Pakistan J. Zool., vol. 48(4), pp. 1099-1107, 2016.

Temporal Variations of Sex Ratio, Length-Weight Relationships and Condition Factor of *Cabdio morar* (Cyprinidae) in the Jamuna (Brahmaputra River Distributary) River, Northern Bangladesh

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ABSTRACT

The fish *Cabdio morar* (Hamilton, 1822) is a member of the family Cyprinidae, commonly known as morari in Bangladesh and Aspidoparia in India. This fish was previously known as *Aspidoparia morar* and is widely distributed in Bangladesh, India, Myanmar, Nepal, Pakistan, and Thailand. The present study describes the temporal variations of sex ratio (SR), length-frequency distributions (LFDs), length-weight relationship (LWRs), and Fulton's condition factor (K_F) of the *C. morar*. A total of 1200 specimens (male = 552, female = 648) ranging from 4.06-12.84 cm TL and 0.53-16.75 g BW were analyzed. The overall SR showed significant differences from the expected value of 1:1 (male: female) (χ^2 = 7.68, P > 0.01), and there was also a significant difference in LFD between the sexes (P < 0.05). The allometric co-efficient (*b)* for the overall LWR indicated positive allometric growth (> 3.00) in males and isometric growth in females (~ 3.00). Hence, LWRs were significantly different between males and females (ANCOVA, P < 0.001). K_F showed significant variation (P < 0.01) between the sexes, with better performance by females (0.88 ± 0.14) than for males (0.86 ± 0.15). In addition, our study uniquely discovered the spawning season based on lower values of allometric co-efficient (*b*) for *C. morar* during December to March in the Jamuna River. These results will help further studies on population assessment and stock management of *C. morar* in the Jamuna River ecosystem.

Article Information
Received 22 April 2015
Revised 23 December 2015
Accepted 30 January 2016
Available online 1 June 2016

Authors' Contribution
MHY designed the experiment and wrote the article. MSA, MIH, MAH and MMI collected samples and recorded the data, MAH helped in writing the article. KY, MMR and ZM performed statistical analysis. AHB and AME provided funds for this work.

Key words
Temporal variations, sex ratio, length-weight relationship, condition factor, *Cabdio morar*.

INTRODUCTION

Cabdio morar (Hamilton, 1822) is a member of the family Cyprinidae, commonly known as morari in Bangladesh (Froese and Pauly, 2015). This fish is widely distributed in Bangladesh, India, Iran, Myanmar, Nepal, Pakistan and Thailand (Talwar and Jhingran, 1991; Froese and Pauly, 2015). *C. morar* is found in streams, rivers, and ponds in plains and montane regions (Chaudhry, 2010). The Morari is one of the dominant fish species in the Jamuna River, northern Bangladesh, and small-scale anglers often target this species (Craig *et al.*, 2004; Kibria and Ahmed, 2005; Hossain, 2010a). It is a major source of animal protein and micronutrients in the diet of rural people (Ross *et al.*, 2003; Hossain *et al.*, 2009). Formerly, *C. morar* was plentiful in rivers and streams of Bangladesh. However, the wild populations have seriously declined because of over-exploitation, as amplified by various ecological changes and natural habitat degradation (Hossain *et al.*, 2012a). Major threats to this species are destructive fishing and habitat degradation (Chaudhry, 2010; Hossain *et al.*, 2015a, b; Hossen *et al.*, 2015).

The relationship between length and weight (LWR) − along with condition factors are useful parameters for assessing the well-being of individuals and to determine probable variations among different stocks of the same species (King, 2007). Furthermore, condition factor is important for assessing the well-being of the fish and also predicting future population success, given its influence on growth, reproduction, and survival (Richter, 2007).

