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Life-history Traits of the Threatened Freshwater Fish *Cirrhinus reba* (Hamilton 1822) (Cypriniformes: Cyprinidae) in the Ganges River, Northwestern Bangladesh

(Ciri Sejarah Kehidupan Ikan Air Tawar Terancam *Cirrhinus reba* (Hamilton 1822) (Cypriniformes: Cyprinidae) di Sungai Ganges, Barat Laut Bangladesh)

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ABSTRACT

The threatened Reba carp, Cirrhinus reba *is a freshwater fish species found in ponds, rivers, canals and tanks of Bangladesh, India, Myanmar, Nepal and Pakistan. The present study describes the first complete and inclusive description of life-history traits including sex ratio, length-frequency distributions (LFD), length-weight relationships (LWR), condition factors (Allometric,* K_A*; Fulton's,* K_F*; Relative condition,* K_R*; Relative weight,* W_R*), form factor (*$a_{3.0}$*) and size at first sexual maturity of* C. reba *in the Ganges River, NW Bangladesh. Sampling was done using traditional fishing gears including cast net, square lift net and conical trap from April 2011 to March 2012. The total length (TL), fork length (FL) and standard length (SL) were measured to the nearest 0.01 cm using digital slide calipers and total body weight (BW) was measured using an electronic balance with 0.01 g accuracy. The LWR was calculated using the expression:* $W = a L^b$*, where W is the BW, L the TL. The size at first sexual maturity of* C. reba *was estimated using the empirical equation by Binohlan and Froese (2009) for male and female, separately. A total of 250 specimens ranging from 8.00 cm – 23.40 cm TL and 4.30 g – 200 g BW were analyzed in this study. The overall sex ratio did not differ significantly from the expected value of 1:1 (*$\chi^2 = 3.38$*,* $p < 0.05$*), but there was significant differences in the TL-frequency distributions (Mann-Whitney U-test,* $p < 0.001$*) between male (median = 12.00 cm) and female (median = 15.80 cm). The calculated b for the LWR indicated positive allometric growth (> 3.00) in male and female and there was significant differences in the intercepts (ANCOVA,* $p < 0.001$*) and in the slopes (ANCOVA,* $p < 0.001$*) between the sexes. In addition, the Mann-Whitney U-test showed significant differences in the Fulton's condition factor between male and female (*$p < 0.001$*). The one sample t-test showed that the mean* W_R *(actual mean = 99.50) did not differ from 100 for male (*$p = 0.523$*) and female (*$p = 0.197$*) in this study, indicating the habitat was still in good condition for* C. reba*. Moreover, the size at sexual maturity of male and female* C. reba *were estimated as 11.50 cm TL and 13.50 cm TL, respectively. The results of this study would be useful for the sustainable conservation of this threatened carp fishery in Bangladesh and also neighboring countries.*

Keywords: Bangladesh; Cirrhinus reba*; condition factor; length-weight relationship; sex ratio; threatened*

ABSTRAK

Ikan karp terancam Cirrhinus reba *merupakan ikan air tawar yang dijumpai di kolam, sungai, terusan dan tangki di Bangladesh, India, Myanmar, Nepal dan Pakistan. Kajian ini menerangkan ciri sejarah kehidupan* C. reba *secara lengkap pertama kali di Sungai Ganges, Barat Laut Bangladesh daripada segi nisbah jantina, taburan frekuensi kepanjangan (LFD), hubungan panjang-berat (LWR), faktor keadaan (allometrik,* K_A*; Fulton's,* K_F*; keadaan relatif,* K_R*; berat relatif,* W_R*), faktor bentuk (*$a_{3.0}$*) dan saiz kematangan jantina terawal. Pensampelan dijalankan dengan menggunakan alat penangkap termasuk jaring sapuan, jaring angkat segi empat dan penangkap konikal dari bulan April 2011 hingga Mac 2012. Panjang keseluruhan (TL), panjang capah (FL) dan panjang piawai (SL) diukur hingga ke 0.01 paling dekat dengan menggunakan kaliper slaid digital dan berat badan keseluruhan (BW) diukur dengan menggunakan pemberat elektronik yang mempunyai ketepatan 0.01 g. LWR dihitung berdasarkan ekspresi* $W = a L^b$*, dengan W adalah BW dan L adalah TL. Saiz pada kematangan terawal* C. reba *dikira berdasarkan persamaan empirikal Binohlan dan Froese (2009) untuk jantan dan betina secara berasingan. Sebanyak 250 spesimen dengan TL berjulat 8.00-23.40 cm dan BW berjulat 4.30-200 g dianalisis dalam kajian ini. Nisbah jantina keseluruhan tidak menunjukkan perbezaan signifikan daripada nilai jangkaan 1:1 (*$\chi^2 = 3.38$*,* $p < 0.05$*), tetapi perbezaan signifikan diperoleh dalam taburan frekuensi-TL (ujian-U Mann-Whitney,* $p < 0.001$*) antara jantan (median = 12.00 cm) dan betina (median = 15.80). Nilai b bagi LWR menunjukkan pertumbuhan alometrik positif (>3.00) dalam jantan dan betina dan perbezaan signifikan diperoleh dalam pintasan (ANCOVA,* $p < 0.001$*) dan cerunan (ANCOVA,* $p < 0.001$*) antara jantina. Tambahan pula, ujian-U Mann-Whitney menunjukkan perbezaan signifikan dalam faktor keadaan Fulton's antara jantan dan betina (*$p < 0.001$*). Ujian-t satu sampel menunjukkan min* W_R *(min sebenar = 99.50) tidak berbeza daripada 100 untuk jantan (*$p = 0.523$*) dan betina (*$p = 0.197$*) dalam kajian ini. Ini menunjukkan habitat masih dalam keadaan baik untuk*

