity is crucial to studies of fish population dynamics because it improves our capacity to estimate recruitment and population growth rates and deepens our understanding of observed changes in reproductive output. Fishes have a variety of reproductive strategies, and the strategy within a genus generally reflects environmental stability, habitat specificity, and reproductive opportunities.

The consumption of small indigenous fish species (SIS, maximum length ≤ 25 cm) was common among South Asian rural people (Minkin, 1993). The most commonly preferred species were *Amblypharyngodon mola*, *Chela cachius*, and *Puntius sophore* (Rahman *et al*., 2018). Millions of rural residents in the area rely mostly on these species for their protein needs, and the majority of them are significant commercial producers. The pool barb, spotfin swamp barb, or stigma barb *P. sophore* is native to inland waters in Asia and is found in Southeast Asian counties (Froese and Pauly 2016). In Bangladesh, this species holds significant commercial value (Froese *et al*., 2011; Rahman *et al*., 2012, 2018, Sarkar *et al*., 2019) and is also a well-liked aquarium fish (Froese and Pauly, 2016). Though, it was one of the dominant species in Bangladesh waters (Rahman *et al*., 2018) but its stock in the Brahmaputra is decreasing as a result of several factors and is considered as a near-threatened species (Sarkar and Banerjee, 2010). It is afraid that this fish may disappear unless proper steps are urgently taken to protect the fish from extinction.

Previous studies have been conducted on the *P. sophore* population, including biology, length-weight relationship, and relative condition factor in Indian waters (Talwar and Jhingran, 1991; Reddy and Rao 1992; Menon 1999); growth in the Jamuna River, Bangladesh (De Graaf, 2003); length-weight and length-length relationships in the Mathabhanga river, Bangladesh (Hossain *et al*., 2006); biometric relationships in three major rivers (Hossain *et al*., 2013); and reproductive biology from Gazipur and Jessore (Hasan *et al*., 2018). However, comprehensive studies are limited to the detailed aspects of the reproductive biology of *P. sophore*. Additionally, gaining a fundamental grasp of a fish species major biological processes is essential for successful fish culture to raise the species conservation status (Samad *et al*., 2017). The most important thing is the knowledge of reproductive biology to have realistic, excellent natural spawning, ideally in several populations spread out throughout the year. The present investigation was designed to examine and update the knowledge of *P. sophore*'s size distribution, sex ratio, condition factor, gonadosomatic index, and fecundity of *P. sophore* over the year. These efforts will help to determine the reproductive biology of this species to ensure the best physiological performance during the captive culture system and conserve the species with sustainable aquaculture.

## Materials and Methods

### *Sample collection and experimental site*

A total of 480 specimens (10.3±1.03 cm TL and 10.6±3.18 g BW) were collected monthly (12 months) from the River Old Brahmaputra (Fig. 1).