Demographic information throughout the year for

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0030-9923/2016/0004-1099 $ 8.00/0

C. morar is scarce in the literature (Hossain *et al.*, 2013a), so this remains an obstacle to the formulation of sound management strategies for this important fishery. Therefore, this study is the first report on the temporal variations of the sex ratio (SR), length frequency distributions (LFDs), length-weight relationships (LWRs) and Fulton′s condition factor (K_F) of *C. morar* using monthly data over one year in the Jamuna River, northern Bangladesh.

MATERIALS AND METHODS

Study site and sampling

The present study was conducted in the Jamuna River (Latitude: 24°30' E and Longitude: 89°44' N), a distributary of Brahmaputra River, Sirajganj, Bangladesh. Monthly samples of *C. morar* were collected from the fisherman catch landed at the Sirajganj Mote Shaber Ghat, Sirajganj during July 2010 to June 2011. This fish is usually caught by means of the traditional fishing gear jhaki jal (cast net). Samples were instantly preserved with ice upon capture, then stored in 10% buffered formalin in the laboratory.

Fish measurement

Fish were sexed by microscopic observation of the gonads. For each individual, total length (TL) was measured to the nearest 0.01 cm by digital slide calipers (Mitutoyo, CD-15PS; Mitutoyo Corporation, Tokyo, Japan). Whole body weight (BW) was taken using a digital balance (Shimadzu, EB-430DW; Shimadzu Seisakusho, Tokyo, Japan) with 0.01 g accuracy.

Length-weight relationships

The LWR was calculated using the expression: $BW= a*(TL)^b$. Parameters *a* and *b* were estimated by linear regression analysis based on natural logarithms: ln (W) = ln (a) + b ln (L). Additionally, 95% confidence limits of *a* and *b*, and the coefficient of determination r^2 were estimated. Based on Froese (2006), all extreme outliers were excluded from the analyses. A t-test was applied to determine significant differences from the isometric value of b = 3 (Sokal and Rohlf, 1987) to declare the growth pattern either isometric or (+/-) allometric. The differences of growth pattern in LWRs between two phases (Phase-1: Immature to maturing; Phase-II: Mature to ripe) was conducted by ANCOVA (Analysis of co-variance), where the size at first sexual maturity was derived from Hossain *et al.* (2013a). In addition, monthly variations of gonadosomatic index (GSI) and allometric co-efficient (*b*) were observed.

Condition factor

The Fulton′s condition factor (K_F) was calculated accccording to Fulton (1904) as $K_F = 100\times (BW/TL^3)$. The scale factor of 100 was used to bring the K_F close to the unit factor (Hossain *et al.*, 2012b). The monthly variations of K_F and *b* were also observed. Furthermore, the relationship between TL *vs.* K_F was conducted in female population of *C. morar*.

Statistical analysis

Statistical analysis were performed using GRAPHPAD PRISM 5 software (GraphPad Software, Inc., San Diego, CA). The chi-square test was used to examine sex-ratio divergence from the expected value of 1:1 (male: female). Homogeneity and normality of data were checked. The Mann-Whitney U-test was used to compare the mean values between sexes as a non-parametruc test. The Kruskal-Wallis test was applied to check the homogeneity of the K_F among months. ANCOVA was used to check the differences of growth pattern between the overall sexes and for two phases (I) immature to maturing and (II) mature to ripe. All statistical analyses were considered significant at 5% ($P < 0.05$).

RESULTS

Sex ratio

The present study revealed that, out of 1200 individuals of *C. morar* collected from the Jamuna River; 552 (46%) were males, and 648 (54%) were females. The male and female ratio was 1:1.17, and the overall sex ratio differ significantly from the expected 1:1 ratio (df = 1, χ^2 = 7.68, $P < 0.01$) (Table I). Females outnumbered males throughout the year during April-May. Monthly sex ratio ranged from 1: 0.96 in May to 1:1.63 in January. Additionally, the variation in sex ratio with length class showed that the male: female ratio was approximately equal for the 7.00-7.99 cm TL class to 9.00-9.99 cm TL class (Table II). However, males dominated somewhat in the 4.00-5.99 cm TL and 8.00-8.99 cm TL classes with significant differences, as did females for the 10.00-12.99 cm TL range.

