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# Population Biology of the Indian River Shad, *Gudusia chapra* (Clupeidae) in the Old Brahmaputra River, North-Eastern Bangladesh

(Populasi Biologi Shad, Sungai India *Gudusia chapra* (Clupeidae) di Sungai Brahmaputra Lama, Timur Laut Bangladesh)

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ABSTRACT

*Population biology including population structure, reproduction, length-weight relationship and condition factor of a commercially important clupeid freshwater fish,* Gudusia chapra *was studied in the Old Brahmaputra River, Bangladesh during January-December 2009. In the present study, a total of 2032 specimens (1091 male; 941 female) were collected. The overall sex ratio showed significant difference from the expected value 1:1 (male: female = 1:0.86,* $\chi^2 = 11.07$, $p<0.001$*). Length-frequency distribution showed a size predominance of females over males, where mean female size consistently exceeded that of males throughout the year. Female size at first sexual maturity was estimated as 8.3 cm in standard length (SL). Monthly gonadosomatic index (GSI) was higher during March-September with a peak in April, indicating this was the main spawning season. The allometric coefficient b of the length-weight relationship (LWR) indicated negative allometric growth in males and females, but the analysis of covariance (ANCOVA) showed significant differences in slope and intercept between the sexes (*$p<0.001$*). Fulton's condition factor by months and SLs varied in both sexes and was attributed to variations in GSI with maturity.*

*Keywords: Clupeidae; gonadosomatic;* Gudusia chapra*; index; management; population biology*

ABSTRAK

*Populasi biologi termasuk struktur populasi, pembiakan, hubungan panjang-berat dan keadaan faktor yang penting secara komersial ikan klupeid air tawar,* Gudusia chapra *telah dikaji di Sungai Lama Brahmaputra, Bangladesh sepanjang Januari-Disember 2009. Dalam kajian ini, sejumlah 2032 spesimen (1091 jantan; 941 betina) telah dikumpulkan. Nisbah jantina secara keseluruhan menunjukkan perbezaan yang ketara daripada jangkaan nilai 1:1 (jantan: betina = 1:0.86,* $\chi^2 = 11.07$, $p<0.001$*). Pembahagian panjang-kekerapan menunjukkan saiz betina kepradominaan berbanding jantan dengan purata saiz betina secara konsisten melebihi jantan sepanjang tahun. Saiz kematangan seksual pertama pada betina adalah dianggarkan sebagai 8.3 cm mengikut piawai panjang (SL). Indeks bulanan gonadosomatik (GSI) adalah lebih tinggi semasa bulan Mac-September dengan puncak pada bulan April yang menunjukkan ini adalah musim bertelur yang utama. Pekali hubungan alometrik b panjang-berat (LWR) menunjukkan pertumbuhan alometrik negatif dalam jantan dan betina, tetapi analisis kovarians (ANCOVA) menunjukkan perbezaan yang signifikan antara jantina dalam cerun dan pintasan (*$p<0.001$*). Faktor keadaan Fulton mengikut bulan dan SLs berubah dalam kedua-dua jantina dan ini disebabkan oleh perubahan dalam GSI dengan matang.*

*Kata kunci: Biologi penduduk; Clupeidae; gonadosomatik;* Gudusia chapra*; indeks; pengurusan*

## INTRODUCTION

The Indian River shad, *Gudusia chapra* (Hamilton 1822), is a freshwater clupeid species which is widely distributed in the river systems of India and Bangladesh affluent to the Bay of Bengal; principally the Ganges and Brahmaputra (Whitehead 1985). The species has also been reported from Nepal and Pakistan (Menon 1999; Shrestha 1994). The species also inhabits lakes, ponds, ditches and inundated fields (Rahman 1989). The species presents an important fishery in the artisanal fisheries of the Indian sub-continent and is an important source of livelihood for many of the subsistence and artisanal fisher folks (Daniels 2002; Jayaram 1999; Talwar & Jhingran 1991).

In Bangladesh, *G. chapra* is one of the important small indigenous fish species reported as both an important food resource and a crucial source of micronutrients essential in preventing malnutrition and vitamin and mineral deficiencies in the rural communities, particularly among women and children (Thilsted 2003; Thilsted et al. 1997). It is commercially important as a target species for the small-scale fishermen (Ahmed et al. 2007; Craig et al. 2004; Kibria & Ahmed 2005).

Several studies on the biological aspects of *G. chapra*, including maturity and fecundity (Chondar 1977; Jhingran & Verma 1967; Mustafa & Ansari 1983; Quddus et al. 1990), morphology, meristic and non-meristic characters

(Chondar 1976, 1975), fecundity (Chondar 1977; Mustafa & Ansari 1983; Quddus et al. 1990), gonadosomatic index and fecundity (Kabir et al. 1998), age and growth (Narejo et al. 2000), biology (Vinci et al. 2005), growth and reproduction (Ahmed et al. 2007), length-weight relationships (Hossain et al. 2009; Sani et al. 2010) and size at sexual maturity and fecundity (Hossain et al. 2010) have been conducted.