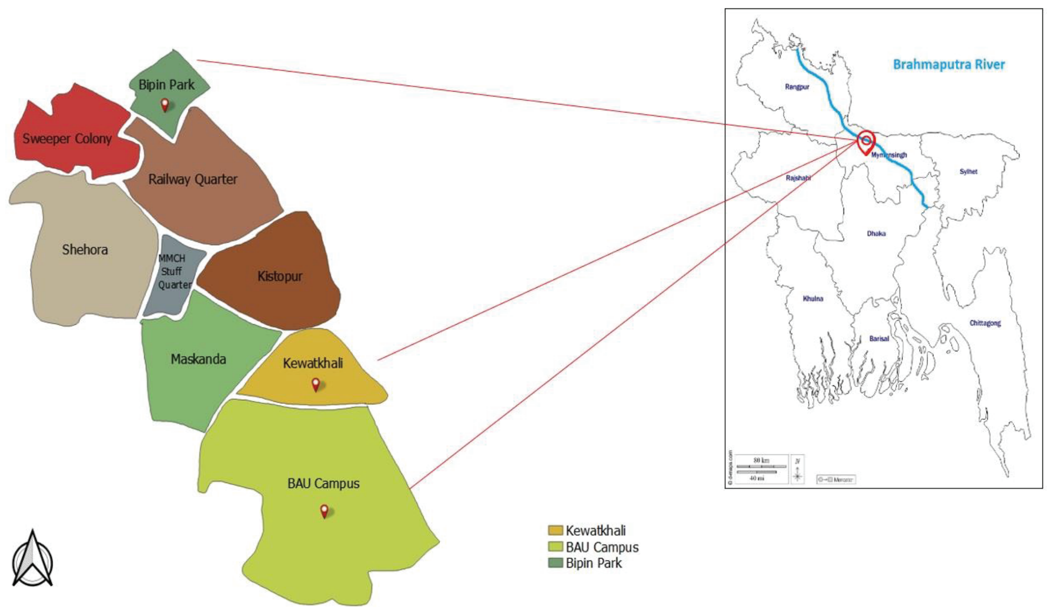


**Fig. 1. Map showing the sampling site.**

On board, a local fishing boat, traditional fishing equipment such as a three-layered trammel net, cast net, scoop net, and trap were used to capture fish samples. After hauling, the catch was taken out, and thoroughly washed, and specimen identification was done using the fishes' surface markings as well as their morphometric and meristic characteristics.

The collected fish were transported to the Department of Genetics and Fish Breeding (GFB) laboratory and the hatchery complex at Bangabandhu Sheikh Mujibur Rahman Agricultural University for analysis.

### *Size proportion and sex ratio*

The fish's total length (TL) was measured from the tip of the snout to the base of the tail end measured to the nearest 0.1 cm by using a measuring scale. An electronic balance (Docbel BRAUN) was used to measure the body weight (BW) and gonad weight (GW) up to 0.01 g after adherent water and other debris were removed from the surface of the body (Mazumder *et al*., 2016). The fish were dissected, and gonads were taken out and put on a glass slide to identify the sex. Following the addition of a few drops of acetocarmine stain, the gonads were compressed with a cover slip. The plates were examined under a microscope to determine the fish's sex. After counting the total number of individuals of the two sexes in the monthly collected samples, the variation in the sex ratio over time was examined. Using the Chi-square ($\chi^2$ test) test, the discrepancies between the sex ratio and the expected ratio of 1:1 were calculated.

### *Condition factor*

The Fulton condition factor (*K*) of *P. sophore*, hereinafter referred as fitness, was calculated according to Fulton (1904) which relates the fish's body length to its weight:

$$K=100^{*}BW/TL^{3}$$

Where, *BW* is the observed individual fish weight in grams (g), *TL* is the observed individual fish total length in centimeters (cm), and 100 is a factor to bring the value of *K* near unity.

***Gonado somatic index (GSI)***

Fish ovaries were inspected macroscopically in the lab, and fresh tissue was used to note characteristics such as color, texture, form, and turgidity. Each fish was assigned to a reproductive phase based on these characteristics. According to Solomon and Ramnarine (2007), paired gonads were individually weighed to the nearest 0.01 g, and GSI was computed:

$$GSI\ (\%) = \left(\frac{GW}{BW}\right) \times 100$$

Where, *GW* is the wet weight of the gonad, *BW* is the body weight of the fish.

***Fecundity estimation***

Using the gravimetric approach, the fecundity of *P. sophore* was estimated. The weight of freshly dissected ovarian tissue was measured to the nearest 0.01 g. Each pair of ovaries had its exterior connective tissues scraped off. The ovaries were dried out by wiping them with paper. Each ovary had three subsamples collected from the base, middle, and apical regions, and each was weighed to the nearest 0.01 g. Each subsample's eggs were counted, and the projected total number of eggs in each ovary was reported as overall fecundity.

*Fecundity (F)=(no.of eggs ×weight of gonad)/ weight of gonad sample*

The relationships of fecundity (*F*) to total length (TL), BW and GW were examined by correlation analysis (Simon *et al*., 2009).

***Statistical analysis***

Prior to statistical analysis, the Kolmogornov-Smirnov test was performed to determine whether all data had normal distribution, and Bartlett's test was used to see whether the variances were homogenous (Sokal and Hohlf, 1995). Throughout the sampling period, a chi-square ($\chi^2$ test) was used to look for any associations between month and sex. To examine the impact of monthly variation in condition factor (*K*) and GSI, analysis of variance and Tukey's *post hoc* tests were performed. Fecundity was found to be linearly related to TL, BW, and GW. $P$<0.05 was used as level of significance for each analysis. Every outcome was presented as mean±S.E. Software programs Origin™ v 2016 and Minitab v 17 were used for all statistical analyses.