Length-frequency distribution

The LFD of *C. morar* showed that the size range was 4.06 - 12.84 cm TL, regardless of sex. TL range was 4.06-12.05 cm for males and 5.00-12.84 cm for females (Fig. 1). The Mann-Whitney *U*-test showed significant differences in the LFDs between sexes ($P < 0.001$). In addition, the results showed that females BW (range 0.85-16.75 g) was significantly higher (Mann-Whitney *U*-test, $P < 0.001$) than that for males (range 0.53-13.45 g).

Table I.- **Monthly number of male, female, and sex ratio (male: female = 1:1) of *Cabdio morar* in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh.**

Sampling date	Number of specimens			Sex ratio	χ^2 (df = 1)	Significance
	Male	Female	Total	(Male / Female)		
Jul., 2010	45	55	100	1 : 1.22	1.00	NS
Aug.	45	55	100	1 : 1.22	1.00	NS
Sept.	41	59	100	1 : 1.44	3.24	NS
Oct.	48	52	100	1 : 1.08	0.16	NS
Nov.	48	52	100	1 : 1.08	0.16	NS
Dec.	41	59	100	1 : 1.44	3.24	NS
Jan., 2011	38	62	100	1 : 1.63	5.76	*
Feb.	49	51	100	1 : 1.04	0.04	NS
Mar.	45	55	100	1 : 1.22	1.00	NS
Apr.	57	43	100	1 : 0.75	1.96	NS
May	51	49	100	1 : 0.96	0.04	NS
Jun.	44	56	100	1 : 1.27	1.44	NS
Overall	552	648	1200	1 : 1.17	7.68	**

NS = not significant, *, significant at 5% level ($\chi^2 > \chi^2_{t\ 1,\ 0.05} = 3.84$); **, significant at 1% level ($\chi^2 > \chi^2_{t\ 1,\ 0.01} = 6.63$).

Table II.- **Sex ratios (male: female) across total length ranges for *Cabdio morar* in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh.**

Length class (TL, cm)	Number of specimens			Sex ratio (Male / Female)	χ^2 (df = 1)	Significance
	Male	Female	Total			
4.00 – 4.99	19	0	19	1 : 0.00	19.00	***
5.00 – 5.99	105	44	149	1 : 0.42	24.97	***
6.00 – 6.99	91	122	213	1 : 1.34	4.51	*
7.00 – 7.99	73	76	149	1 : 1.04	0.06	NS
8.00 – 8.99	110	79	189	1 : 0.72	5.08	*
9.00 – 9.99	94	103	197	1 : 1.10	0.41	NS
10.00 – 10.99	34	107	141	1 : 3.79	37.79	***
11.00 – 11.99	24	91	115	1 : 3.79	39.03	***
12.00 – 12.99	2	26	28	1 : 13.00	20.57	***

NS, not significant; S, significant at 5% level ($\chi^2_{t\ 1,\ 0.05} = 3.84$), 1% level ($\chi^2_{t\ 1,\ 0.01} = 6.63$), and 0.1% ($\chi^2_{t\ 1,\ 0.01} = 10.83$).

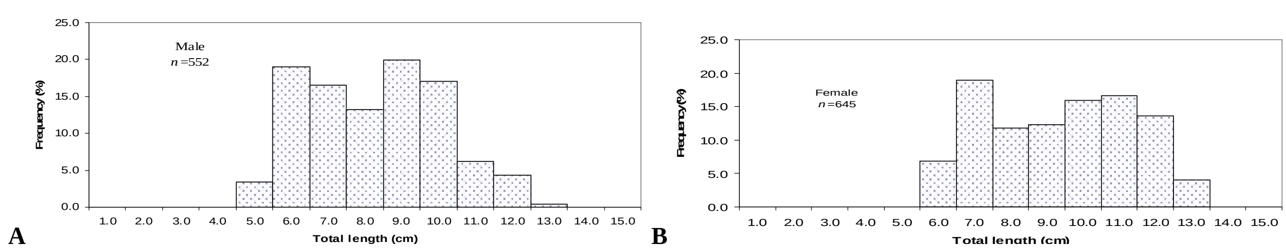

Fig. 1. The length-frequency distribution of male and female *Cabdio morar* in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh.

