

Variation in the life-history traits of a Schilbid catfish, *Clupisoma garua* (Hamilton, 1822) in the coastal waters of southern Bangladesh*

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Abstract For the first time, the present study reports the life-history traits, comprising length-frequency distribution (LFD), sex ratio (SR), length-weight relationships (LWRs), condition factors (CFs), and relative growth (W_R), of *Clupisoma garua* in the coastal waters of Bangladesh. A total of 150 specimens ranging from 8.60 to 25.20 cm total length (TL) and 4.26 to 128.80 g body weight (BW) were collected using traditional fishing gear from August 2013 to July 2014. The overall sex ratio of males to females in the study did not differ significantly from the expected value of 1:1 ($\chi^2=0.96$, $P<0.05$) but there were significant sex differences ($P<0.05$) in the intercepts and slopes of graphs characterizing traits in *C. garua*. The calculated b values for the LWRs were 2.955, 2.893 and 2.927 for males, females and combined sexes, respectively, and there was negative allometric growth in all cases ($b<3$). The condition factors (K_A, K_F, K_R) and relative growth (W_R) also did not differ significantly ($P<0.05$) between the sexes. This study provides a useful tool for fishery specialists to evaluate the relative condition of fish and to initiate early management strategies and regulations for the sustainable management of the remaining stocks of this species in the entire coastal region of southern Bangladesh.

Keyword: size frequency; length-weight; sex ratio; allometric growth; *Clupisoma garua*

1 INTRODUCTION

The southern coastal waters of Bangladesh are very rich in fishery resources and regular, intense interaction takes place between more saline and more turbid habitats, which provides juvenile fish with abundant food resources as well as some refuge from predation (Laegdsgaard and Johnson, 2001). Moreover, a large number of rivers and estuaries support mangrove forests. These make the southern coastal region of Bangladesh an ideal nursery and breeding ground for many offshore and estuarine shellfish and finfish (Mandal et al., 2013).

Clupisoma garua belongs to the order Siluriformes and is an important component of riverine and

brackish water fisheries in Bangladesh. It is commonly known as Garua Bachcha which is preferred by all classes of consumers due to its taste and nutritive quality. This species was once extensively available in the coastal waters of Bangladesh and also occurs neighboring countries including India, Myanmar, Nepal and Pakistan (Talwar and Jhingran, 1991). But over the past decade, increasing anthropogenic and natural hazards have limited the species' geographical distribution across the region (Siddik et al., 2013;

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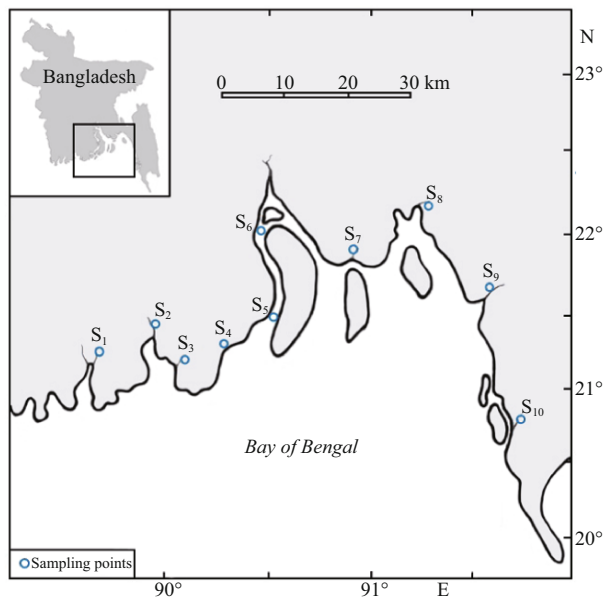


Fig.1 Sampling sites of *C. garua* in the waters of southern coastal region of Bangladesh