The Old Brahmaputra River is considered as an important spawning and feeding ground for riverine fishes of Bangladesh and a large numbers of these species including *G. chapra* fished by both small and large-scale fisheries throughout the year (Hossain & Ahmed 2008). However, there is no published report on the biology of *G. chapra* from the Old Brahmaputra River of Bangladesh, which attracted our attention extensively. Therefore, the present study describes the population biology of *G. chapra* including sex ratio, population structure, size at first sexual maturity, spawning season, length-weight relationship and condition factor in order to provide the much needed data and information for the sustainable management of this species.

## Materials and Methods

The present study was conducted in the Old Brahmaputra River of Bangladesh which is comprised of two channels: A main channel, the Jamuna which running through Bangladesh, and an old channel, commonly known as the Old Brahmaputra River running through the northeastern district of Mymensingh, Bangladesh, straddling 23º 58´ and 25º 25´ N, and 89º 38´ and 91º 15´ E.

Monthly samples were collected from several predetermined sites of the river section passing through Bangladesh Agricultural University campus during January-December 2009. The sampling was conducted from a boat using a combination of fine meshed cast nets and seine nets of <2 mm mesh size in order to include all size groups within the population in the catch. Monthly water temperature was also recorded at each sampling. All specimens were preserved in ice and transferred to the laboratory prior to analysis. The standard length (*SL*) of all individuals was measured to the nearest 1 cm using a measuring scale, while body weight (*BW*) was recorded using a digital balance (Shimadzu, EB-430DW, Japan) to 0.01 g accuracy. Sexing was conducted by incision of the abdomen of each individual and visual inspection of the gonad. All fat, connective tissue and blood vessels were carefully removed from the gonads and the weight of the gonads measured to the nearest 0.001 g.

Monthly sex ratio (females/total) was calculated and results were analyzed by use of a $\chi^2$ test (1:1; $p<0.05$). Temporal changes in the population structure of *G. chapra* were investigated by examining *SL* frequency distributions, which were obtained by sex using 0.5 cm interval on pooled data for the whole sampling period as well as by group for each month. The gonadosomatic index (*GSI*) was calculated as: $GSI\ (\%) = (GW / BW) \times 100$. Female size at first sexual maturity was estimated by the relationship between the *GSI* and *SL*. Spawning season was estimated based on the monthly variations of *GSI*.

The relationship between *BW* and *SL* was calculated using the equation: $BW = a\ SL^b$, where *a* and *b* are the intercept and slope, respectively, of the linear regression analysis equation based on natural log equations of the relationship between BW and SL as follows: $\ln (BW) = \ln (a) + b \ln (SL)$. Significant deviation of *b* value from the theoretical isometric value ($b = 3$) indicates either positive ($b > 3$) or negative ($b < 3$) allometric growth (Tesch 1971), which was verified with Student's *t*-tests (Sokal & Rohlf 1981). Analysis of covariance (ANCOVA) (Zar 1984) was used to test for significant differences in slopes and intercepts between sexes. Fulton's condition factor (*K*) was estimated using the equation: $K = (BW / L^3) \times 100$ for both monthly and in terms of size (*SL* in cm) class.

## Results

A total of 2032 specimens of *G. chapra* were collected during this study, with 1091 (53.7%) males and 941 (46.3%) females. The *SL* ranged at 3.5-12.5 cm in males and 3.1-13.7 cm in females, whereas BW ranged at 0.80-33.01 g and 0.91-44.54 g for male and female respectively (Table 1). The sex ratio was 1:1 for almost all the year (Figure 1), except in June, August, September and December when males were significantly more abundant than females ($\chi^2$ test, $p<0.05$). However, the overall sex ratio showed significant difference from the expected value of 1:1 (male:female = 1:0.86, $\chi^2 = 11.07$, $p<0.001$) (Figure 1).

The pooled size-frequency distribution was polymodal and asymmetrical for larger sizes, with the main mode peaking at approximately 7 cm for both sexes (Figure 2). Monthly changes in size-frequency distributions by sex showed the occurrence of different size groups of *G. chapra* in the population during the year (Figure 3). There was a size predominance of females over males, with mean female size consistently exceeding that of male throughout the year.

The relationship between *SL* and *GSI* of female *G. chapra* is shown in Figure 4. The lowest and highest *GSI* recorded during this study was 0.02 and 12.64 respectively. The *GSI* of < 8 cm *SL*- females was low (<4.0). However, the *GSI* rose sharply at around 8.3 cm *SL*. Therefore, the size at first sexual maturity of *G. chapra* was considered to be 8.3 cm *SL*.