Length-weight relationships

The descriptive statistics for monthly length and weight measurements, sample sizes (*n*), regression parameters and 95% confidence limit for *a* and *b* of the LWR, and coefficients of determination (r^2) of *C. morar* in the Jamuna River are illustrated in Table III. The allometric coefficient (*b*) of males indicated positive allometric growth in the months July to August, November, February, and April - May, but negative allometric growth in September, December to January,

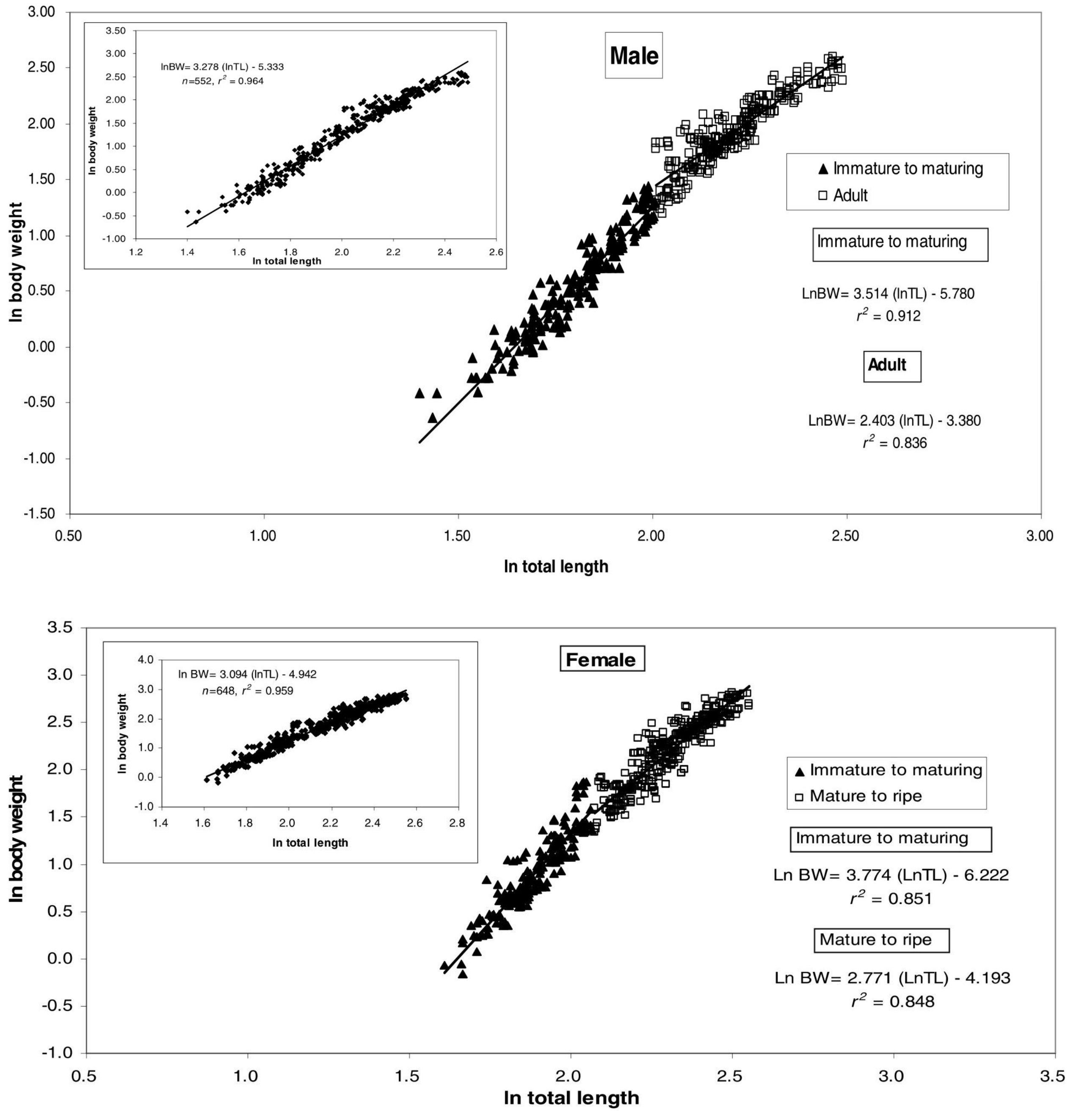

Fig. 2. The relationships (ln BW= ln *a* + *b* ln TL) between body weight (BW) and total length (TL) of the overall, immature to maturing, and mature to ripe phases of male and female *Cabdio morar* in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh.

March, and June; isometric growth was seen only in October. On the other hand, females showed isometric growth during May, August and November, but negative allometric growth in September – October, December, and March; positive allometric growth was seen only in April. In addition, overall growth and the growth pattern between two phases are shown in Figure 2. The overall *b* value for the LWR indicated significantly positive allometric growth (> 3.00) in males (95% CL of *b* = 3.23 – 3.33) and isometric growth (~ 3.00) in females (95% CL of *b* = 3.04 – 3.14). Significant differences in the intercepts (*a*) of the regression lines ($P < 0.001$) between male (95% CL of *a* = 0.0043 – 0.0054) and female (95% CL of *a* = 0.0064 – 0.0080) were also revealed. All LWRs were highly significant, with all r^2 values exceeding 0.830. The ANCOVA stated that the growth pattern were different between the two phases, *i.e.