## Results

***Length-frequency distribution***

The collected males and females ranging in total length from 7 to 11 cm and 7.8 to 13.1 cm respectively. The mean total length was found to vary from 8.3 (December) to 9.88 (April) for males and 9.4 (December) to 11.07 (September) for females. The length-frequency distribution of *P. sophore* from the Old Brahmaputra River showed that the length of a maximum number (>140) of individuals of a catch or catch sample were in 9-11 cm length interval, while the fish with a total length of 8-9 cm and 11-12 cm were in around 70 samples of catch. The fish remaining total length < 8cm and >12cm contained less than 20 number of samples ($P$ < 0.05) (Fig. 2).

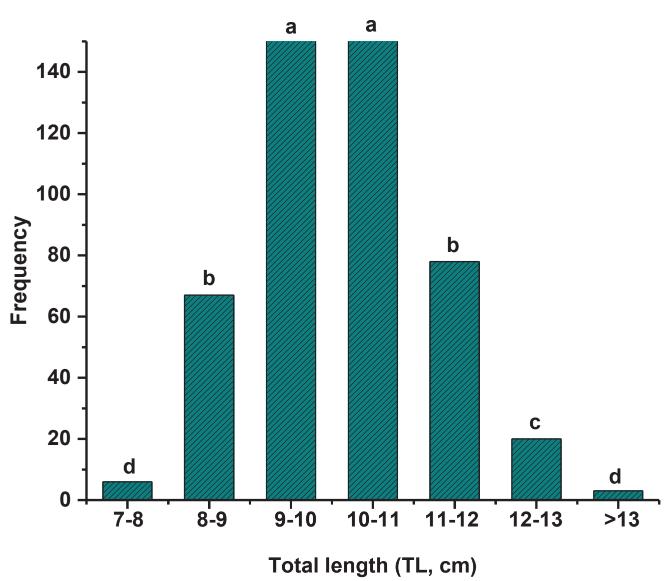


**Fig. 2. Length frequency distribution of *P. sophore* from the Old Brahmaputra River, Mymensingh.**

### *Sex ratio*

Data presented in Table 1 reveals no significant difference among all the parameters ($P > 0.05$) from randomly collected samples in every month. The number of males and females of *P. sophore* caught each month was used to calculate the sex ratios male: female (M: F). Out of 480 fishes, 199 (41.5%) were male and 281 (58.5%) were female. Monthly sex ratio between males and females ranged from 1:1.0 (December) to 1:1.85 (May, August) and average was 1: 1.40 ($\chi^2 = 0.34$, $P > 0.05$) which indicates that female's dominance over males in the Old Brahmaputra River population of *P. sophore* throughout the year.

**Table 1. Number of males and females *Puntius sophore* collected by month; total length range (cm), mean total length (cm), standard deviation (SD) and sex ratio (M: F), coupled with $\chi^2$ test's value, degrees of freedom (df) and probability (*P*)**