C. reba. *Saiz pada kematangan jantina terawal bagi jantan dan betina* C. reba *dianggarkan pada 11.50 cm* TL *dan 13.50 cm* TL *masing-masing. Hasil daripada kajian ini bermanfaat kepada pemuliharaan mampan perikanan ikan karp di Bangladesh dan juga negara jirannya.*

Kata kunci: Bangladesh; Cirrhinus reba*; faktor keadaan; hubungan panjang-berat; nisbah jantina; terancam*

INTRODUCTION

Life-history traits' information of threatened fishes is essential for the enactment of appropriate management strategies for conserving the commercially important threatened fish like *Cirrhinus reba* (Hamilton 1822) (Hossain et al. 2012a).

The Reba carp *C. reba* is a freshwater fish of the family Cyprinidae. It is found in Bangladesh, India, Myanmar, Nepal and Pakistan (Hossain & Haque 2005; Jha et al. 2006; Menon 1999; Mirza & Alam 2002; Talwar & Jhingran 1991). This carp fish is known as *Raik*, *Tatkini*, *Bata*, *Laacho* and *Bhagna* in Bangladesh and *Suhnee* and *Sunee* in Pakistan (IUCN Bangladesh 2000; Narejo 2006). It mainly inhabits rivers and clear streams but also found in tanks, canals, ponds, *beels* and inundated fields (Bhuiyan 1964; Rahman 1989; Talwar & Jhingran 1991). The Reba carp is primarily plankton and detritus feeder but also feeds on mud, vegetables, crustaceans and insect larvae (Bhuiyan 1964; Talwar & Jhingran 1991). The flesh of this fish is oily and tasty and preferred by the consumers (Rahman 1989). However, the wild population of the species could be declining due to heavy harvest, habitat loss and other ecological changes to their habitat and subsequently categorized as vulnerable by Bangladeshi water bodies (IUCN Bangladesh 2000; Sarkar et al. 2008).

Study of the size structure (length frequency) in riverine fish reveals many ecological and life-history traits such as the river health, stock conditions and breeding period of the fish (Ranjan et al. 2005). The size structure of a fish population at any point in time can be considered a 'snapshot' that reflects the interactions of the dynamic rates of recruitment, growth and mortality (Neumann & Allen 2001).

The relationship between body length and weight is useful for assessing the well-being of the individuals and for determining possible differences among different stocks of the same species (King 2007). This relationship is also very important for proper exploitation and management of fish population (Anene 2005). Moreover, morphometric relationships including length-weight relationships (LWRs), relative condition factor (K_R) and Fulton's condition factor (K_F) are important biological parameters for fishes, from which the condition of stocks' health of fish populations can be deduced (Bagenal & Tesch 1978). Indeed, an aquatic animal's condition reflects recent environmental (physicochemical and biotic) circumstances, as it fluctuates by interaction among feeding conditions, parasitic infections and physiological factors (Le Cren 1951). In addition, relative weight (W_R) is one of the most popular indexes for assessing condition of fishes in the USA for the last two decades (Rypel & Richter 2008). Furthermore, the form factor ($a_{3.0}$) can be used to determine whether the body shape of a given population or species is significantly different from others (Froese 2006).

A number of studies have been conducted on different aspects of *C. reba* including spawning behaviour (Rao et al. 1972), internal rhythm of sexual cycle under artificial conditions of darkness (Verghese 1975), biology (Gupta 1975) fecundity (Khan 1986), LWRs and K_R (Narejo 2006), gonadosomatic index (GSI) and fecundity (Lashari 2007) and LWRs (Muralidharan 2011). Even though a few studies have been conducted on the sex ratio, LFD, LWRs, condition and form factor of several fish species from the region (Hossain et al. 2006a; 2006b; 2008; 2009a; 2009b; 2009c; 2012a; 2012b; 2012c; 2012d; 2012e; Hossain 2010a; 2010b; Rahman et al. 2012a; 2012b), but detailed and sound studies on the life history traits of *C. reba* are evidently lacking from Bangladesh. Therefore, this study reported the first complete and inclusive description of life-history traits including sex ratio, length-frequency distributions, length-weight relationships, condition factors, relative weight, form factor and size at first sexual maturity of *C. reba* in the Ganges River, NW Bangladesh.

