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Original Article

# Reproductive biology of Gagora catfish (*Arius gagora*) at Meghna river system, Kushiara River, Bangladesh

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**Abstract:** The gagora catfish, *Arius gagora* is a species of Ariidae family normally exist in estuaries and tidal rivers of Bangladesh and India. In the present study, the reproductive biology of *A. gagora* was assessed in Meghna River system at Kushiara River. Length-weight relationship was found strongly correlated for male ($r^2 = 0.98$), female ($r^2 = 0.97$) and combined sex ($r^2 = 0.81$), respectively. Chi-square tests revealed no significant difference between sex ratios round the year and not deviated from the expected value of 1:1 ($\chi 2 = 5.57$) and the critical chi-square value calculated was 143.25. The fecundity found to be ranged from 43333.12±829.83 to 53948.81±1743.28 in April to August. The relationship of fecundity with ovary weight ($r^2 = 0.79$), ovary length ($r^2 = 0.88$), total length ($r^2 = 0.85$) and total weight ($r^2 = 0.68$) were found positively correlated. Monthly study of gonadosomatic index (GSI) revealed that the breeding season for this fish species may be between July to August with a single peak spawning month in August. Size at sexual maturity was estimated as 30.01 cm total length. Fulton's condition factor (K) value varied in both males and females and indicates that the overall health condition of both the male and female were excellent. Breeding season was found significantly correlated with rainfall, but not with other biological, meteorological, and hydrological parameters. Ovarian development of *A. gagora* was assessed macroscopically and three broad gonad developmental stages were identified. Maturity was specified based on the presence of green egg in the peritoneal cavity. These findings should benefit and improve the sustainable management and conservation of this species both in Bangladesh and its bordering countries.

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## Introduction

The Ariidae family comprised of 14 genera and 120 species of tropical and sub-tropical marine catfishes (Kailola, 1999). The gagora catfish, *Arius gagora* (Hamilton, 1822) is found in estuaries and tidal rivers of Bangladesh and India (West Bengal and Orissa) (Talwar and Jhingran, 1991) and reported from the Hooghly Estuary (Talwar and Jhingran, 1991) and Meghna River (Rahman, 1989; Rahman, 2005). According to Rahman (2005), gagora catfish is found in estuaries, tidal rivers, and the Bay of Bengal.

In respect to their gonadal conditions, generative potential of a species is one of the basic demands to designate the individuals of that species (Jhingran and Verma, 1972). The reproductive biology of a fish could be defined by its reproductive characters and it also expresses the combination of the species-specific reproductive mode (Winemiller and Rose, 1992; Murua and Rey, 2003; Morgan, 2008). In addition, for success in fish culture, assessment of the yearly breeding sequence of culturable fishes are very important (Stoumboundi et al., 1993). According to Murua and Rey (2003), information about the reproductive biology and the estimation of fecundity and egg production are fundamental topics in the study of the biology and population dynamics of fish species. The fecundity and egg production of a fish may vary annually and spatially both within and among stocks (Hunter and Leong, 1981) in relation to their condition and environmental factors (Somarakis et al., 2000; Takasuka et al., 2005). Reproducing of a fish may occurs during a certain phase of reproductive

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cycle; some breeds once annually while others at regular intermissions throughout the year. Knowledge of gonadal maturation and spawning season of a species permit subsequent studies on spawning frequency, which is important for its management (Chakrabarti and Barun, 2017).

Gonado somatic index (GSI) is used to determine the spawning season, (Verghese, 1975; Jacob and Nair, 1983; Ha and Kinzie, 1996; Shankar and Kulkarni, 2005) and considered as a sensitive and proved noteworthy parameter to monitor gonadal maturation (Belsare, 1962; Lehri 1968; Hong-Yang and Yon, 1992; Shashi and Akela, 1996). The cyclical factors might greatly impact the maturation of ovary results the consecutive changes in the gonads and body weights (Lincoln et al., 1980). Condition factor states the well-being of a certain species (Radkhah and Eagderi, 2015; Zamani-Faradonbeh et al., 2015) and its degree of fatness, the state of sexual maturity, the degree of food sources availability, age and sex of some species and the system of environment which depends on weight of the fish sampled (Pauly, 1983; Fafioye and Oluajo, 2005; Isa et al., 2010; Alam et al., 2014; Keivany et al., 2015; Abbasi et al., 2019).

Reproductive biology parameters such as fecundity, spawning, sex ratio etc. are among the important aspects of the biology of fishes which must be understood to explain the dissimilarities in the level of populations to make efforts to increase the amount of harvest (Azadi and Siddique, 1996). Fish reproduction may be influenced by various factors, including seasonal changes in photoperiod, rainfall and water temperature, along with physio-chemical features of the water body (Bromage et al., 2001; Glasser et al., 2004; Dorostghoal et al., 2009). Therefore, length-weight relationship (LWR), condition factor (K), gonadosomatic index (GSI), hepatosomatic index (HSI), fecundity and macroscopic gonadal maturity were considered as rudimentary parameters for assessing the reproductive condition of *A. gagora.* Despite ecological significance of freshwater fishes, length-weight relationship and condition factor data are often lessened (Mouludi-Saleh and Eagderi, 2019). The