| Month | Males | | | | Females | | | | Sex ratio | | df | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | range | mean | SD | N | range | mean | SD | M : F | $\chi^2$ | | |
| January | 16 | 8.5-11 | 9.1125 | 0.59 | 24 | 8.5-11.6 | 10.04 | 0.91 | 1:1.50 | 1.6 | 1 | 0.20 |
| February | 18 | 9.0-10.3 | 9.57 | 0.53 | 22 | 9.8-11.5 | 10.43 | 0.56 | 1:1.22 | 0.4 | 1 | 0.52 |
| March | 16 | 8.0-11.0 | 8.93 | 0.80 | 24 | 8.2-11.8 | 10.18 | 0.79 | 1:1.50 | 1.6 | 1 | 0.20 |
| April | 19 | 9.0-10.8 | 9.88 | 0.55 | 21 | 10.0-12.0 | 10.81 | 0.68 | 1:1.10 | 0.1 | 1 | 0.75 |
| May | 14 | 8.3-10 | 9.11 | 0.50 | 26 | 9.2-12.4 | 10.32 | 0.82 | 1:1.85 | 3.6 | 1 | 0.06 |
| June | 18 | 7.4-10.9 | 9.33 | 0.91 | 22 | 8.9-12.2 | 10.65 | 0.94 | 1:1.22 | 0.4 | 1 | 0.52 |
| July | 16 | 8.3-10.3 | 9.18 | 0.87 | 24 | 8.0-13.0 | 10.57 | 1.27 | 1:1.50 | 1.6 | 1 | 0.20 |
| August | 14 | 8.1-9.3 | 8.98 | 0.46 | 26 | 7.8-12.6 | 10.54 | 1.10 | 1:1.85 | 3.6 | 1 | 0.06 |
| September | 19 | 8.3-10.5 | 9.54 | 0.54 | 21 | 9.4-13.1 | 11.07 | 0.93 | 1:1.10 | 0.1 | 1 | 0.75 |
| October | 16 | 9.9-11.0 | 9.67 | 0.58 | 24 | 10.0-12.0 | 10.75 | 0.60 | 1:1.50 | 1.6 | 1 | 0.20 |
| November | 17 | 7.9-9.7 | 8.96 | 0.52 | 23 | 9.2-11.3 | 10.69 | 0.87 | 1:1.35 | 1.2 | 1 | 0.61 |
| December | 20 | 7.0-9.6 | 8.3 | 0.64 | 20 | 8.0-11.0 | 9.4 | 0.74 | 1:1.0 | 0.1 | 1 | 0.75 |

### *Condition factor (K)*

Mean condition factor (*K*) was different in different in different months. The mean *K* value of male *P. sophore* started to increase steadily from February to March. After being stable, it begins to rise sharply from April and reached to peaks in June. From June to August, it then begins to fall gradually. From August, it dropped progressively to September and continued to be stable until November. For male *P. sophore*, the mean *K* value peaked in June (1.22±0.09) and fell in February (0.86±0.03) (Fig. 3a). However, the mean *K* value of male *P. sophore* was different significantly from others ($P< 0.05$). Similarly, mean *K* value of female *P. sophore* increased gradually from January to June to reach the apex and then started to decrease gradually to November 2020. However, the mean condition factor in June (1.41±0.09) was different significantly ($P < 0.05$) from rest of the months (Fig. 3b).

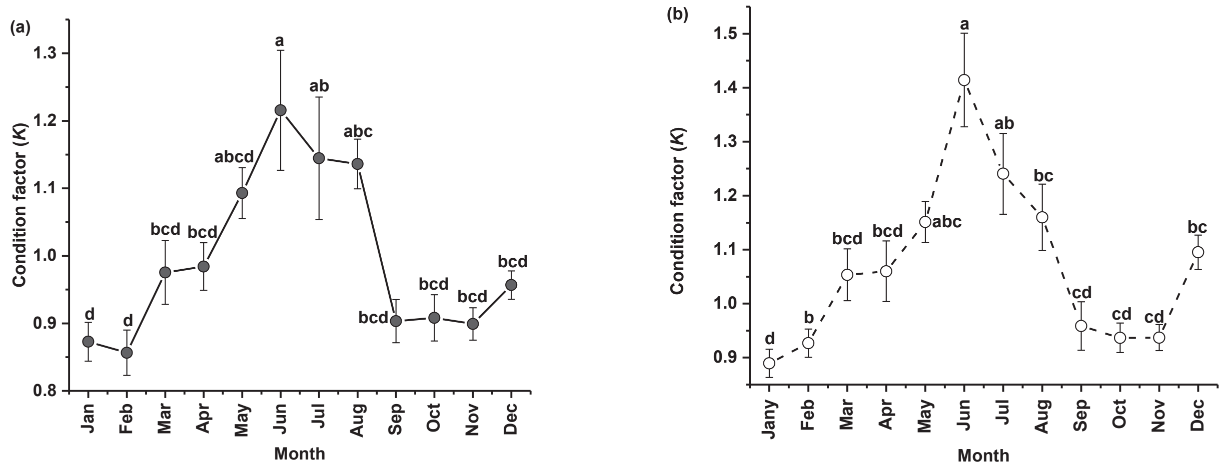


**Fig. 3. Monthly changes in mean condition factor of *P. sophore* (a) male and (b) female from the Old Brahmaputra River, Bangladesh. Values are mean ± SE. Different letters above the mean values indicate significant differences in mean condition factors at *P*<0.05.**