MATERIALS AND METHODS

STUDY SITE AND SAMPLING

The sampling was conducted at the Ganges (also known as Padma River in Bangladesh) River, northwestern Bangladesh. The Padma River, second longest river of Bangladesh, is the habitat of the richest freshwater fish fauna of Bangladesh and is believed to be an important spawning and feeding ground for riverine fish species of northwestern Bangladesh (Jones et al. 2003). In a recent study, Rahman et al. (2012c) recorded 80 species of fish from lower part of the Ganges River including *C. reba*. Samples of *C. reba* were collected during daytime on a seasonal basis from different fishermen's catch landed at Jahaj ghat, Rajshahi to Godagari, Rajshahi (24°46'N; 88°32'E) during April 2011 to March 2012. The main gears used by the commercial fishers include traditional fishing gears such as cast net (*jhaki jal*), square lift net (*tar jal*) and conical trap (*dughair*). The fresh samples were immediately chilled in ice on site and fixed with 10% buffered formalin upon arrival at the laboratory. All morphometric measurements were collected according to Froese and Pauly (2012). The fixed specimens were individually measured and weighed. Total length (TL), fork length (FL) and standard length (SL) were measured to the nearest 0.01 cm using digital slide calipers (Mitutoyo, CD-15PS) and total body weight (BW) was measured using

an electronic balance (Shimadzu, EB-430DW) with 0.01 g accuracy.

SEX RATION AND LENGTH-FREQUENCY DISTRIBUTIONS

Sex ratio is the ratio of male to female in a population. A chi-square test was used to identify the sex-ratio divergence from the expected value of 1:1 (male: female). The LFD for each sex was constructed using 1 cm intervals of TL.

LENGTH-WEIGHT RELATIONSHIPS

The relationship between length and weight was calculated using the expression: $W = a\ L^b$, where W is the total body weight (BW, g), L the total length (TL, cm), a and b are the parameters of regression analysis. Parameters a and b of the LWR were estimated by linear regression analysis based on natural logarithms: $ln(W) = ln(a) + b\ ln(L)$. Additionally, 95% confidence limits of the parameters a and b and the statistical significance level of r^2 (coefficient of determination) were estimated. The later was estimated as an indicator of the quality of linear regressions (cf., Hossain et al. 2009c). The coefficient of determination (r^2) is the square of the correlation coefficient (r). The r^2 value of the coefficient lies between 0 and 1 and it describes the proportion of the variation of one of the correlated variables which can be explained by the variation of the other variable (King 2007). Even though the r^2 may indicate a relationship between the variables, the correlation may not be significant because of small sample sizes or correlation in comparison to the other value. In this situation, a one-tailed t-test, $t = r\sqrt{(n-2)}/\sqrt{(1-r^2)}$ for independent means might be applied to express correlation between two variables. In addition, to confirm whether b values were significantly different ($p \leq 0.05$) from the isometric value ($b \approx 3$), the equation of Sokal and Rohlf (1987): $t_s = (b-3) / s_b$ was applied, where t_s is the sample t-test value, b is the slope and s_b is the standard error of the slope (b). The comparison between t_s and tabled, critical values for b allowed determination statistical significance and their classification as isometric ($b \approx 3$) or allometric (negative allometry for $b<3$ or positive allometry for $b>3$). If there are several LWRs > 3 and the a and b parameters are available for the species, then a plot of log a over b which form a straight line can be used to detect outliers (Froese 2006). In this study, prior to the regression analysis of ln BW on ln TL, ln-ln plots of length and weight values were performed for visual inspection of outliers, with extremes being excluded from the regression analyses.

CONDITION FACTORS

Fulton's condition factor (K_F) (Fulton 1904) was calculated following the equation: $K_F = 100 \times (W/L^3)$, where W is the total body weight (BW, g) and L is the total length (TL, cm). The scaling factor of 100 was used to bring the K_F close to unit. In addition, the relative condition factor (K_R) for each individual was calculated using the equation of Le Cren (1951): $K_R = W/(a \times L^b)$, where W is the BW, L is the TL and a and b are the LWR parameters. Furthermore, the allometric condition factor (K_A) was calculated using the equation of Tesch (1968): W/L^b, where W is the BW, where L is the TL and b is the LWR parameter.

RELATIVE WEIGHT

Relative weight (W_R) was calculated by the equation given by Froese (2006) as $W_R = (W / W_S) \times 100$, where W is the weight of a particular individual and W_S is the predicted standard weight for the same individual as calculated by $W_S = a\ L^b$ where the a and b values were obtained from the relationships between TL and BW.

FORM FACTOR

The form factor ($a_{3.0}$) for each species was calculated using the equation given by Froese (2006) as: $a_{3.0} = 10^{\log a - s(b-3)}$, where a and b are regression parameters of LWRs and S is the regression slope of *ln a vs. b*. In this study, a mean slope S = -1.358 (Froese 2006) was used for estimating the form factor because the information on LWRs is not available for these species for estimation of the regression (S) of *ln a vs. b*.

SIZE AT FIRST SEXUAL MATURITY

The size at first sexual maturity of *C. reba* in the Ganges River was calculated using the empirical equation by Binohlan and Froese (2009) for male and female, separately.