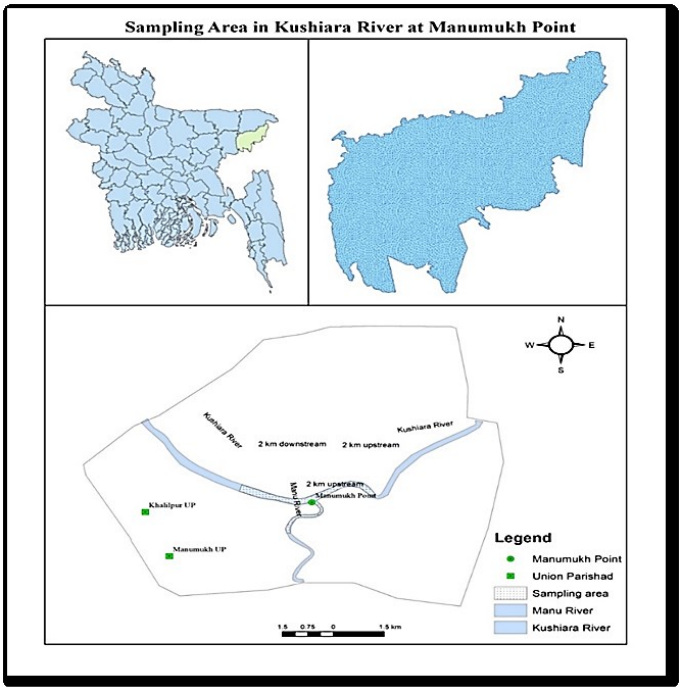



Figure 1. Map showing study area of Meghna river system at Kushiara River, Southeast Bangladesh.

evidence on the general biology of *A. gagora* is also scant in literature from Bangladesh and elsewhere. This is one of the utmost important target species for small-scale fisheries.

## Materials and Methods

The Kushiara (Kushiyara) River is originated from India. The original Barak River separated into two rivers named Surma and Kushiara after entering Bangladesh and thereafter both the rivers combined near the Bhairab Bazar, and later joins to massive river Meghna. A yearlong research was conducted in Maghna river system at Kushiara River (Fig. 1) in five successive sampling points and monthly samples were collected.

A total of 117 individual of *A. gagora* procured from Kushiara River through bush trap. The following extents were made for assessing the general biology of *A. gagora*: total length (TL) with an accuracy of 0.1 mm from the tip of mouth to the distal end with digital slide caliper (Mitutoyo, CD-6"CSX), total weight (TW) with accuracy of 0.01 gm (AND EK-6100i); and gonad, liver and intra-peritoneal fat weight (GW) with accuracy of 0.01 gm (AND EK-6100i). Sex ratio (female/male) was calculated monthly. Length-weight

Table 1. Length (cm) and weight (gm) measurement for male, female, and combined sexes of *Arius gagora*.

| Sex | Parameter | Min. | Max. | Yearly Mean | Equation | $r^2$ | P values |
|---|---|---|---|---|---|---|---|
| Male | TL (cm) | 19.2 | 39.65 | 29.98±5.45 | $BW=a\times TL^b$ | 0.98 | $0.000^{***}$ |
| | BW (gm) | 235.09 | 492.69 | 362.42±62.36 | | | |
| Female | TL (cm) | 21.20 | 40.40 | 31.87±5.23 | $BW=a\times TL^b$ | 0.97 | $0.000^{***}$ |
| | BW (gm) | 272.37 | 688.65 | 479.3±109.64 | | | |
| Combined | TL (cm) | 19.2 | 40.4 | 30.98±5.39 | $BW=a\times TL^b$ | 0.81 | $0.000^{***}$ |
| | BW (gm) | 235.09 | 688.65 | 424.36±107.53 | | | |

P-value shows level of significance; *** highly significant.

relationship was estimated through the equation: $W=aL^b$, where W is the total body weight (g), and L is the total length (cm). Fulton's condition factor (1904) was estimated by the equation: $K=100\times(W/L^3)$, where W is the total body weight (BW, g), L is the total length (TL, cm) and scaling factor of 100 was used to fetch the K close to the unit factor (Hossain et al., 2012).

To identify gonad maturation stages two indices were considered: (a) gonadosomatic index (GSI) = (GW/BW) ×100 (Nikolsky, 1963) and (b) Dobriyal index (DI) = $\sqrt[3]{GW}$ (Dobriyal et al., 1999). The total length size at sexual maturity was assessed by the relationships of total length against GSI and total length against DI. Breeding season of *A. gagora* was estimated based on the monthly differences of GSI value. Hepatosomatic index (HSI) and Intra-peritoneal fat index (IPFI) were calculated to find out energy investment in the breeding event by the equation: Liver weight (gm)/Body weight (gm) x 100 (Cek and Yilmaz, 2009) and Intra-peritoneal fat weight (gm)/Body weight (gm) x 100, respectively.