*, (I) immature to maturing (P > 0.01) *vs.* (II) mature to ripe (P < 0.001).

Monthly variations of GSI and *b* values were also observed in this study. Mean values of GSI were increased from December to March and then dropped, whereas *b* values decreased from December to March and increased thereafter (Fig. 3). Hence, the Spearman rank correlation test indicated a significant negative correlation between monthly changes of GSI and *b* values (Spearman, r = -0.627, P = 0.031).

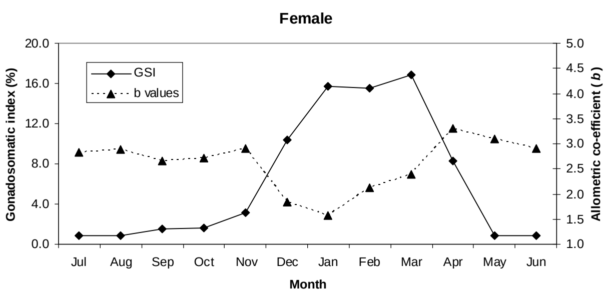

Fig. 3. Monthly variations of gonadosomatic index and allometric co-efficient (*b*) of female *Cabdio morar* in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh.

Condition factor

The monthly variations of the Fulton's condition factor, K_F of Morari in the Jamuna River are shown in Figure 4. The minimum *vs.* maximum K_F values for males was 0.58 in June-July but 1.50 in February, respectively. For females, the minimum K_F value was found in June (0.61) and maximum value in March (1.47). The Mann-Whitney *U*-test showed that K_F is significantly different between males and females (P = 0.006). The K_F started to increase in April, but decreased in November (at the start of the spawning season) for both males and females. The Kruskal-Wallis test showed significant seasonal differences in K_F among months (P < 0.05) for males and females.