STATISTICAL ANALYSES

Statistical analyses were performed using Microsoft® Excel-add-in-DDXL and GraphPad Prism 5. Tests for normality of each group were conducted by visual assessment of histograms and box plots and confirmed using the Kolmogorov-Smirnov test, where the normality assumption was met, the one sample test was used to compare the mean relative weight (W_R) with 100 (Anderson & Neumann 1996). The Unpaired t-test (with Welch's correction) test was used to compare the W_R between sexes. However, in case of non-parametric statistics, the Spearman rank test was used to correlate body measurements (BW) with condition factors. The Mann-Whitney U test was used to compare the LFD between the sexes. A Chi-square test was used to identify the sex-ratio divergence from the expected value of 1:1 (male: female). Moreover, the parameters a and b of the LWR between sexes were compared by ANCOVA. All statistical analyses were considered significant at 5% ($p<0.05$).

RESULTS

SEX RATIO

From the 250 specimens (male = 139; female = 111; male: female = 1: 0.79) of *C. reba* collected in the Ganges River

during this study, 56% were male and 44% were female, however the overall sex ratio did not differ significantly from the expected value of 1:1 (df = 1, $\chi^2 = 3.38$, $p<0.05$). The total length dependent sex ratio of *C. reba* is shown in Table 1. However, the variation in sex ratio with total length class showed that male dominated vaguely for the 8.00-10.99 cm TL size groups, whereas female dominated somewhat in the 20.00-20.99 cm TL range ($\chi^2 = 7.36$, $p<0.01$) or upper groups, however statistically they were not significantly different ($p> 0.05$).

LENGTH-FREQUENCY DISTRIBUTIONS

Table 2 and Figure 1 illustrate the descriptive statistics and 95% confidence limit (CL) for length and weight measurements of the Reba carp. The TL ranged from 8.00 cm to 20.80 cm (mean ± SD = 12.64 ± 3.31) for male and 8.70 cm to 23.40 cm (mean ± SD = 15.41 ± 3.63) for female of *C. reba*. TL frequency distribution showed that the male and female of *C. reba* were not normality distributed (Shapiro-Wilk normality test; $p< 0.001$) in the Ganges River during this study. So, the Mann-

TABLE 1. Number of male, female and sex ratio (male: female = 1:1) of the *C. reba* (Hamilton 1822) in the Ganges River, NW Bangladesh

Length class (TL, cm)	Number of specimens			Sex ratio (Male/ Female)	χ^2 (df=1)	Significance
	Male	Female	Total			
8.00 – 8.99	10	2	12	1 : 0.20	5.33	*
9.00 – 9.99	24	7	31	1 : 0.29	9.32	**
10.00 – 10.99	29	9	38	1 : 0.31	10.53	**
11.00 – 11.99	6	6	12	1 : 1.00	0.00	ns
12.00 – 12.99	7	6	13	1 : 0.86	0.08	ns
13.00 – 13.99	11	5	16	1 : 0.45	2.25	ns
14.00 – 14.99	13	12	25	1 : 0.92	0.04	ns
15.00 – 15.99	16	14	30	1 : 0.88	0.13	ns
16.00 – 16.99	7	14	21	1 : 2.00	2.33	ns
17.00 – 17.99	2	4	6	1 : 2.00	0.67	ns
18.00 – 18.99	6	7	13	1 : 1.17	0.08	ns
19.00 – 20.99	7	11	18	1 : 1.57	0.89	ns
20.00 – 20.99	1	10	11	1 : 10.00	7.36	**
21.00 – 21.99	0	2	2	-	2.00	ns
22.00 – 22.99	0	1	1	-	1.00	ns
23.00 – 23.99	0	1	1	-	1.00	ns
Overall	139	111	250	1 : 0.79	3.38	ns

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

TABLE 2. Descriptive statistics on the length (cm) and weight (g) measurements of the *Cirrhinus reba* (Hamilton 1822) in the Ganges River, northwestern Bangladesh

Measurements	*n*	Min	Max	Mean ± SD	$CL_{95\%}$
Male	139				
TL		8.00	20.80	12.64±3.31	12.09-13.20
FL		6.80	18.20	10.89±2.88	10.41-11.38
SL		6.10	16.70	9.95±2.76	9.49-10.41
BW		4.30	75.76	22.16±18.54	19.05-25.27
Female	111				
TL		8.70	23.40	15.41±3.63	14.73-16.10
FL		7.40	20.50	13.38±3.15	12.79-13.98
SL		6.60	19.00	12.28±2.99	11.72-12.84
BW		5.42	200.00	54.39±45.51	45.83-62.95
Combined sex	250				
TL		8.00	23.40	13.87±3.71	13.41-14.33
FL		6.80	20.50	12.00±3.24	11.60-12.40
SL		6.10	19.00	10.99±3.08	10.61-11.37
BW		4.30	200	36.46±36.90	31.86-41.05

n, sample size; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values; TL, total length; FL, fork length; SL, standard length; BW, body weight