The ventral incision was made longitudinally from the anus towards the lower jaw by using scissors and eviscerated. The gonads were removed; sex was determined and weighed to the nearest 0.01 gm and preserved in Bouin's fixatives. Mature fishes were subjected to calculate absolute fecundity as stated by Ahyaudin (1999). Absolute fecundity was calculated by gravimetric method described by Babiker and Ibrahim (1979) and Narejo et al. (2002). The numbers of eggs were counted under a binocular microscope (JP Selecta, 3,000-B LED) for each sample. Total numbers of oocytes (N) in both ovaries were calculated using the following formula: Weight of two ovaries (gm)/Weight of sub-sample × No. of counted oocytes in sub-sample × 100. This research has focused more on ovaries because ovarian development typically defines the breeding season (De Martini and Fountain, 1981). Monthly rainfall, air temperature and photoperiod/total sunshine data were obtained from the MET report logbook of Meteorological Department of Bangladesh (Khatun et al, 2017) and water temperature was determined *in situ.* Then monthly mean meteorological data were correlated with monthly mean GSI of *A. gagora* using Spearman rank-correlation test.

**Statistical Analysis**: SPSS software (version 23.0) was for used data processing and analysis. The Spearman rank-correlation test was applied to analyze the relationship of GSI with HSI, IPFI, meteorological and hydrological data. Monthly mean HSI and environmental parameters, including rainfall, air temperature, water temperature and photoperiod were correlated with the breeding season (mean GSI) of *A. gagora* using Spearman rank-correlation test Chi-square tests ($\chi 2$) were conducted to observe the deviation of sex ratio from the expected value of 1:1. All statistical analyses were considered significant at 5 % level of significance ($P<0.05$).

## Results

A total of 117 *A. gagora* were collected from Meghna river system at Kushiara River for 12 months. This species exhibited overall sex ratio of 1:1.12 (male: female) and the percentage occurrence was 52.99% for females and 47.01 % for male. Chi-square tests revealed no significant different between sex ratios round the year and not deviated from the expected value of 1:1 ($\chi 2 = 5.57$, P = 0.65) and the critical chi-

Table 2. K value standards adopted by Barnham et al. (1998).

| K value | Comments |
|---|---|
| **1.6** | Excellent condition, trophy class fish |
| **1.4** | A good, well-proportioned fish |
| **1.2** | A fair fish, acceptable to many anglers |
| **1** | A poor fish, long and thin |
| **0.8** | Extremely poor fish, big head, and narrow, thin body |

Table 3. Descriptive statistics showing length (cm) and weight (gm) measurement for male, female, ovipositor diameter (vertical and horizontal) and ovipositor color of female *Arius gagora*.

| Month | BL (cm) | BW (gm) | OPD (V) | OPD (H) | OPC |
|---|---|---|---|---|---|
| July | 37.74±1.14 | 623.28±38.28 | 0.56±0.09 | 0.35±0.1 | P-LP |
| August | 38.4±1.35 | 648.87±23.42 | 0.58±0.07 | 0.36±0.04 | R |
| September | 22.34±0.76 | 304.65±15.55 | 0.29±0.03 | 0.24±0.02 | LP |
| October | 23.97±2.38 | 325.23±44.64 | 0.29±0.02 | 0.24±0.01 | LP |
| November | 25.96±0.38 | 362.58±8.43 | 0.4±0.1 | 0.23±0.03 | LP |
| December | 27.7±1.14 | 398.53±20.65 | 0.35±0.04 | 0.25±0.03 | LP-P |
| January | 29.74±0.6 | 429.97±14.26 | 0.41±0.05 | 0.26±0.04 | LP-P-R |
| February | 31.1±0.9 | 449.49±14.34 | 0.41±19.57 | 0.26±0.04 | LP-RP |
| March | 32.95±0.92 | 486.42±14.76 | 0.39±0.01 | 0.26±0.05 | LP-P-DP |
| April | 34.37±0.94 | 508.04±15.31 | 0.47±0.05 | 0.28±0.025 | P-DP-R |
| May | 34.35±1.09 | 510.2±16.04 | 0.48±0.025 | 0.3±0.0 | LP-LR-R |
| June | 36.78±2.14 | 552.42±42.27 | 0.56±0.08 | 0.35±0.1 | LP-LR-R |

OPD (V) = Ovipositor diameter (vertical), OPD (H) =Ovipositor diameter (horizontal), OPC = Ovipositor color, LP = Light Pink, P = Pink, DP = Dark Pink, LR=Light Red, R=Red

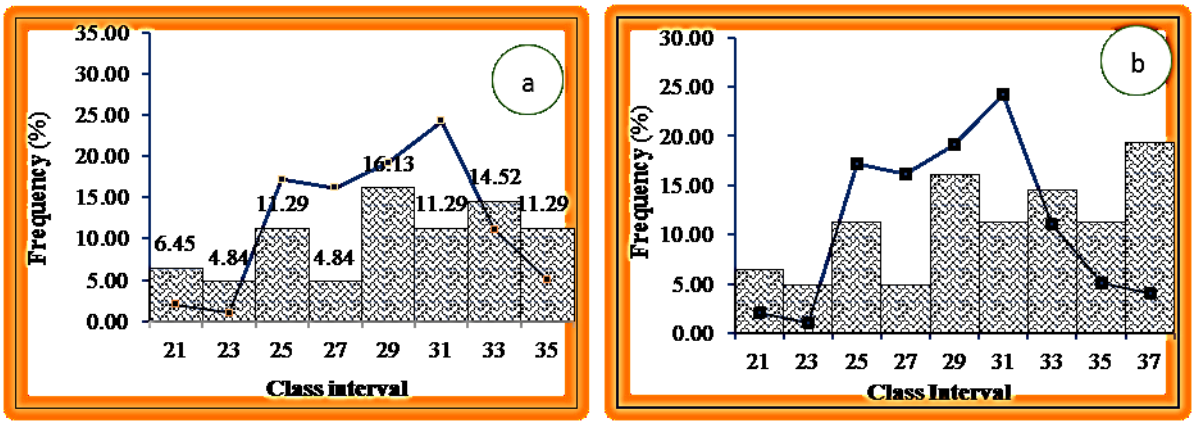



Figure 2. Total length frequency distributions of male (a) and female (b) *Arius gagora* in Meghna river system at Kushiara River round the year.

square value calculated was 143.25.