***Gonadosomatic index (GSI)***

Fig. 4 depicts the fluctuation in GSI that occurs during the reproductive cycle in both male and female adult fish. GSI in male *P. sophore* remained stable from January to March and then started to increase gradually. The mean GSI reached the peak in June and lessened in August. However, from August the mean GSI values dropped sharply to October 2020. The mean GSI values for male *P. sophore* in June, July, and August, however, differ significantly from those of the other months (*P*<0.05). Similar to male fish, female fish's GSI increased steadily from a minimum in January to a maximum in June and July. It dropped to a low level in August, showing that spawning had taken place. But starting in August, the GSI started to fall, and it did so through December. Nevertheless, female had significantly varied mean GSI values between months (*P*<0.05) (Fig. 4).

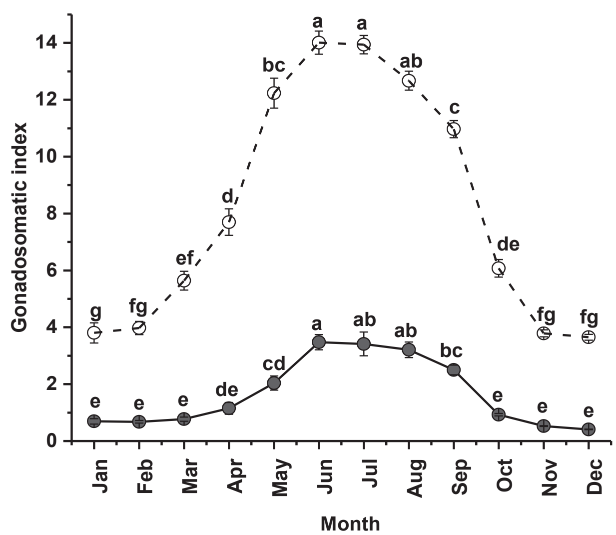


**Fig. 4. Changes in the mean and range of the gonadosomatic index on a monthly basis for male (•…..•) and female (O….O) *P. sophore* through the fish's reproductive cycle. Each point represents the average of 40 fish.**

***Fecundity***

Total fecundity of *P. sophore* varied from 960 to 5680 (3116 ± 1411). With increasing TL, BW, and OW, the fecundity increased. The arithmetic equations of fecundity against TL, BW, and OW gave the following results: $F$ = 3409.33 + 615.35 TL, $F$ = 462.47 + 40.20 $BW$, and $F$ = 2932.9 + 2839.32 $OW$ (Fig. 5). The scatter diagram between fecundity with TL, BW, and OW of *P. sophore* demonstrated a linear relation between fecundity with the two variables and showed a close and positive association between the three variables (Fig. 5).