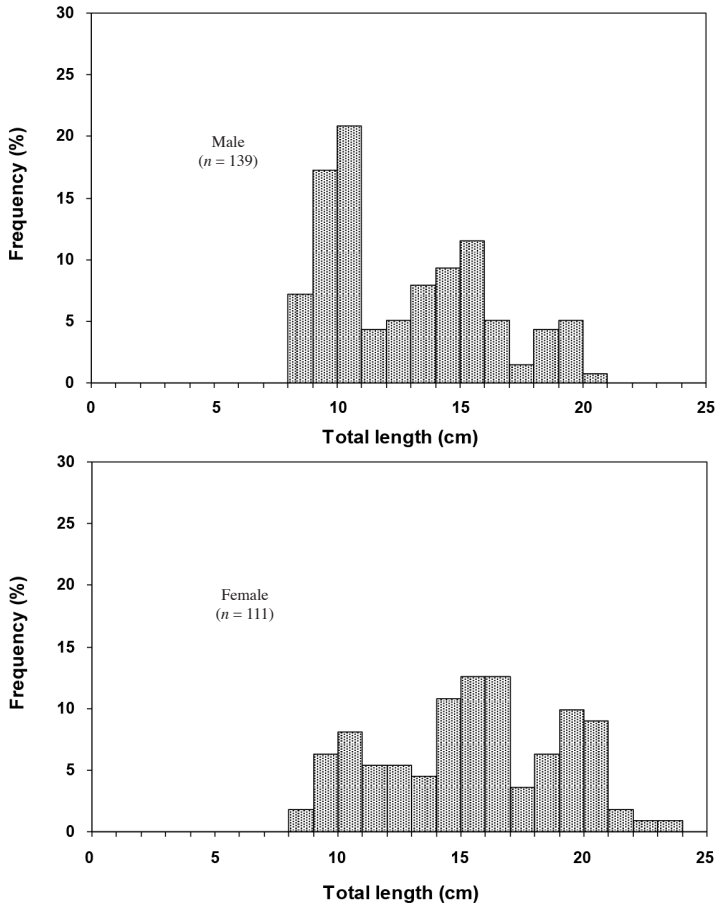

FIGURE 1. Length-frequency distribution of the *Cirrhinus reba* (Hamilton 1822) in the Ganges River, NW Bangladesh

Whitney U-test showed significant differences in the TL-frequency distributions (Two tailed, Mann Whitney U = 4318, $p<0.001$) between male (median = 12.00 cm, 25% Percentile = 10.00 cm, 75% Percentile = 15.20 cm) and female (median = 15.80 cm, 25% Percentile = 12.00 cm, 75% Percentile = 18.60 cm) in the Padma River.

Furthermore, the body weight of *C. reba* varied from 4.30 g to 75.76 g (mean ± SD = 22.16 ± 18.54) in male and 4.30 g to 200 g (mean ± SD = 54.39 ± 45.51) in female. The BW frequency distribution revealed that male and female of *C. reba* were not normality distributed (Shapiro-Wilk normality test; $p<0.001$) in the Padma River during this study. So, the Mann-Whitney U-test exposed that BW of female (median = 38.71 g, 25% Percentile = 16.65 g, 75% Percentile = 81.18 g) was significantly higher (Two tailed, Mann-Whitney U = 3919, $p<0.001$) than that for male (median = 14.90 g, 25% Percentile = 7.75 g, 75% Percentile = 35.02 g).

LENGTH-WEIGHT RELATIONSHIPS

The sample sizes (n), regression parameters and 95% confidence intervals for a and b of the LWR, coefficients of determination (r^2) and growth type of *C. reba* are given in Figures 2 and 3 and in Table 3. The calculated b of the LWR indicated positive allometric growth (> 3.00) in male and female and there was significant differences in the intercepts (ANCOVA, F = 31.43, df = 246, $p<0.001$) and in the slopes (ANCOVA, F = 29.59, df = 244, $p<0.001$) between the sexes of *C. reba* in the Ganges River.

CONDITION FACTORS

The Fulton's condition factor ranged from 0.65 to 1.05 (mean ± SD = 0.87 ± 0.09) in male and 0.67 to 1.79 (mean ± SD = 1.14 ± 0.30) in female (Table 4). The Spearman rank test revealed that K_F was strongly correlated with TL for male (Two tailed, $r_s = 0.540$, 95% CL of $r_s = 0.406 – 0.651$, $p<0.001$) and female (Two tailed, $r_s = 0.634$, 95% CL of $r_s = 0.504 – 0.737$, $p<0.001$). In addition, there was also highly correlation between K_F and BW for male (Spearman rank test, Two tailed, $r_s = 0.629$, 95% CL of $r_s = 0.513 – 0.722$, $p<0.001$) and female (Spearman rank test, Two tailed, $r_s = 0.770$, 95% CL of $r_s = 0.679 – 0.838$, $p<0.001$) Reba carp in the Padma River. Furthermore, the Mann-Whitney U-test showed significant differences in the Fulton's condition factor between male and female (Two tailed, Mann-Whitney U = 3083, $p<0.001$).