Mean values of K_F for females increased from December to March and then dropped. This was opposite of *b* values, which decreased from December to March and increased thereafter (Fig. 5). For female *C. morar*, the maximum K_F value was ~7.5 cm TL (Fig. 6). Based on a Spearman rank correlation test, TL and K_F were significantly related (Spearman, r = 0.286, P < 0.001).

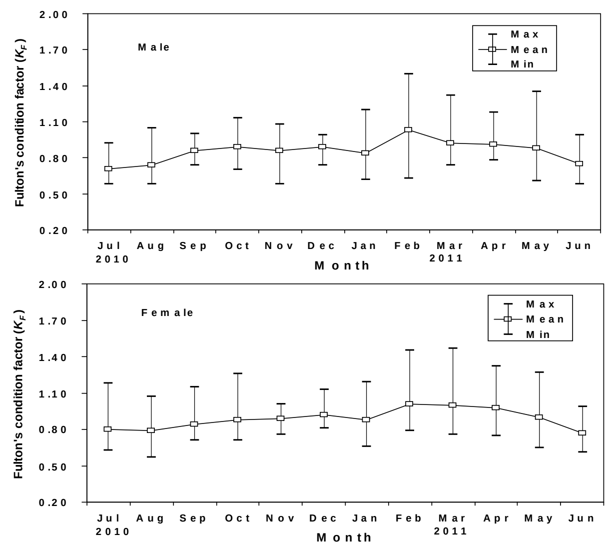

Fig. 4. Monthly variations of Fulton′s condition factor (K_F) for male and female of *Cabdio morar* in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh.

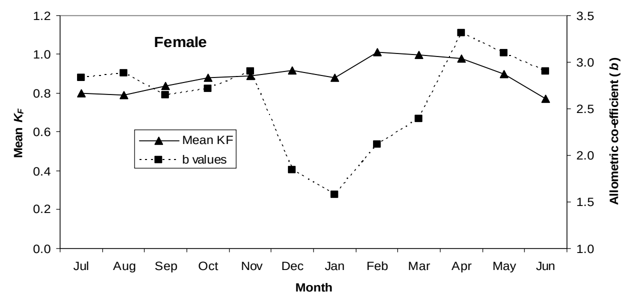

Fig. 5. Mean monthly variations for Fulton′s condition factor (K_F) and allometric co-efficient (*b*) of female *Cabdio morar* in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh.

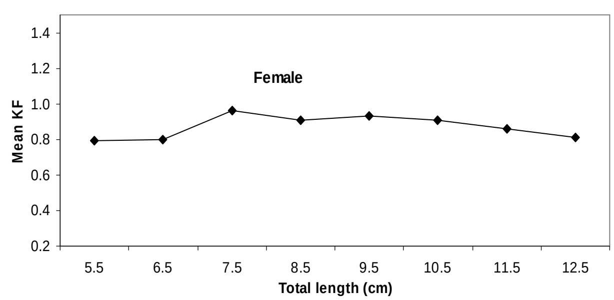

Fig. 6. The relationship of mean values of Fulton′s condition factor and total length for female *Cabdio morar* in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh.

Table III.- **Descriptive statistics and estimated parameters of the length-weight relationships ($BW = a \times TL^b$) for *Cabdio morar* in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh**