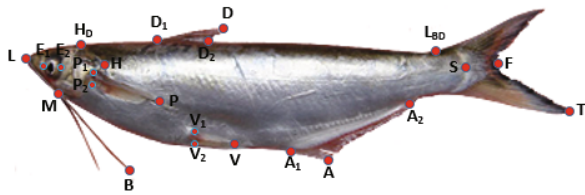


Fig.2 Schematic image of *C. garua* showing 15 morphometric attributes to infer morphological differences among the populations

Total length (TL); fork length (FL); standard length (SL); head length (LH); head depth (H_{D1}); highest body depth (D_{21}); lowest body depth (L_{BD1}); pre-dorsal length (LD_1); post-dorsal length (D_2S); height of dorsal fin (D_1); height of pectoral fin (P_1); height of ventral fin (V_1); height of anal fin (A_1); length of anal base (A_1A_2); maximum barbell length (MB).

Chaklader et al., 2014; Hanif et al., 2015a; Sharker et al., 2015; Nahar et al., 2015) and has resulted in the species being categorized as critically endangered in Bangladesh (Hanif et al., 2015b; IUCN, 2015).

Studies on life history traits of any particular species are important for estimating how fish weight changes as a function of length, ascertaining the condition of the fish, comparing fish growth among habitats, and as a complement to species-specific reproduction and feeding studies (Le Cren, 1951; Ecoutin et al., 2005; Froese, 2006; Cicek et al., 2006; Sun et al., 2013; Chaklader et al., 2016a, b; Siddik et al., 2016c). Traits are also crucial for understanding fish biology, taxonomy, ecology as well as for sustainable management and conservation of fish (Chaklader et al., 2015; Siddik et al., 2015). Over the years morphometric characters, as a relatively cheap

biological tool, have been used to study growth patterns and ontogenic changes in various species (Oscoz et al., 2005; Tarkan et al., 2006; Heydarnejad, 2009; Simon et al., 2010; Siddik et al., 2016a, b). Despite the available research on the life-history traits of different fish in southern Bangladesh, information about the critically endangered *C. garua* has not been investigated before. Therefore, this article describes length-frequency distribution (LFD), sex ratio (SR), length-weight relationships (LWRs), condition factors (CFs), relative growth (W_R) and form factors ($a_{3,0}$) in *C. garua* in the coastal waters of Bangladesh.

2 MATERIAL AND METHOD

2.1 Study area and sampling

The specimens of *C. garua* were collected occasionally from 10 stations along the entire coastal region of Bangladesh using traditional fishing gear during the daytime over a period of one year from August 2013 to July 2014 (Fig.1). Samples were immediately preserved with ice in the fish landing areas and fixed with 5% formalin prior to being brought to the laboratory, Faculty of Fisheries, Patuakhali Science and Technology University, Bangladesh. Morphometric characters were measured using slide calipers and body weight (BW) was measured by a digital balance (Fig.2).

2.2 Estimation of length-weight relationships (LWR)

The LWR was calculated using the allometric equation $W=aL^b$, where W is body weight (g), L is total length (cm), a is a coefficient of body form and b is an exponent of the growth type (Simon et al., 2010). The values of a and b were calculated by natural logarithms $\ln W=\ln a+b\ln L$ based on linear regression analysis. In addition, 95% confidence limits of b and the coefficient of determination R^2 were estimated. Following Froese (2006) \ln - \ln plots of length and weight values were visually inspected for outliers prior to the regression analysis of $\ln BW$ on $\ln TL$, with extremes being omitted from the regression analyses. Values of b are required to determine from the linear regressions when the allometric relationship varied from the isometric value ($b=3$).