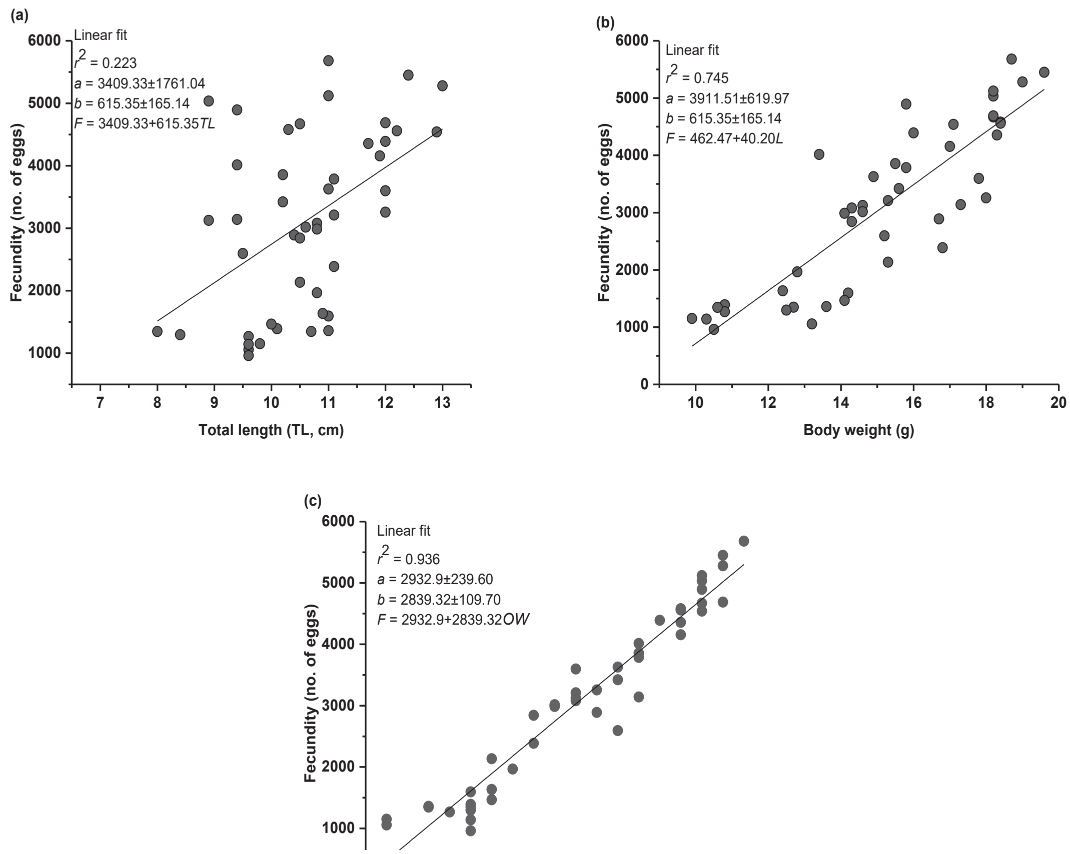


**Fig. 5. Scatter diagrams showing the relationship between fecundity and TL (a), BW (b), and OW (c) of *P. sophore* from the Old Brahmaputra River. The solid circle represents individual fish fecundity whereas solid bar represents linear fit.**

**Discussion**

The present study examined certain fundamental population biological parameters utilizing a year's worth of data, which was essential for gaining a thorough understanding of the life history of this commercially significant species and for the creation of effective stock enhancement and management programs. The assessment of the catch's status was collected from the species from the Old Brahmaputra River, Mymensingh by length-frequency distribution containing 9-11 cm total length of the maximum sample. Mean total length was highest in April and September for males and females, respectively. Seasonal differences in the sex ratio were seen, but the overall tendency of more females persisted. According to P. sophore's monthly sex-ratio data, there is a female predominance males in the population, which is different from the expected ratio of 1:1. The sex ratio was at its peak in May and August, where it included a 1.00:1.85 ratio, indicating that females were substantially bigger and larger than males. The result obtained in the present work showed that females dominated the natural population throughout the year, according to the percentage of each month and the total percentage of males and females, which is similar to the studies by Yesilyurt (2019), Das et al., (2018), Rahman et al. (2018) but differed from Gogoi and Goswami's findings (2014). However, several authors (Adebiyi, 2013; Okey, 2018) came to the conclusion that the metabolic strain of spawning was often larger in older males than in older females, resulting in increased mortality among male than females, especially during the spawning season. According to Parker (1992), increased female body size in fish is typically a selective reaction to increased fecundity, and it has been linked to changes in male body size (Young, 2005). Rahman et al., (2018) also observed female dominance in the P. sophore in the Padma River of Bangladesh. The current study shows that for P. sophore, June to August was the ideal time to gather brooder from the wild for spawning. However, appropriate measures must be taken to protect the fish species in their native habitat.