The length and weight measurement of *A. gagora* reveal that the females were significantly larger than males both in terms of length and weight (Table 1) and showed predominance over male. In addition, LFDs showed that, here 37.00-40.99 cm total length size groups were numerically dominant for female constituted together 57.70% of the total population and 29.0-30.99 size group for male (Fig. 2). The relationship between body weight and total length provided a positive correlation (Table 1) for male ($r^2$ = 0.98), female ($r^2$ = 0.97) and combined sex ($r^2$ = 0.81).

The monthly K-values varied for both sexes calculated as ranging from lowest average value 1.12±0.49 (June) and maximum 2.74±0.16 (September) for female and lowest 0.81±0.02 (August) and uppermost 2.94±0.36 (September) for male, respectively. The yearly average condition factor for male *A. gagora* was found 1.50±0.61 and

Table 4. Relationship between dependent variables (genital papilla and ovipositor diameter) and independent variables of both sexes of *Arius gagora*.

| Sex | Dependant variable | Independent variable | Pearson squares ($r^2$ Values) |
|---|---|---|---|
| Male | Genital papilla length vertical | Total length | $r^2 = 0.66$ |
| | Genital papilla length horizontal | Total length | $r^2 = 0.26$ |
| | Genital papilla length vertical | Body weight | $r^2 = 0.67$ |
| | Genital papilla length horizontal | Body weight | $r^2 = 0.26$ |
| Female | Ovipositor diameter length vertical | Total length | $r^2 = 0.73$ |
| | Ovipositor diameter length horizontal | Total length | $r^2 = 0.46$ |
| | Ovipositor diameter length vertical | Body weight | $r^2 = 0.71$ |
| | Ovipositor diameter length horizontal | Body weight | $r^2 = 0.46$ |

Table 5. Monthly mean ± SD fecundity of female *Arius gagora* collected from the Meghna river system at Kushiara River, southeast Bangladesh.

| Month | Body Length (cm) | Body Weight (gm) | Absolute Fecundity |
|---|---|---|---|
| **Jul'13** | 37.95±0.98 | 625.25±39.19 | 50761.44±1586.21 |
| **Aug'13** | 38.33±9.99 | 648.87±163.07 | 53948.81±1743.28 |
| **Sep'13** | 21.34±11.36 | 352.39±189.48 | Uncountable |
| **Jan'14** | 29.74±9.09 | 489.97±152.68 | Uncountable |
| **Apr'14** | 34.37±9.05 | 568.04±150.97 | 43333.12±829.83 |
| **May'14** | 34.35±9.14 | 570.2±152.47 | 45195.56±1754.85 |
| **June'14** | 36.78±9.32 | 612.42±155.67 | 49860.67±2111.97 |

The mean values were calculated as mean ±standard deviation (SD).