Sampling date	Sex	n	Range		Regression parameters				r^2
			TL cm	BW g	*a*	95% CL of *a*	*b*	95% CL of *b*	
Jul., 2010	M	45	4.20-6.78	0.53-2.45	0.0030	0.0017 - 0.0053	3.48	3.16 – 3.80	0.918
	F	55	5.29-10.49	1.23-7.38	0.0111	0.0076 - 0.0163	2.83	2.63 – 3.03	0.939
Aug.	M	45	5.61-9.06	1.76-6.51	0.0036	0.0018 - 0.0074	3.41	3.00 – 3.82	0.869
	F	55	6.55-9.95	2.68-7.54	0.0100	0.0067 - 0.0148	2.88	2.67 – 3.08	0.938
Sep.	M	41	5.68-10.74	1.74-9.33	0.0120	0.0086 - 0.0168	2.84	2.68 – 3.00	0.971
	F	59	6.18-11.38	1.89-11.21	0.0175	0.0130 - 0.0236	2.65	2.51 – 2.79	0.960
Oct.	M	48	4.91-9.73	1.11-4.48	0.0067	0.0047 - 0.0095	3.15	2.96 – 3.33	0.963
	F	52	5.00-10.26	0.93-8.92	0.0158	0.0101 - 0.0246	2.72	2.50 – 2.93	0.929
Nov.	M	48	5.39-10.38	0.99-9.81	0.0025	0.0016 - 0.0039	3.57	3.37 – 3.78	0.964
	F	52	7.39-11.28	3.64-12.48	0.0111	0.0068 - 0.0182	2.90	2.68 – 3.12	0.936
Dec.	M	41	8.13-11.57	5.10-11.45	0.0308	0.0179 - 0.0530	2.45	2.22 – 2.69	0.917
	F	59	9.45-11.92	8.43-13.89	0.1433	0.0847 - 0.2424	1.84	1.62 – 2.06	0.830
Jan., 2011	M	38	6.02-12.05	1.85-12.14	0.0198	0.0111 - 0.0354	2.61	2.36 – 2.87	0.924
	F	62	9.03-12.44	8.75-14.13	0.2587	0.1700 - 0.3938	1.58	1.40 – 1.75	0.843
Feb.	M	49	5.75-11.92	1.33-13.20	0.0067	0.0035 - 0.0126	3.20	2.90 – 3.51	0.902
	F	51	7.01-12.79	4.27-16.75	0.0805	0.0550 - 0.1180	2.12	1.96 – 2.28	0.935
Mar.	M	45	6.63-11.92	2.61-13.45	0.0345	0.0207 - 0.0574	2.41	2.18 – 2.63	0.913
	F	55	7.01-12.07	3.72-14.89	0.0403	0.0265 - 0.0611	2.39	2.21 – 2.57	0.930
Apr.	M	57	6.26-9.82	2.00-9.55	0.0049	0.0030 - 0.0080	3.29	3.06 – 3.53	0.935
	F	43	6.02-11.50	1.97-12.67	0.0051	0.0031 - 0.0083	3.31	3.08 – 3.54	0.954
May	M	51	4.24-11.72	0.66-12.76	0.0042	0.0046 - 0.0114	3.35	3.17 – 3.53	0.967
	F	49	5.28-12.84	1.08-1478	0.0072	0.0046 - 0.0114	3.10	2.88 – 3.32	0.945
Jun.	M	44	4.06-6.84	0.66-2.52	0.0121	0.0072 - 0.0205	2.72	2.42 – 3.02	0.884
	F	56	5.27-9.64	0.95-5.85	0.0092	0.0065 - 0.0132	2.90	2.71 – 3.09	0.949

n, sample size; M, male; F, female; TL, total length; BW, body weight; *a* and *b*, regression parameters; CL, confidence limit.

DISCUSSION

Biological information on *C. morar* from the Jamuna River is deficient except for Hossain *et al.* (2013a) and brief studies of sex ratio, LWR, and LLR from the Ganges River, northwestern Bangladesh (Hossain *et al.*, 2009; Esmaeili *et al.*, 2014). To our knowledge, few studies of sex ratio, LWR, condition factor, and GSI of freshwater fishes across a a full year are available from the Indian sub-continent (*e.g.*, Hossain *et al.*, 2006a, Ahmed *et al.*, 2012a). During our study, a large number of specimens from the Jamuna River was collected using traditional fishing gear (cast net) throughout the year. But catching fishes smaller than 4.00 cm TL was impossible during the study period, which may indicate selectivity of the fishing gear (Hossain *et al.*, 2012b, 2015c, 2016) rather than their absence on the fishing ground. Hossain (2010a, b) made a similar hypothesis when studying small indigenous species from the Ganges River. However, the sampling bias might be overcome if specimens below 4.00 cm TL could be collected by larval survey nets, to adjust length-frequency data for gear selectivity (Ahmed *et al.*, 2012b).