The monthly mean *GSI* with minimum and maximum values of female *G. chapra* were plotted (Figure 5). The mean *GSI* varied from 0.82 in January to 4.83 in April. The *GSI* value began to rise from March and remained high until September with a peak in April. The *GSI* then decreased from October and remained low until February.

The relationships between *SL* and *BW* indicated negative allometric growth both in males and females as the allometric coefficient *b* values were significantly different from the expected isometric value of 3 (t-test; $p<0.05$). Significant difference in both slope (*b*) and intercept (*a*) was

TABLE 1. Monthly descriptive statistics and estimated parameters of length–weight relationships for *G. chapra* in the Old Brahmaputra River, northeastern Bangladesh

| Month | Sex | n | SL (cm) | | BW (g) | | Regression parameters | | 95% Cl of b | $r^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | Min | Max | a | b | | |
| January 2009 | M | 99 | 3.5 | 8.4 | 0.80 | 11.45 | 0.0157 | 3.15 | 3.03-3.27 | 0.981 |
| | F | 85 | 4.1 | 9.9 | 1.43 | 20.00 | 0.0229 | 2.96 | 2.86-3.06 | 0.988 |
| February | M | 91 | 3.7 | 10.1 | 0.89 | 20.94 | 0.0157 | 3.10 | 3.02-3.18 | 0.992 |
| | F | 75 | 3.1 | 10.2 | 0.91 | 20.18 | 0.0208 | 2.96 | 2.87-3.06 | 0.991 |
| March | M | 82 | 3.8 | 10.0 | 1.26 | 18.70 | 0.0231 | 2.93 | 2.86-2.99 | 0.995 |
| | F | 79 | 3.7 | 13.2 | 1.06 | 38.97 | 0.0275 | 2.85 | 2.80-2.91 | 0.996 |
| April | M | 98 | 4.5 | 12.5 | 1.84 | 33.01 | 0.0290 | 2.79 | 2.72-2.88 | 0.991 |
| | F | 100 | 4.5 | 13.7 | 1.74 | 41.12 | 0.0241 | 2.89 | 2.81-2.97 | 0.991 |
| May | M | 95 | 4.0 | 5.7 | 1.32 | 3.94 | 0.0216 | 2.96 | 2.71-3.20 | 0.921 |
| | F | 87 | 4.3 | 11.5 | 1.67 | 33.44 | 0.0245 | 2.95 | 2.87-3.03 | 0.992 |
| June | M | 109 | 3.5 | 11.4 | 0.85 | 28.00 | 0.0234 | 2.91 | 2.87-2.96 | 0.996 |
| | F | 88 | 3.6 | 12.3 | 1.00 | 37.90 | 0.0221 | 2.95 | 2.91-3.00 | 0.998 |
| July | M | 87 | 5.2 | 9.5 | 3.05 | 16.06 | 0.0367 | 2.81 | 2.59-3.04 | 0.930 |
| | F | 87 | 5.4 | 13.7 | 3.14 | 44.54 | 0.0230 | 2.90 | 2.80-2.99 | 0.987 |
| August | M | 99 | 5.7 | 6.6 | 3.70 | 6.13 | 0.0607 | 2.39 | 2.06-2.70 | 0.771 |
| | F | 65 | 5.5 | 12.0 | 3.48 | 31.75 | 0.0268 | 2.84 | 2.66-3.02 | 0.971 |
| September | M | 97 | 4.3 | 7.1 | 1.59 | 7.97 | 0.0314 | 2.78 | 2.63-2.94 | 0.956 |
| | F | 75 | 4.0 | 12.4 | 1.34 | 29.00 | 0.0390 | 2.67 | 2.59-2.75 | 0.992 |
| October | M | 87 | 5.2 | 6.9 | 3.21 | 6.70 | 0.0420 | 2.66 | 2.47-2.85 | 0.941 |
| | F | 79 | 5.0 | 13.6 | 3.08 | 35.02 | 0.0460 | 2.58 | 2.50-2.67 | 0.989 |
| November | M | 65 | 5.2 | 7.0 | 3.32 | 7.78 | 0.0463 | 2.59 | 2.30-2.89 | 0.886 |
| | F | 65 | 5.2 | 11.8 | 3.27 | 30.68 | 0.0411 | 2.66 | 2.53-2.80 | 0.975 |
| December | M | 82 | 4.3 | 12.0 | 1.77 | 32.93 | 0.0337 | 2.78 | 2.70-2.85 | 0.990 |
| | F | 56 | 4.4 | 9.5 | 1.73 | 16.67 | 0.0353 | 2.75 | 2.51-2.99 | 0.939 |
| Overall | M | 1091 | 3.5 | 12.5 | 0.80 | 33.01 | 0.0236 | 2.92 | 2.89-2.96 | 0.980 |
| | F | 941 | 3.1 | 13.7 | 0.91 | 44.54 | 0.0289 | 2.83 | 2.80-2.85 | 0.989 |
| | B | 2032 | 3.1 | 13.7 | 0.80 | 44.54 | 0.0260 | 2.87 | 2.85-2.89 | 0.986 |