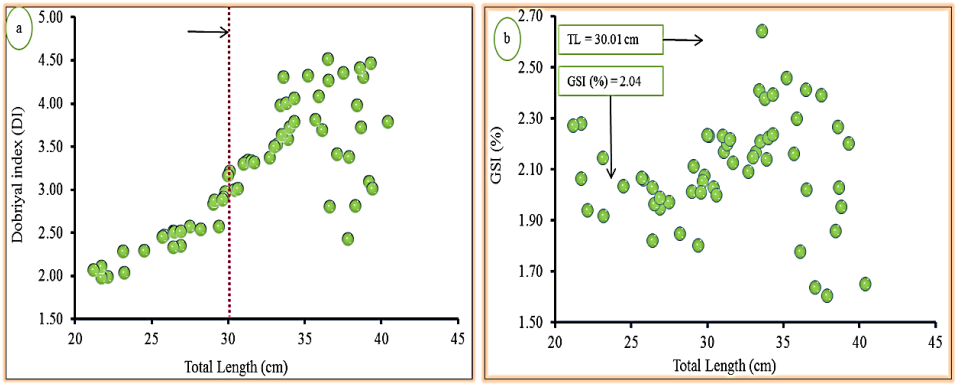


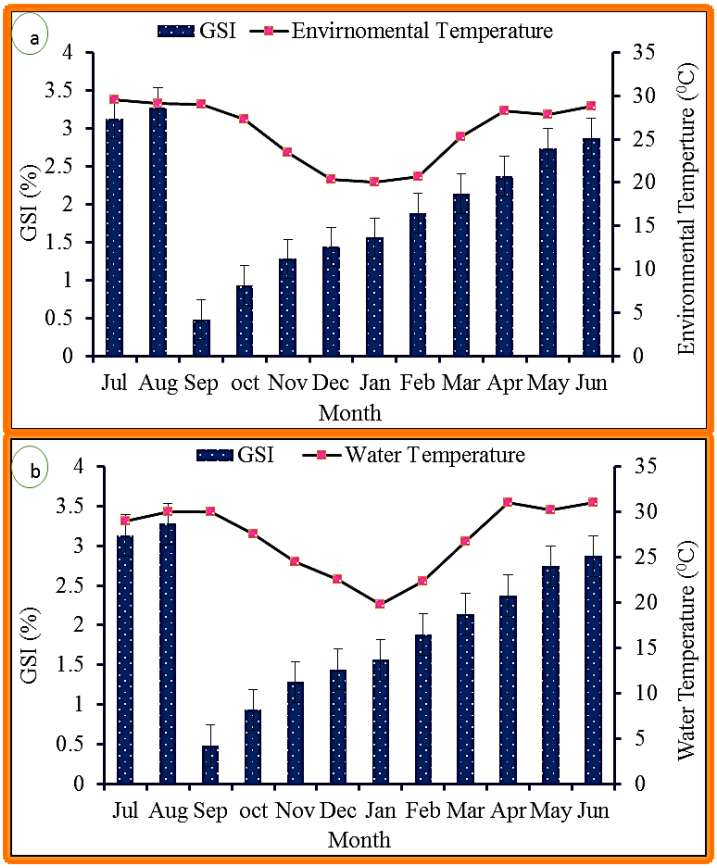

Figure 3. Relationships between (a) Dobriyal index (DI) and total length, and (b) gonadosomatic index (GSI) with total length of female *Arius gagora* in the Meghna river system at Kushiara river, southeast Bangladesh.

1.57±0.50 for female which indicates that the overall health condition of both the male and female were excellent (Table 2).

The interactions between total length against gonadosomatic index and total length against Dobriyal index (DI) of female *A. gagora* are shown in Figure 3. During this study period, GSI ranged from 1.13 to 3.95 with a yearly average 1.97±0.45 and DI ranged from 1.98 to 4.51 with yearly average value of 3.21±0.72. The GSI (>2.04%) and DI (>3.21) rose sharply at ~30.01 cm SL for most of the female population.

The results of Spearman rank-correlation test indicated significant results between rainfall and breeding season ($r_s = 0.606$, $P<0.05$), but no relation was found between HSI and GSI ($r_s = -0.231$, $P = 0.471$), air temperature and GSI ($r_s = 0.517$, $P = 0.085$), water temperature and GSI ($r_s = 0.460$, $P = 0.133$) and photoperiod and GSI ($r_s = -0.336$, $P= 0.286$) (Fig. 4).

Male brood fishes were identified based on pointed muscular genital papilla and oozing of milt when a slight pressure is applied on the abdomen (Fig. 5). The



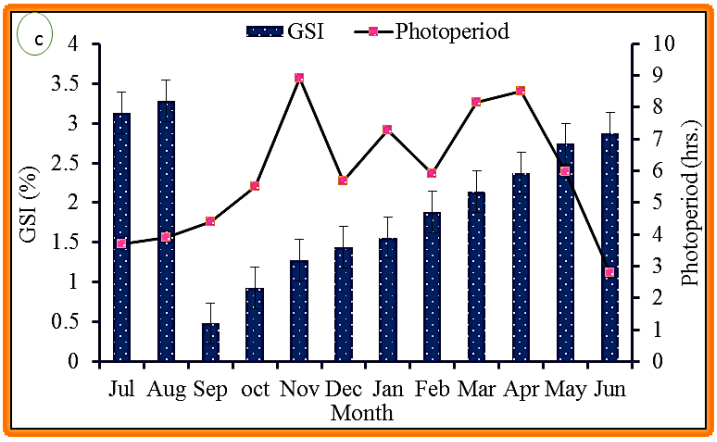




Figure 4. Relationships between (a) monthly mean air temperature (b) monthly mean water temperature and (c) monthly mean photoperiod with monthly mean GSI of female *Arius gagora* in the Meghna river system at Kushiara River, southeast Bangladesh.


Figure 5. A general view of phenotypic sexual characteristics in male (left, ♂) and female (right, ♀) *Arius gagora* (a).

female broods of *A. gagora* was recognized through a bulging abdomen; soft inflated belly and red genital vent (Fig. 5). The genital opening varied from Red (matured) dark pink (maturing) to light pink (immature) in color for females (Table 3). Vertical ovipositor length of female and genital papillae of male were significant (Table 4) both in terms of total body weight and length (female, BW = 0.71, TL = 0.73; male BW = 0.67, TL = 0.66).

The testes of *A. gagora* were paired, elongated, leaf-like and exposed enormous number of dentations. The ovaries of *A. gagora* were paired tubular organs and the color of ovaries was found to oscillate from brownish to greenish depending on maturation stages as showed in Figure 6. In mature ovary, noticeable blood vessels were encountered. Ovaries linked only at the posterior where they opened into the genital aperture. The maximum GSI value of female found to be maximum 3.28±0.11 in August and minimum 0.48±0.003 in September. On the other hand, the highest HSI value for female was observed 0.67±0.006 in April and lowest 0.38±0.09 in August (Fig. 7). The monthly mean GSI and HSI values of female *A. gagora* were plotted with rainfall (Fig. 7).