Several studies have reported that the sex ratio in the spawning season is low for species with high fecundity but high for species with low fecundity (cf. Wu *et al.*, 2012). In our study, the higher sex ratio of *C. morar* during the main spawning season might be related to its low fecundity (Hossain *et al.*, 2013a). In addition, Fumio (1960) reported that an increase in sex ratio with body size for some other fish species might be due to the high mortality of males and greater longevity of females. For *C. morar*, sex ratio could also reflect other incluences, including thermal effects on sex determination and predatory effects on mortality, behavior, growth rate, or longevity (Rahman *et al.*, 2012a; Hossain *et al.*, 2012c, 2013b, 2014).

The values of *b* for *C. morar* in our study were within the limits (2.5-3.5) reported by Froese (2006). The *b* values for females were quite low during December to March, opposite of the mean values for GSI, which confirmed that the spawning season extended from December to March, as Hossain *et al*. (2013a) had found for the Jamuna River. Several indices - including GSI, modified GSI, ovarian maturation stages, and direct observation - were used to determine the spawning period, but our study also used *b* values across months to determine the spawning period for this species. The latter may be new method in fisheries science, with low time/ cost constraints and without sacrificing fish. However, the monthly variations of *a* and *b* in the Jamuna River for Morari might be ascribed to variations in fish physiology (Le Cren, 1951), gonadal development (Hossain *et al.*, 2006a), feeding rate (Tarkan *et al.*, 2006), and behavior (Hossain *et al.*, 2012a). Hossain *et al.* (2009) recorded isometric growth in *A. morar* (*b* = 3.00 for combined sexes) from the Ganges River, northwestern Bangladesh, which is in accordance with the females for our study. In contrast, Esmaeili *et al.* (2014) reported positive allometric growth (*b* = 3.31 for combined sexes) of *A. morar* in Iran, which is in accordance with males in our study. However, the differences in *b* values may also reflect other factors that we did not study: habitat availability, seasonal effects, degree of stomach fullness, gonad maturity, gender, fish health, preservation techniques, and differences in the observed length ranges (Hossain *et al.*, 2006b, 2013c, 2014). We collected LWRs monthly at roughly equal time intervals throughout the year, so our equations are assumed to be of general use for *C. morar*.

The K_F values between the sexes were significantly different in our study, likely indicating the presence of mature females. In general, the seasonal cycle in fish condition suggested a relationship with gonadal development (Hossain *et al.*, 2006a; Rahman *et al.*, 2012b). Our study showed that the reproductive period of *C. morar* began in December, and ended in March when the highest values of the Fulton's condition factor (K_F) indicated their recovery (Hossain *et al.*, 2013a). Monthly values of K_F increased and *b* values decreased from December to March, which are indicative of the spawning season. In addition, for the relationship between TL *vs.* K_F in female *C. morar*, the maximum K_F value was ~7.5 cm in TL, which may reflect sexual maturation.

In conclusion, this study has provided basic information on the sex ratio, LFD, LWR, and K_F, which are relevant to via stock assessment and sustainable fishery management in the Jamuna River. We introduced a new method for estimating the spawning season, based on lower seasonal values of *b* for *C. morar*. Also, this research has established a strong base for monitoring the biological changes (allometric co-efficient, conditions, GSI) of this important species due to high fishing pressure, climate changes, and other factors within the Brahmaputra River basin. Finally, this study will form an important baseline for future studies here and for surrounding South Asian ecosystems.

ACKNOWLEDGEMENTS

The authors would like to extend their sincere appreciation to the Deanship of Scientific Research at King Saud University for its funding this Research group NO (RG-1436-025).

Statement of conflict of interest

Authors have declared no conflict of interest.

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