M, male; F, female; B, both sexes; n, sample size; Min, minimum; Max, maximum; *a*, intercept; *b*, slope; Cl, confidence limits; $r^2$, coefficient of determination

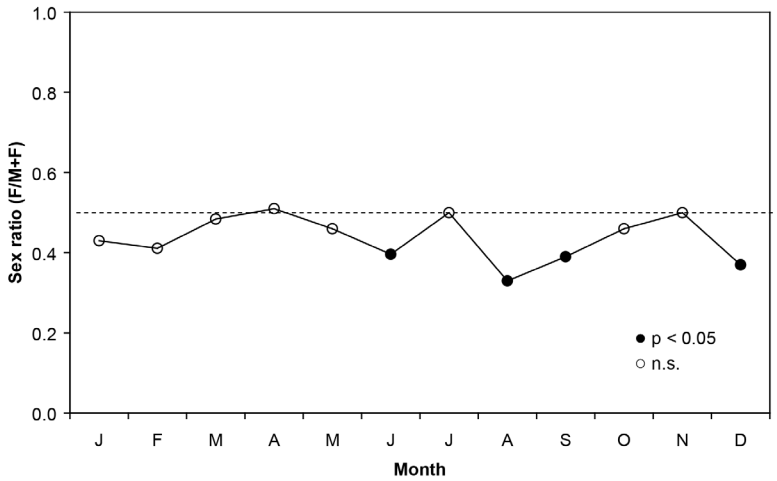


FIGURE 1. Temporal variation in sex ratio of *Gudusia chapra* (● statistically significant difference from 1:1 ratio, O non-significant) in the Old Brahmaputra River, northeastern Bangladesh

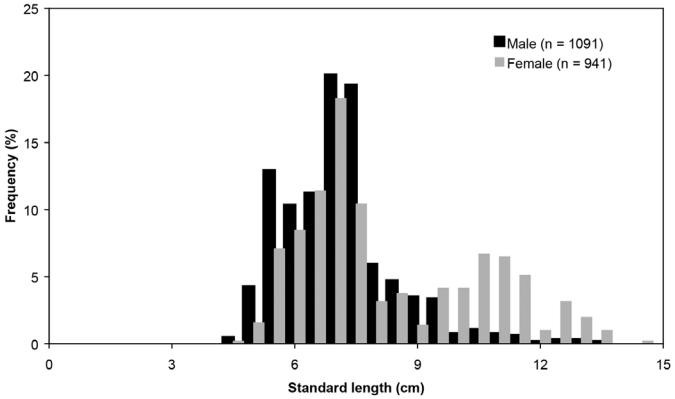


FIGURE 2. Size-frequency distribution of pooled male and female *Gudusia chapra* in the Old Brahmaputra River, northeastern Bangladesh