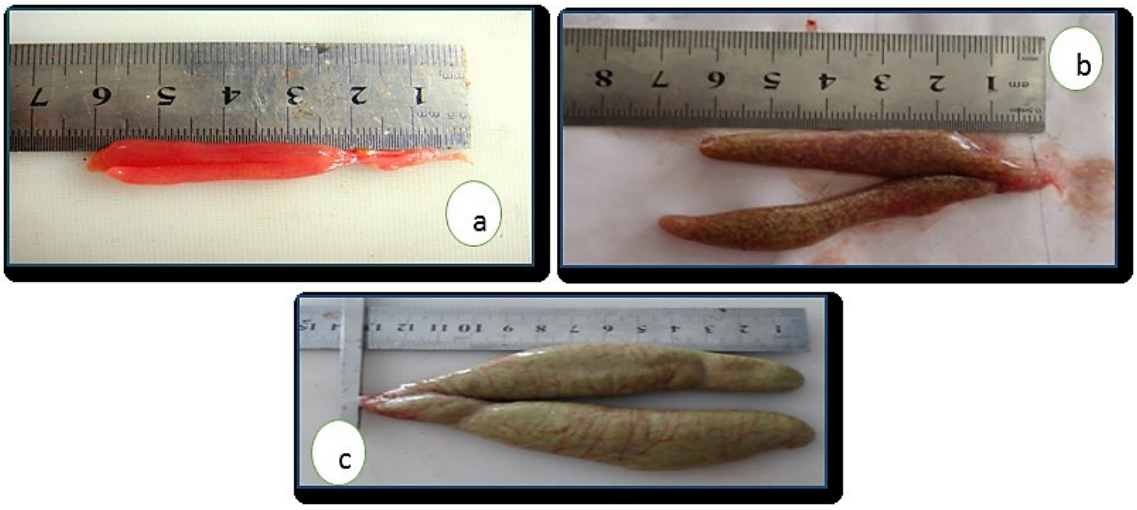



Figure 6. (b) Immature: Sex organs very small and semi-transparent, grayish red in color and possess half or slightly more than the half of abdominal length of enclosure (September-January), (b) Maturing: ovaries become grey brownish in color, partial red blood capillary and occupies more than half of the yard of abdomen, eggs are visible in naked eye (April -June), and (c) Matured: sex organs courtyard filled abdominal and eggs completely round. The color of the ovaries becomes dark green and the red blood capillary was conspicuous (July-August).

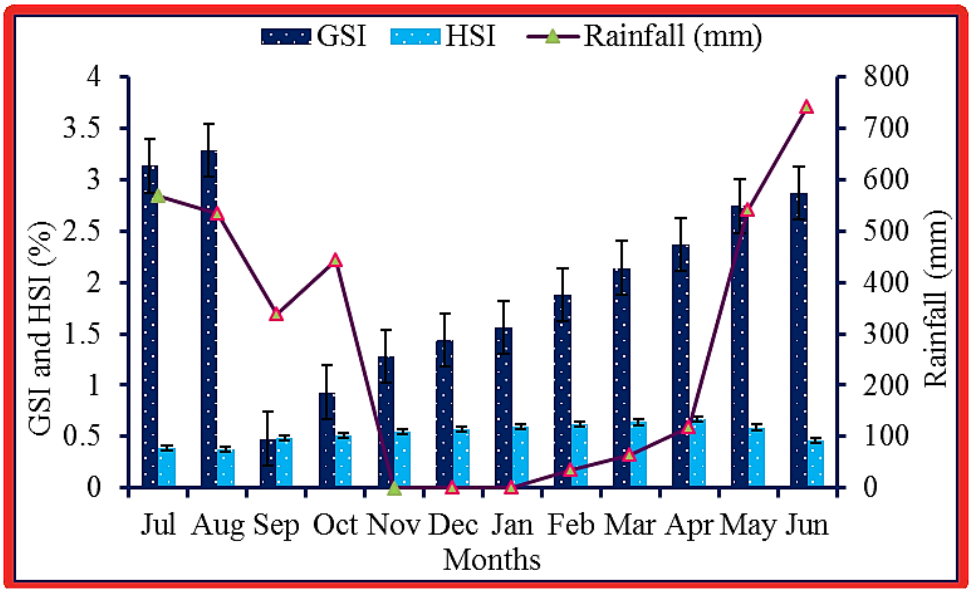



Figure 7. Monthly variation of GSI and HSI of female *Arius gagora* with mean monthly rainfall in the Meghna river system at Kushiara River, southeast Bangladesh.

The ovary of *A. gagora* is tabular shaped and comprising two lobes in which right sided one is found to greater in length than left one found in the peritoneal cavity (Fig. 6). According to gross morphology of the gonad, the complete reproductive cycle of female fish was categorized into three stages.

In the present study, for the assessment of absolute fecundity 28 randomly scooped up matured female fish were used (Table 5). The absolute fecundity was found to differ from 43333.12±829.83 (in April) to 53948.81±1743.28 (in August). The relationship between fecundity and total length, fecundity, and body weight (Table 6) provided a positive correlation ($r^2$ = 0.85 and $r^2$ = 0.68, respectively). Moreover, fecundity and ovary length, fecundity, and ovary weight (Table 5) revealed a positive correlation ($r^2$ = 0.88 and $r^2$ = 0.79 respectively).