On the other hand, minimum and maximum values of the relative condition factor for male and female *C. reba*

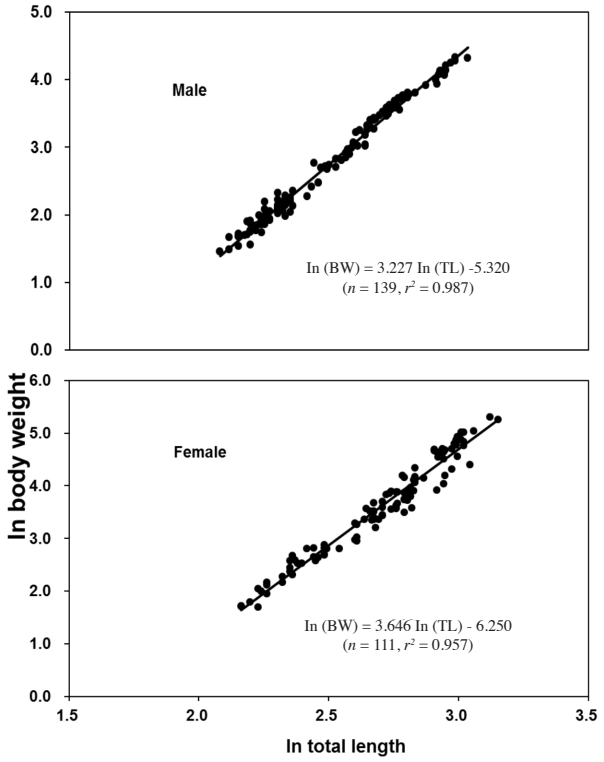

FIGURE 2. Length-weight relationships (*ln W = ln a + b ln L*) of the *Cirrhinus reba* (Hamilton 1822) in the Ganges River, NW Bangladesh

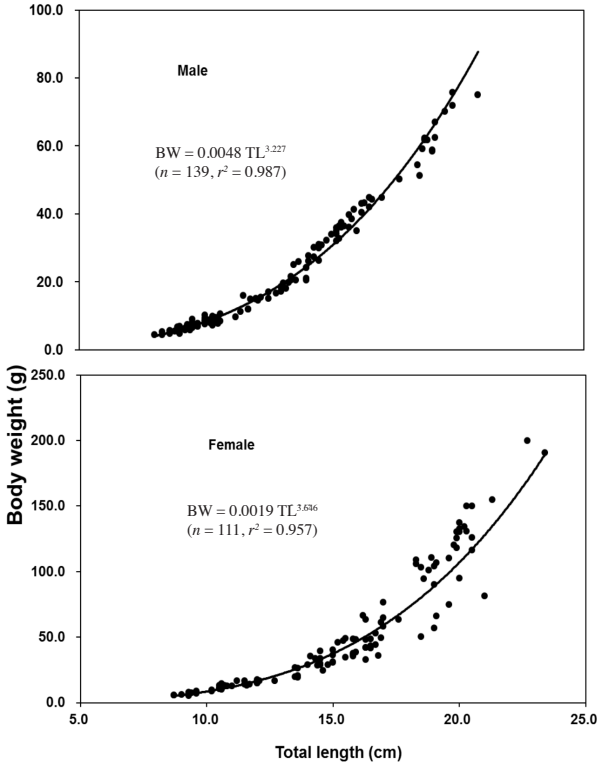

FIGURE 3. Length-weight relationships ($W = a \times L^b$) of the *Cirrhinus reba* (Hamilton 1822) in the Ganges River, NW Bangladesh

TABLE 3. Descriptive statistics and estimated parameters of the length-weight relationships ($BW = a \times TL^b$) of the *Cirrhinus reba* (Hamilton 1822) in the Ganges River, northwestern Bangladesh

Sex	*a*	*b*	$CL_{95\%}$ of a	$CL_{95\%}$ of b	r^2	t_s	GT
Male							
(*n* = 139)	0.0049	3.227	0.0042-0.0057	3.165-3.288	0.987	2.88	A+
Female							
(*n* = 111)	0.0019	3.647	0.0013-0.0029	3.499-3.792	0.957	3.22	A+
Common gender							
(*n* = 250)	0.0025	3.523	0.0020-0.0031	3.443-3.602	0.968	4.95	A+

n, sample size; *BW*, body weight; *TL*, total length; *a*, intercept; *b*, slope; CL, confidence limits; r^2, coefficient of determination; GT, growth type (A+, positive allometric growth based on: $t_s = (b\text{-}3) / s_b$, where t_s is the *t*-test value, *b* the slope and s_b the standard error of the slope (*b*)

were 0.79 and 1.27 (mean ± SD = 1.00 ± 0.09) and 0.63 and 1.41 (mean ± SD = 1.02 ± 0.19), respectively (Table 4). The Mann-Whitney U-test showed that K_R was not significantly different (Two tailed, Mann-Whitney U = 6828, $p = 0.119$) between male (median = 0.99, 25% Percentile = 0.94, 75% Percentile = 1.06) and female (median = 1.04, 25% Percentile = 0.88, 75% Percentile = 1.18).

Furthermore, the allometric condition factor varied from 0.0039 to 0.0062 (mean ± SD = 0.0049 ± 0.0005) for male and 0.0012 to 0.0027 (mean ± SD = 0.0019 ± 0.0004) for female (Table 4). The Mann-Whitney U-test exposed that K_A of male (median = 0.0048, 25% Percentile = 0.0046, 75% Percentile = 0.0052) was significantly higher (Two tailed, $p<0.001$) than that for female (median = 0.0020, 25% Percentile = 0.0017, 75% Percentile = 0.0022).