The present study represent the value of the condition factor is greater than 1 from May to August for males and March to August for females indicating that the fishes were in good condition and the value was significantly higher in June for males (1.2) and females (1.4) where females appeared to be in slightly better condition than males, indicating that this coefficient is affected by genital product maturation which could be due to food proficiency, physiological or other better environmental factors of the water body, differed from Das et al., (2018) who explained males appeared to be in slightly good condition. Probably due to very high metabolic rates, the condition factor of P. sophore, decreases at the start of the spawning period, gradually increases during the reproductive period, and then returns to normal. The fish were physiologically in stable condition at least in the Old Brahmaputra River, Bangladesh, as evidenced by the mean condition factors (K), which were around 1.0 in all seasons with the exception of January and February. For both sexes of P. sophore, the monthly variation in mean K values revealed a single peak in June. The relationship between condition factor and gonad weight revealed that K value rose with increasing gonad weight, peaked shortly before spawning, then fell throughout the spawning month due to the loss of gonadal products, validating May to August as the spawning months for this fish species. Similar results were also found by Hasan et al., (2018).

The present study showed an interesting feature on the gonado-somatic index where females had a higher GSI than males, increasing from May to August and the mean GSI values increased, with two peaks in June for males and June, and July for females which is more or less similar to Hossain *et al*. (2012) but differs from Yesilyurt (2019). As was previously stated, there is a relationship between GSI and spawning periodicity; GSI tends to rese with gonad maturation (beginning of breeding season), reach its peak during the period of peak maturity, and then suddenly decline after that as the fish exhausts itself following gamete extrusion and/or reabsorption (Gupta and Banerjee, 2013). As a result, when the GSI value of any fish species is studied on a monthly basis, the month(s) in which the GSI value(s) reaches its peak(s) represents the spawning period for that particular fish species, and the months in which the GSI value(s) is/are high represents the breeding periodicity of that particular fish species.

In the current study, total fecundity of *P. sophore* varied from 960 to 5680 (3116±1411). According to Hossain *et al*. (2012), fecundity ranged from 1580 to 16590 (5300±2700), which is higher to the results of the current investigation. Within species, fecundity may change over time, but the difference seems to be rather small (Óskarsson *et al*., 2002; Thorsen *et al*., 2006; Yoneda and Wright, 2004). Size may also affect fecundity within species, but this phenomenon may only make matters worse by disproportionately hurting larger individuals (Kamler, 2005). The linear relationship between fecundity with TL, BW, and OW indicated a close and positive correlation between them which can explain the increase in fecundity with the increase in TL, BW and OW. When size distribution is known, the fecundity-size connection has mostly been used to predict the fertility of fish stocks quickly (Dulcic *et al*., 1998). Wooton (1979) examined the energy costs of egg production and environmental factors that affect fecundity. Various authors reported similar linear relationships between these parameters while conducting a study on different fish species, viz. Perry and Vanderkooy (2015), Phukon and Biswas (2012), Bithy *et al*. (2012), Singh (2009), Somdutt and Kumar (2004). Although these factors were not taken into account for this study due to the small number of female specimens with different ovarian-maturation stages, other factors such as condition, Gonadosomatic index, and OW were counted. The obtained results demonstrated that OW is a superior index to BW or TL for estimating fecundity. As opposed to OW, which is more difficult to quantify in field conditions, BW or TL are easier to use as indices for assessing fecundity. The fish in the study were all the same size, but variable number of eggs were found in their ovaries. The ecologica circumstances of the Brahmaputra River migh be the cause of the variations in fertility of the *P. sophore.* Some past research on other fish also note these kinds of variances (Rahman *et al*., 2018).

## Conclusion

The current study contributes to the body o knowledge necessary for the creation of effective *P. sophore* management strategies by providing some critical baseline data on the population biology of the commercially important species *P. sophore* as thi fisheries have historically relied on capture. Startin its captive culture is now necessary. However, i will be important to keep an eye on these biologica indicators' patterns and look into the variables tha may be affecting them. The study indicates the bes physiological performances on the seasonal basi that may help to ensure sustainable aquaculture an conservation of this small indigenous species.

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## Author contribution

Conceptualization, Methodology, Formal analysis: Sabuj K. Mazumder. Investigation and writing original draft: Sutapa Debi. Writing – review & editing: Mohammad A. Salam, Mohammad L. Rahman, Md. S. Hossain, Sabuj K. Mazumder and Mohammad A. Salam Funding acquisition: Sabuj K. Mazumder and Mohammad A. Salam.

## *Declaration of competing interest*

The authors affirm that they have no known financial or interpersonal conflict that would have appeared to have an impact on the research presented in this study.

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