The food components found in the guts were only small fishes (Fig. 8). The monthly mean GSI and IPFI values of female *A. gagora* were plotted in the Figure 9. The highest IPFI value was observed 0.84±0.03 in April and lowest 0.08±0.03 in August for female (Fig.

Table 6. Relationship between fecundity and independent variables of female *Arius gagora* collected from the Meghna river system at Kushiara River, southeast Bangladesh.

| Dependant variable | Independent variable | Pearson squares ($r^2$ Values) |
|---|---|---|
| Fecundity | Total length | $r^2 = 0.85$ |
| Fecundity | Body weight | $r^2 = 0.68$ |
| Fecundity | Ovary length | $r^2 = 0.88$ |
| Fecundity | Ovary weight | $r^2 = 0.79$ |

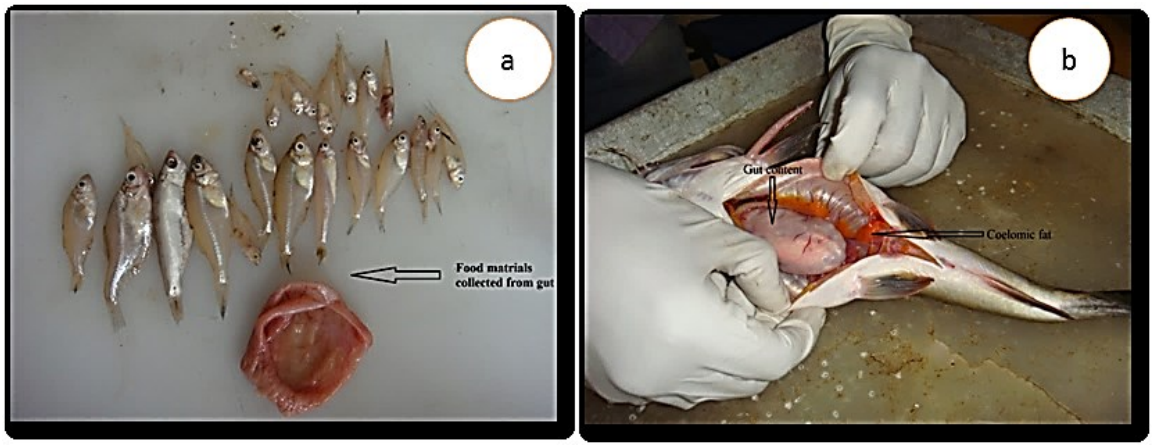



Figure 8. Clear image showing food materials in gut (a) and intra-peritoneal fat (b) of female *Arius gagora* collected from the Meghna river system at Kushiara River, southeast Bangladesh

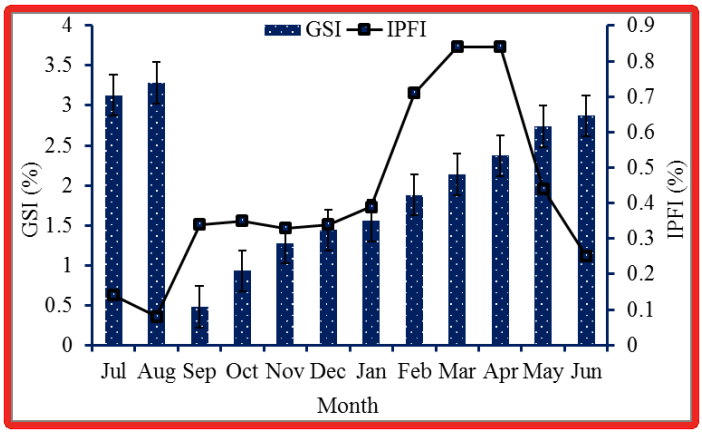



Figure 9. Monthly correlation between GSI and IPFI of female *Arius gagora* in the Meghna river system at Kushiara River, southeast Bangladesh.

9).

## Discussions

According to Nikolsky (1963), the sex ratio may vary from year to year in the same population, but in most fish species, it is close to one. However, the sex ratio of *A. gagora* showed a predominance of female, a similar trend also reported from *M. gulio* (Islam et al., 2008) and *O. pabo* (Gupta et al., 2014). In *A. gagora*, the females were larger than males, similar results also reported by Shinkafi et al. (2002, 2011) in *S. eupterus* and *S. clarias* (Shinkafi et al., 2002) and *S. schall* and *S. nigrita* (Laleye et al., 2006).

The relationship between body weight and total length provided a positive correlation. Noor (2013) assessed TL-BW relationships in *R. rita* and found to be highly significant with correlation coefficient values of 0.97 and 0.95 for male and female, respectively which correlates the present findings. The investigators could not sample individuals of smaller size group because of biased selection of fishing technique (bush trap), or fishermen did not set trap where the smaller fish were (Hossain et al., 2012, 2016; Azad et al., 2018; Khatun et al., 2018), or perhaps the small fish's absence on the sampling areas (Hossain, 2010a, b, 2012, 2013, 2017).