RELATIVE WEIGHT

The relative weight for male and female *C. reba* ranged from 78.86 to 127.08 (mean ± SD = 99.50 ± 9.19) and 62.85 to 141.11 (mean ± SD = 102.32 ± 18.82), respectively (Table 4). The one sample t-test showed that the mean W_R (actual mean = 99.50) did not differ from 100 for male (Two tailed, df = 138, $p = 0.523$) and female (Two tailed, df = 110, $p = 0.197$) in this study, indicating the habitat was still in good condition for *C. reba*. However, the results

TABLE 4. Condition factors and form factor of the *Cirrhinus reba* (Hamilton 1822) in the Ganges River, NW Bangladesh

Condition factor	*n*	Min	Max	Mean ± SD	$CL_{95\%}$
Male	139				
K_F		0.65	1.05	0.87±0.09	0.85-0.88
K_R		0.79	1.27	1.00±0.09	0.98-1.01
K_A		0.0039	0.0062	0.0049±0.0005	0.0048-0.0050
W_R		78.86	127.08	99.50±9.19	97.96-101.04
Form factor ($a_{3.0}$)				0.0101	
Female	111				
K_F		0.67	1.79	1.14±0.30	1.09-1.20
K_R		0.63	1.41	1.02±0.19	0.99-1.06
K_A		0.0012	0.0027	0.0019±0.0004	0.0019-0.0020
W_R		62.85	141.11	102.32±18.82	98.78-105.86
Form factor ($a_{3.0}$)				0.0145	
Combined sex	250				
K_F		0.65	1.79	0.99±0.25	0.96-1.02
K_R		0.66	1.56	1.02±0.18	0.99-1.04
K_A		0.0017	0.0039	0.0025±0.0005	0.0024-0.0026
W_R		66.09	156.50	101.70±18.15	99.44-103.96
Form factor ($a_{3.0}$)				0.0127	

n, sample size; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values; K_F, Fulton's condition factor; K_R, relative condition factor; K_A, allometric condition factor; W_R, relative weight

showed that mean W_R differed significantly between sexes (Unpaired t-test with Welch's correction, Two tailed, df = 151, $p<0.001$) in the Ganges River.

FORM FACTOR

Form factor ($a_{3.0}$) of male, female and combined gender of *C. reba* was calculated as 0.0101, 0.0145 and 0.0127, respectively (Table 4).

SIZE AT FIRST SEXUAL MATURITY

The size at sexual maturity of male and female *C. reba* were estimated as 11.50 cm TL and 13.50 cm TL, respectively.

DISCUSSION

SEX RATION

Departure from a 1:1 sex ratio is not expected for most aquatic (fin and shellfish) species, although some finfish and prawn populations may show a strong bias in this ratio (Hossain et al. 2012f). In the present study, out of the 250 specimens of *C. reba* sampled, the male and female sex ratio was 1:0.79. The overall sex ratio did not differ significantly from the expected value of 1:1. However, lack of adequate information on sex ratio of this species restrains the comparison with other studies. Nonetheless, an increase in sex ratio with body size has been documented for other species, possibly due to the differences in mortality rates between sexes (Hossain et al. 2012f). Additionally, differences in growth between sexes, sexual dimorphism and migration may also be factors. No sexual dimorphism was found in the present study. Hence the increase of the sex ratio with size might be related to different growth between sexes (Rahman et al. 2012b).

LENGTH-FREQUENCY DISTRIBUTIONS

During the study, 250 specimens with various body sizes were sampled using traditional fishing gears, yet it was impossible to catch *C. reba* smaller than 8.00 cm TL during the sampling period, which can be ascribed either to the absence of small sized fishes (< 8.00 cm TL) in the populations or selectivity of the fishing gears (Hossain et al. 2012f). The maximum length (TL) of *C. reba* found in the present study was 23.40 cm which is lower than the maximum recorded value of 32 cm TL in Baigul reservoir (U.P) India (Khan 1986) and 30 cm TL in fish ponds of the district Jacobabad, Sindh, Pakistan (Lashari et al. 2007). However, Narejo (2006) recorded the maximum size of *C. reba* as 22.50 cm (TL) in Manchar Lake, Pakistan and Muralidharan et al. (2011) reported the maximum length as 18.40 cm in Cauvery River, south India which are lower than that found in the present study. These regional differences in total length perhaps depend on the

ecological conditions in the areas of study. Furthermore, the effects of water temperature can be directly related to biological production rates and food availability, as well as to nekton and plankton species composition, both of which influence fish growth (Colerbook 1982; Weatherley & Gill 1987). However, Hossain et al. (2012g) reported that the information on maximum length is necessary to estimate the population parameters including asymptotic length and growth coefficient of fishes, which is important for fisheries resource planning and management.

In addition, the maximum body weight of *C. reba* found in the present study was 200 g which is higher than that found by Narejo (2006) as 102.50 g in Manchar Lake, Pakistan and Muralidharan et al. (2011) as 147.00 g in Cauvery River, south India. Moreover, this study also revealed that, female of Reba carp are significantly larger than the male. The differences in the recorded maximum sizes of individuals of *C. reba* in different regions might be attributed either to the absence of larger-sized individuals in the populations in fishing grounds (Hossain et al. 2012f) and/or shrinkage in body size of the formalin-preserved specimens. In addition, the variations in the fishing gear used and the selectivity on the target species may greatly influence the size distribution of the individuals caught resulting in highly biased estimations of the various population parameters including the maximum size (Hossain et al. 2012c).