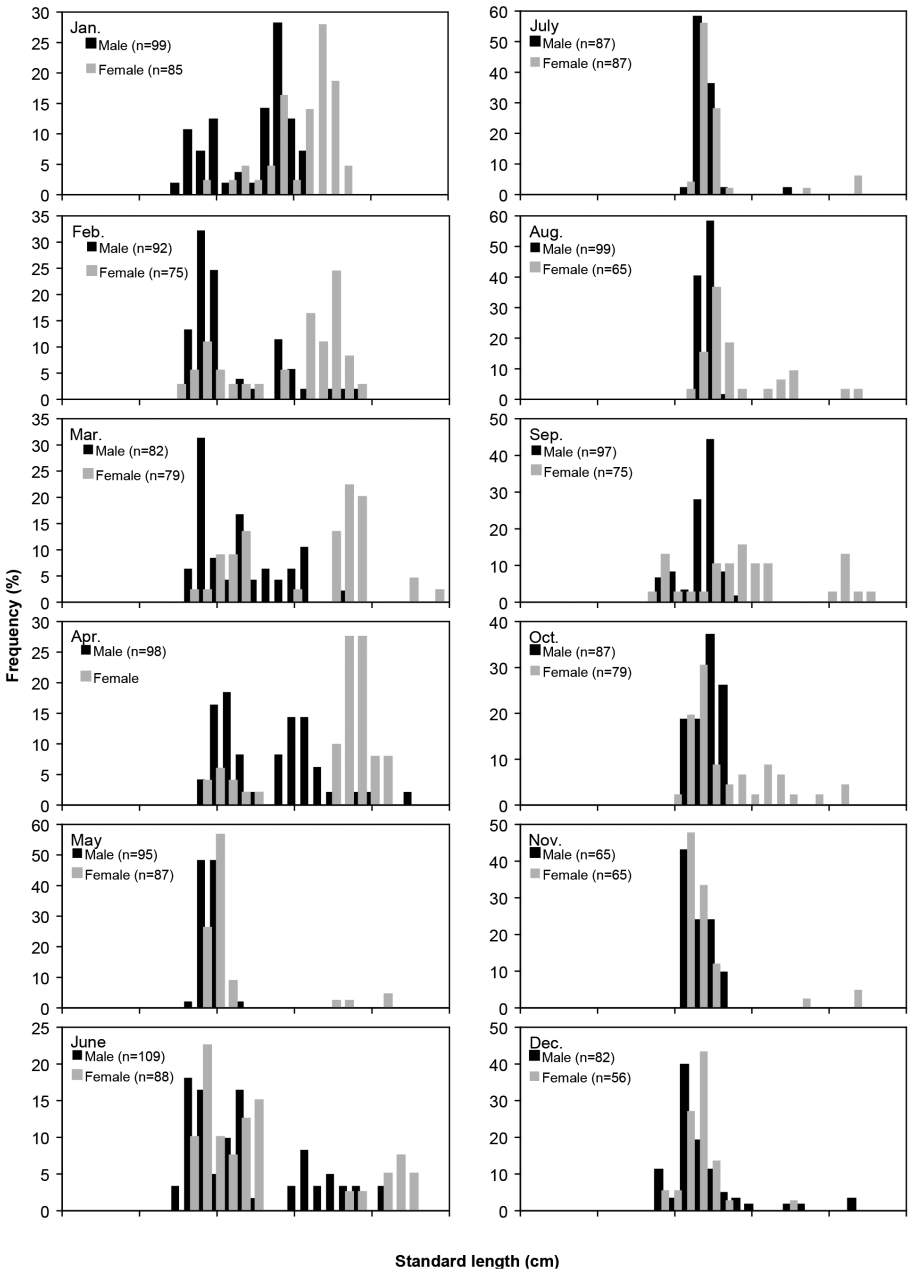


FIGURE 3. Monthly size-frequency distribution of males and females *Gudusia chapra* in the Old Brahmaputra River, northeastern Bangladesh

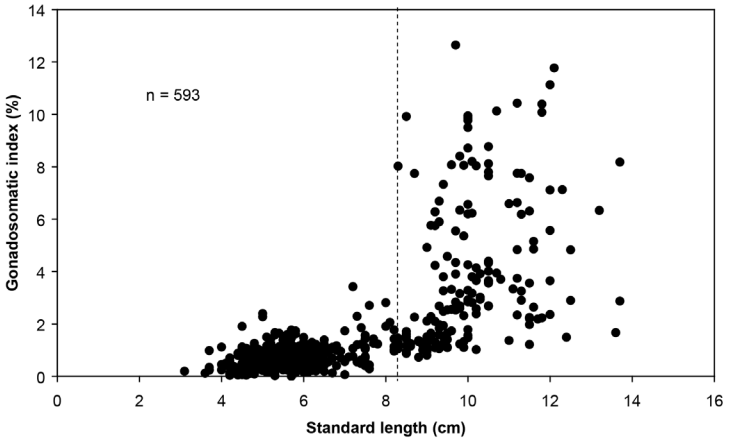


FIGURE 4. Relationship between gonadosomatic index and standard length (cm) for female *Gudusia chapra* in the Old Brahmaputra River, northeastern Bangladesh. The vertical dot line indicates estimate of size at first maturity

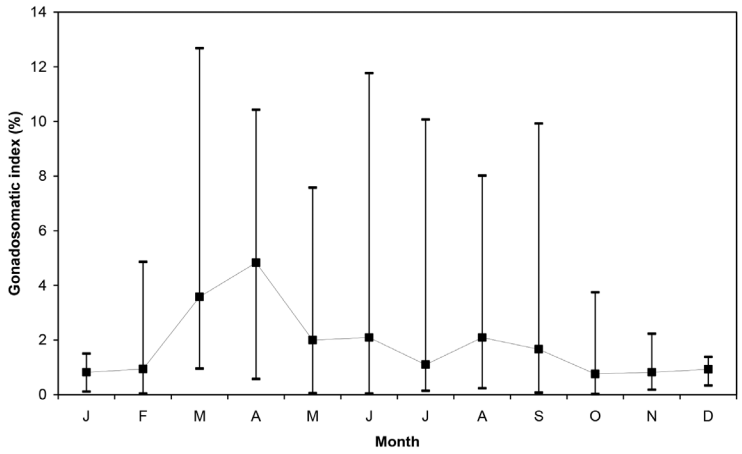


FIGURE 5. Monthly changes of mean gonadosomatic index (*GSI*) with minimum and maximum values, for female *Gudusia chapra* in the Old Brahmaputra River, northeastern Bangladesh