The monthly K-values was lowest in June and maximum in September for female and lowest in August and uppermost in September for male. The condition factor of a fish states physical condition, fatness, or well-being (Mir et al., 2012) of that fish, based on the hypothesis that weightier fish of a given length are in better condition. Konan et al. (2014) found lowest K values in female *C. buettikoferi* during

April 0.75±0.09 which support the present findings. Brito and Bazzoli (2003) studied *P. coruscans* and found lowest K value 1.15±0.19 in spent and highest 1.20±0.23 in resting female which also corroborates the present findings.

The mean GSI varied from 0.48 (September) to 3.28 (August). Monthly study of gonadosomatic index (GSI) revealed that, the breeding season for this fish species may be between July to August with a single peak spawning month in August. The size at sexual maturity was considered to be at 30.01 cm of total length, and individuals with a GSI ≥2.04% and DI ≥3.21 could be roughly defined as mature *A. gagora* females in the Meghna river system at Kushiara River, southeast Bangladesh.

The sharp fall in IPFI was encountered onset of breeding. Spearman rank-correlation test shows no significant correlation between GSI and IPFI ($r_s$ = -0.253, $P$ = 0.428). The present finding is found to be congruent with Brito and Bazzoli (2003) in catfish *P. coruscans.*

Male brood fishes were identified based on pointed muscular genital papilla. Presence of genital papilla in males of catfish species has been perceived earlier before and reported from *Mystus gulio* (Mookherjee et al., 1941; David, 1963), *Gagata* spp. and *Batasio* spp. (Hora and Law, 1941) and *G. reticulam* (Mukherji, 1936). The testes of sexually mature catfish are paired elongated structures located dorsally in the body cavity and the left testis is usually longer than the right one (Vandyk and Pieterse, 2008) which supports the present findings. Spawning period of *A. gagora* was determined by the monthly mean Gonadosomatic Index (GSI) values. The studies on seasonal variation suggested that, the HSI values gradually increase before the onset of the breeding season and its values exhibited a sharp decline with the onset of the breeding activities.

Fish reproduction may be influenced by various factors, including seasonal changes in photoperiod, rainfall and water temperature, along with physic-chemical features of the water body and relating to holding conditions (Bromage et al., 2001; Glasser et al., 2004; Dorostghoal et al., 2009). Isa et al. (2012) noted that male *A. argyropleuron* reached higher GSI value in November, whereas females reached maturity in April followed by June. It does not support the present findings. Kabir et al. (2012) noted that GSI of *P. hypophthalmus*, increased significantly with each morphological stage until the 7$^{th}$ month of culture period coinciding with the final stages of oocyte maturity, during of eight months study in captive condition. But the present findings agreed with the findings *M. tengara* (Banu et al., 1992). On the other hand, if HSI values did not decrease during ovary development, indicates that the stored energy in liver was not utilized during this period and this is likely due to adequate provision of food to the fish (Cek and Yilmaz, 2009; Reidel et al., 2010). But in the present study, HSI values decreased during ovary development, indicating that the stored energy in liver was utilized during this period and this is likely due to inadequate provision of food to the fish. Kabir et al. (2012) noted peak of GSI and HSI of *P. hypophthalmus* in November which is not congruent with the present findings.

Based on macroscopic evaluation, the gonadal development stages of *A. gagora* were divided into 3 broad stages. Five gonad developmental stages were identified including spent phase in *Rasbora tawarensis* (Muchlisin et al., 2010) and *Clarias gariepinus* (Tyor and Pahwa, 2017). Fish with gonad stage three (matured) were considered sexually mature in case of *A. gagora.*

Musa and Bhuiyan (2007) stated fecundity range of 4,652-57,932 in *M. bleekeri*; Bhatt et al. (1977) 20,064-46,443 and 3,314-63,135 for *M. seenghala* and *M. cavasius,* respectively. The current research findings were found to be correlated with the above-mentioned findings. Fecundity correlates with total body length, body weight and ovary weight (Sultan and Khan, 1982). The relation concerning fecundity and ovary length was found to be conspicuous among all the relationships. Present findings found to correlate with the findings of Gupta and Banerjee (2013) in *M. tengara* with a bit exception in case of total body weight.

Generally, catfishes are strong carnivorous species,

the food item taken by them generally being reported as remain intact in shape inside the stomach. Samples collected from bush trap fishing were dissected in the laboratory. Earlier studies on *Arius dussumieri* (Devanesan and Chidambaram, 1953; Suseelan and Nair, 1969; Menon, 1979) and *O. militaris* (Devanesan and Chidammbaram, 1953; Venkataraman, 1960; Srikrishna, 1981) revealed these species to be carnivorous which is congruent with the present findings. Fishes mainly catfishes start to store fats as energy reserve in the coelomic cavity which is known as intra-peritoneal fat or coelomic fat during the pre-spawning period. Thereafter, this reserved energy gradually started to be decreasing prior to pre-spawning-onset of spawning.

## Conclusion

Information on reproductive biology for planning, conservation and management is important for a threatened fish species. The findings of the current study would be effective tools towards scheming management and conservation plans for sustainable conservation and captive maturation. The information gathered through the current study may be used for better management of Gagla catfish fishery in this country towards conservation and for induction of a potential species into aquaculture. However, manipulation of environmental parameters resembled to the month of July-August can be effective for artificial breeding and beginning of gonadal maturation. Further study should be carried out for more reliable information on the breeding biology of *A. gagora.* Studies are needed to culture the species in captive condition with other species

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