LENGTH-WEIGHT RELATIONSHIPS

A total of 250 specimen of *C. reba* were used to estimate the *b* value. The parameter *b* values vary between 2 and 4, however, values ranging from 2.5 to 3.5 are more common (Carlander 1969; Froese 2006). In general and regardless of the many variations in fish forms between species, *b* is close to 3, indicating that fish grow isometrically; values significantly different from 3.0 indicate allometric growth (Tesch 1971). However, in this study, the *b* value for male, female and combined gender of *C. reba* were within the range of 2 and 4. The growth of *C. reba* is thus positively allometric in the Padma River, NW Bangladesh that means faster in weight than in length. In a recent study, Muralidharan et al. (2011) recorded the length-weight regression parameters as $a = 0.007$ and $b = 3.20$ for *C. reba* from Cauvery River, south India, which are in accordance with the present study. Furthermore, Narejo (2006) described the growth of *C. reba* as positively allometric in Manchar Lake, Pakistan, which is also in accordance with the present study. However, the LWR in fishes can be affected by several factors including habitat, area, seasonal effect, degree of stomach fullness, gonad maturity, sex, health, preservation techniques and differences in the observed length ranges of the specimen caught (Tesch 1971), all of which were not accounted in the present study. In addition, growth increment, differences in age and stage of maturity, food, as well as environmental conditions such as temperature, salinity and seasonality can also affect the value of *b* for the same species (Weatherley & Gill 1987). The LWR with *b* values significantly different from 3.0 were often associated with narrow size ranges of the specimens examined; such LWRs should be used only within these size ranges (with caution for sample-size inadequacy). Since sample of *C. reba* were collected over an extended period of time, this data are not representative of any particular season, so should be treated only as mean-annual values for comparative purposes.

CONDITION FACTORS

There is no previous information on the condition factor of *C. reba* except Narejo (2006) who studied the relative condition factor of *C. reba* in Manchar Lake, Pakistan. He reported the relative condition factor of *C. reba* as 0.96-1.10 (mean ± SD = 1.02 ± 0.20), 0.99-1.07 (mean ± SD = 1.03 ± 0.18) and 0.96-1.05 (mean ± SD = 1.01 ± 0.20) for male, female and combined gender, respectively, which are in accordance with the present study. Additionally, the Fulton's condition factor (K_F) values were found significantly different between sexes, likely indicating the presence of mature female.

Moreover, the most popular index (relative weight, W_R) was used to focus the present status of the threatened Reba carp in the Padma River (Froese 2006). The relative weight showed no significant differences from 100 for male and female in this study, indicating the habitat was still in good condition for *C. reba*. However, this fish species is categorized as vulnerable in Bangladeshi waters by IUCN Bangladesh (2000) which might be attributed to other reasons rather than water quality. Nonetheless, this information would allow for urgent detection of any long-term declines in condition that may have occurred, possibly as a result of environmental change as the relative condition integrates key physiological components of fish life history (lipid storage and growth), it suggests a strong, handy metric that managers can use to evaluate the overall health and fitness as well as population-level responses to ecosystem disturbance (cf. Rypel & Richter 2008). However, Rahman et al. *(*2012a) studied the relative weight of *P. sophore* in the Chalan *beel*, north-central Bangladesh and found the habitat was still in good condition for supporting the growth of *P. sophore*.

FORM FACTOR

The application of the form factor ($a_{3.0}$) can be used to verify whether the body shape of individuals in a given population or species is significantly different from others (Froese 2006). There is no reference regarding the form factor of this species in the literature, so this is the first such study on this regard of the Reba carp which will provide the foundation for future studies.

SIZE AT FIRST SEXUAL MATURITY

Studies on size at first sexual maturity of fish from Bangladeshi waters are quite scarce (except Hossain et al. 2010c; Hossain et al. 2012d; 2012g). This study presents

the first attempt to determine the size at first sexual maturity for *C. reba* from the Padma River. This size parameter is of special interest in fisheries management and is widely used as an indicator for minimum permissible capture size (Lucifora et al. 1999). However, in the present study, the size at sexual maturity of male and female *C. reba* were estimated in this study as 11.50 cm TL and 13.50 cm TL, respectively. Since there are no references dealing with the size at sexual maturity for *C. reba* are available, therefore, this study will provide the basis for more detailed studies to provide further insight into the specific combination of factors affecting the size at first sexual maturity and spawning size in different populations of *C. reba*.

Conclusion

This study provides an important baseline information on the LWRs, condition- and form-factors, size at sexual maturity of the threatened *C. reba* from Bangladesh. These results of this study would be an effective tool for fishery biologists, managers and conservationists to initiate prompt management strategies and regulations for the sustainable conservation of the remaining stocks of this species in the Padma River ecosystem. In addition, information on LWRs, condition factors and form factor for *C. reba* are evidently lacking from literature and data bases including FishBase. Therefore, the results of this study will provide vital information for the online FishBase database, as well as providing an important baseline for future studies within the Ganges River and surrounding ecosystems.

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