observed between sexes (ANCOVA; $p<0.001$) (Figure 6). The monthly *SL-BW* relationships of *G. chapra* presented in Table 1 shows that the calculated allometric coefficients varied between 2.39 (August) and 3.10 (January and February) in males and between 2.58 (October) and 2.96 (January and February) in females. High values for coefficients of determination (Table 1) were obtained in all *SL-BW* analyses, indicating that the relationships were statistically significant ($p<0.001$) and applicable to the population as a whole.

The Fulton's condition factors (*K*) varied monthly for both sexes (Figure 7). The monthly *K* ranged from 1.84 to 2.28 in males and from 1.88 to 2.28 in females. The lowest *K* was found in February and April for males and females, respectively, while the highest was in December for both sexes. In majority of the months, *K* in females was higher than that in males except in April, July, August and September. The *K* with regard to length class is presented in Figure 8. Males recorded minimum *K* value at 12.5 cm and maximum at 5.5 cm, whereas females showed minimum value at 13.5 cm and maximum at 3.5 cm. The *K* for females was better than that for males at most length classes. The *K* tended to be lower after 8.0 cm for both sexes.

Monthly variations of water temperature of the Old Brahmaputra River are shown in Figure 9. The temperature was low in January, then gradually increased beginning February and remained high from April to October and thereafter started to decrease gradually until December.

## DISCUSSION

The present study represents the sex ratio, population structure, size at first sexual maturity, spawning season, length-weight relationship and condition factor of *G. chapra*. The overall yearly sex ratio was found to be slightly in favor of male. Monthly sex ratio was equally presented in most of the months except in June, August, September and December when male was predominant over female. Sex ratio variations may be attributed to reproduction, growth and longevity of a species (Chilari et al. 2005; Oh et al. 2002). However, in the present study,

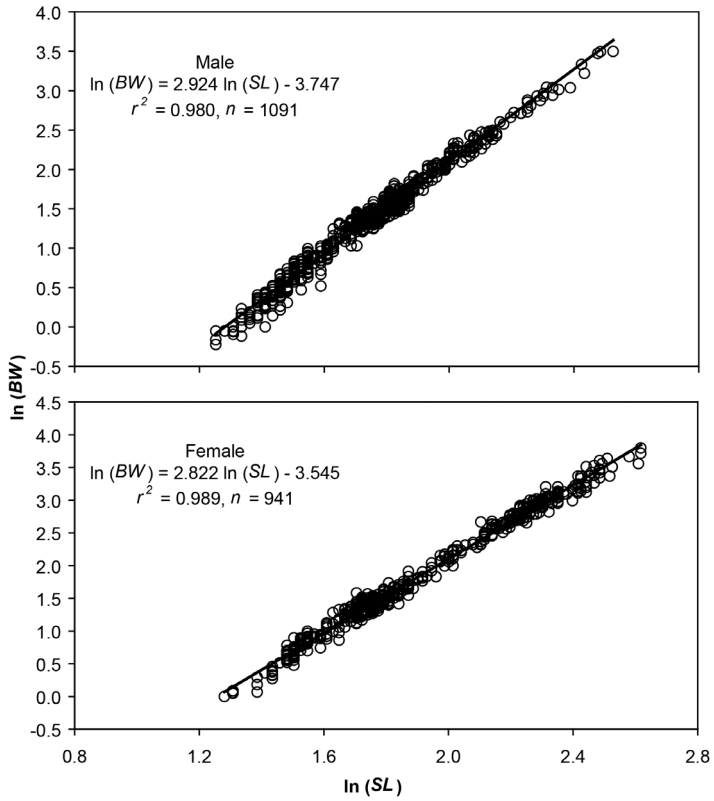


FIGURE 6. Relationship between log-transformed standard length and log-transformed body weight for male and female *Gudusia chapra* in the Old Brahmaputra River, northeastern Bangladesh

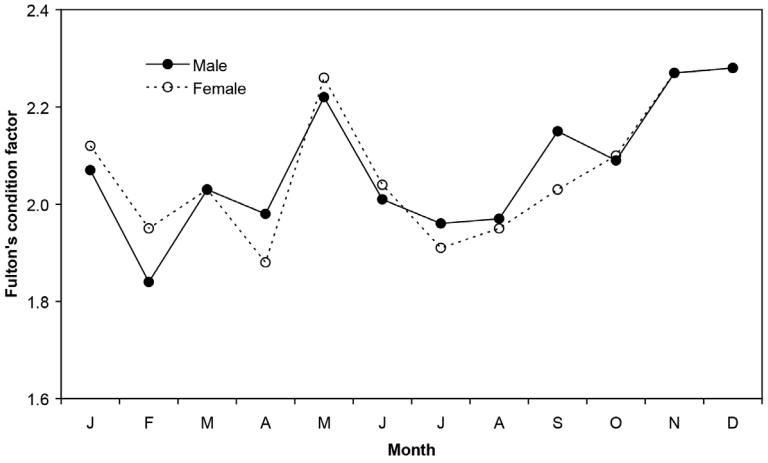


FIGURE 7. Monthly changes of Fulton's condition factor for male and female *Gudusia chapra* in the Old Brahmaputra River, northeastern Bangladesh

it was not clear which factors might be responsible in the fluctuation of male-female sex ratio.

The monthly size-frequency distributions showed that more than one size groups were found to be present in each month for both sexes. In accordance with other studies (Maiorano et al. 2002), a size predominance of female over male was found, with female size consistently exceeding that of male throughout the year. Several studies (Colloca 2002; Dailey & Ralston 1986; Ohtomi 1997) indicated that size predominance in female is a common feature. This size difference between male and female might be attributed to several factors, such as physiological changes influenced by temperature change, feeding regime and reproductive cycle (Morales-Nin & Ralston 1990; Newman et al. 2000; Utagawa & Taniuchi 1999).

The size at sexual maturity is of special interest in fisheries management and is widely used as an indicator for minimum permissible capture size (Lucifora et al. 1999).

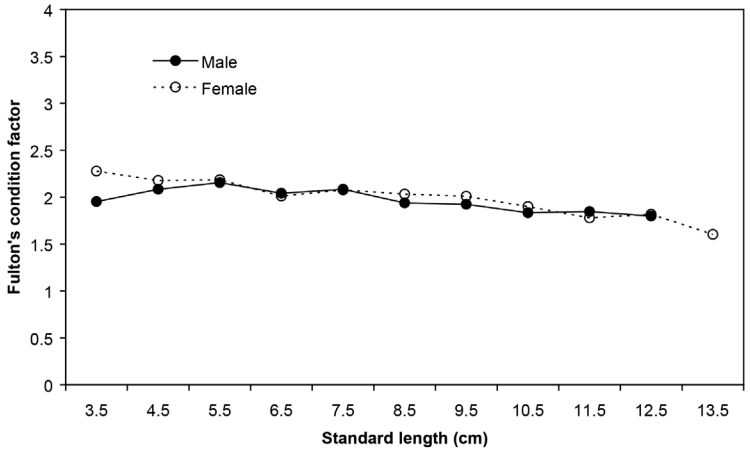


FIGURE 8. Fulton's condition factor with regard to standard length (cm) class for male and female *Gudusia chapra* in the Old Brahmaputra River, northeastern Bangladesh

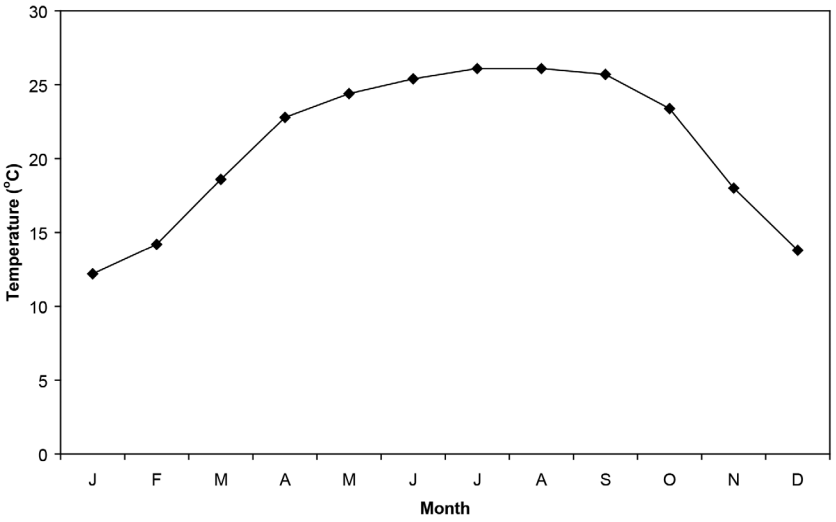


FIGURE 9. Monthly changes of water temperature in the Old Brahmaputra River, northeastern Bangladesh

Available information on size at sexual maturity of fishes from plots of percentage occurrence of mature females against length class can be obtained from the resulting logistic equation (Cha et al. 2004; Choi et al. 2005; Yamada et al. 2007). However, several studies have reported low accuracy in the estimation of size at sexual maturity for fishes using this logistic equation (Gab-Alla et al. 1990; Hossain et al. 2012), hence its suitability for organisms with short life cycles such as *G. chapra* is questionable (Hossain et al. 2010). In the present study, the size at first sexual maturity of *G. chapra* was estimated as 8.3 cm *SL* on the basis of the relationship between *SL* and *GSI*. This result was in agreement with the study by Kabir et al. (1998) who reported that the sexual maturity for female *G. chapra* in a perennial earthen pond was 9.3 cm *SL*. Hossain et al. (2010) reported the first sexual maturity as 8.0 cm *SL* in the Ganges River. The difference in the size at first sexual maturity may be influenced by the abundance and seasonal availability of food, temperature, photoperiod and other environmental factors in different zoogeographical regions (King 1995).

Monthly variations of *GSI* indicated that *G. chapra* has an elongated spawning season from March to September with a peak in April, which might be attributed to the monthly variations of water temperature, as monthly water temperature in the present study followed a similar pattern of *GSI*. Several studies reported the water temperature as an important factor controlling spawning (Ahamed & Ohtomi 2012; Allen 1966; Bauer 1992; Kikuchi 1962).

Length-weight relationship (*LWR*) can be derived from length and weight measurements of the same fishes throughout their lives or from a sample of fish taken at a particular time (Wootton 1990). The parameters of length-weight relationship are influenced by a series of factors including season, habitat, gonad maturity, sex, diet, stomach fullness, health of the individuals in their

TABLE 2. Regression coefficients for length-weight relationships of *Gudusia chapra* from different geographical locations of the world

| River / Basin / Location | n | Sex | Length | *a* | *b* | $r^2$ | Author/s |
|---|---|---|---|---|---|---|---|
| Floodplain wetland, West Bengal, India | 200 | C | $SL^{mm}$ | 0.00860 | 2.86 | 0.918 | Vinci et al. (2005) |
| Large perennial pond, Mymensingh, Bangladesh | 1334 | M | $SL^{mm}$ | 0.00003 | 2.97 | 0.955 | Ahmed et al. (2007) |
| | 1254 | F | $SL^{mm}$ | 0.00004 | 2.82 | 0.976 | |
| Ganges River, northwestern Bangladesh | 220 | C | $SL^{cm}$ | 0.01300 | 3.11 | 0.985 | Hossain et al. (2009) |
| Betwa (Yamuna River tributary) River, Uttar Pradesh, India | 30 | C | $TL^{cm}$ | 0.00790 | 2.98 | 0.950 | Sani et al. (2010) |

n, sample size; M, male; F, female; C, combined gender; SL, standard length; TL, total length; mm, millimeter; cm, centimeter; *a*, intercept; *b*, slope; $r^2$, coefficient of determination

natural habitats as well as the treatment of specimens and preservation techniques after sampling (Bagenal & Tesch 1978; Tesch 1971). Subsequently, if these length-weight relationships were obtained monthly throughout a complete annual cycle as in the present study, then the simulated parameters would be more appropriate. This would apply as well as for entire length-weight relationship data. The allometric coefficient (*b*) generally lies between 2.5 and 3.5 (Froese 2006), but they can vary between 2.0 and 4.0 (Bagenal & Tesch 1978). In the present study, both male and female indicated negative allometric growth. However, all allometric coefficients (*b*) estimated in the present study were within the expected range according to earlier research (Table 2) except the studies in the Ganges River, northwestern Bangladesh, where Hossain et al. (2009) recorded positive allometric growth. The differences in *b* values can be attributed to the combination of one or more factors including habitat, area, season, stomach fullness, gonadal condition, sex, health, preservation methods and differences in the size of the specimens caught (Hossain et al. 2011), which were not accounted in this study.

In the present study, the *K* values of *G. chapra* were the lowest in February and April for male and female respectively, whilst the highest in December for both sexes. Fulton's *K* is correlated with the monthly changes of *GSI* (Hossain et al. 2006). The present study indicated that the *GSI* for both sexes started to increase rapidly in February and remained high from March to September with a peak in April, thereafter started to decrease in the subsequent months and was the lowest in December. Therefore, it appears that *K* of *G. chapra* started to decrease with the start of reproductive period and recovered at the end of reproductive period. The *K* with regard to length class showed a noticeable decrease after 8.0 cm for both sexes, which might be attributed to the start of sexual maturation, as indicated in the present study, which recorded the size at first sexual maturity of *G. chapra* as 8.3 cm.

In conclusion, this is the first comprehensive study on the biological aspects of this shad fish in the Old Brahmaputra River, NE Bangladesh. The findings of this study would be useful for fishery biologists/managers to impose adequate regulations for conservation of this critically endangered fishery in Bangladesh and neighbouring countries.

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