2.3 Calculation of condition and form factors

For the calculation of Fulton's condition factor

Table 1 Comparative relationship of morphometric measurements for each sex of *C. garua* (Hamilton, 1822) in the waters of Bangladesh

Morphometric	Male				Female				T_s	T_m
	Mean (\pm SD)	a	b	R^2	Mean (\pm SD)	a	b	R^2		
FL	12.51 (\pm 3.23)	-0.122	0.994	0.998*	12.61 (\pm 2.96)	-0.118	0.990	0.997*	232.99	0.040
SL	11.31 (\pm 2.97)	-0.261	1.008	0.996*	11.42 (\pm 2.75)	-0.227	1.102	0.990*	149.77	0.058
LH	2.29 (\pm 52)	-1.292	0.796	0.792	2.31 (\pm 0.53)	-1.632	0.922	0.865	26.20	0.064
H _{D1}	1.72 (\pm 0.35)	-0.834	0.515	0.453	1.69 (\pm 0.31)	-0.870	0.519	0.463	11.09	0.363
D ₂₄	2.62 (\pm 0.81)	-1.897	1.070	0.802	2.61 (\pm 0.75)	-2.053	1.120	0.847	25.93	0.018
L _{BD1}	1.26 (\pm 0.29)	-1.133	0.509	0.328	1.23 (\pm 0.34)	-1.986	0.812	0.496	9.79	0.435
LD ₁	3.22 (\pm 0.87)	-1.155	0.870	0.737	3.24 (\pm 0.76)	-1.000	0.812	0.753	20.65	0.035
D ₂ S	6.75 (\pm 2.19)	-1.124	1.165	0.724	6.87 (\pm 2.07)	-1.444	1.251	0.705	19.23	0.117
D ₁	1.72 (\pm 0.91)	-2.573	1.154	0.677	1.69 (\pm 0.50)	-2.602	1.163	0.893	21.43	0.063
P ₁	1.89 (\pm 0.55)	-2.267	1.086	0.890	1.89 (\pm 0.53)	-2.366	1.119	0.892	34.59	0.008
V ₁	1.26 (\pm 0.23)	-0.892	0.423	0.430	1.27 (\pm 0.23)	-1.021	0.471	0.493	11.17	0.067
A ₁	1.23 (\pm 0.23)	-0.704	0.343	0.304	1.24 (\pm 0.22)	-1.009	0.457	0.467	9.35	0.010
A ₁ A ₂	3.22 (\pm 0.98)	-1.747	1.091	0.837	3.22 (\pm 0.85)	-1.682	1.062	0.831	27.25	0.000
MB	5.02 (\pm 1.37)	-0.981	0.971	0.829	5.17 (\pm 1.38)	-1.213	1.064	0.857	27.91	0.437

Note: a =intercept; b =slope; R^2 =correlation coefficient; T_s =test of slope; T_m =test of adjusted mean; * Significant at $P<0.05$.

(K_F) (Fulton, 1904), the following equation $K_F=100 \times (W/L^3)$ was used, where W and L are given in g and cm, respectively. Relative condition factor (K_R) was calculated following the equation, $K_R=W/a \times L^b$ (Le Cren, 1951). Allometric condition factor (K_A) was calculated using the formula, $K_A=W/L^b$ (Tesch, 1971). Also, relative weight (W_R) was estimated using the formula, $W_R=(W/W_S) \times 100$ (Froese, 2006). The form factor ($a_{3,0}$) is used whether the body shape of a given population or species is significantly different from others (Froese, 2006). The equation that was used to calculate the form factor ($a_{3,0}$) is: $a_{3,0}=10^{\log a - S(b-3)}$ (Froese, 2006), where a and b are regression parameters of the (LWR), S is the regression slope of $\log a$ vs b . A mean slope of $S=-1.358$ was used for estimating the form factor during this study due to lack of information on LWRs in this species.

2.4 Statistical analysis

A χ^2 goodness-of-fit test was applied to evaluate the sex-ratio from the expected value of 1:1 (male: female). The Kolmogorov-Smirnov test was applied to make comparisons between the sexes for length-frequency distributions. Following Anderson and Neumann (1996), the non-parametric Wilcoxon rank test was used to compare the mean relative weight of a population with 100 and Spearman rank test was used to correlate morphometric measurements such

as TL, SL, and BW with Fulton's condition factor (K) and relative weight (W_R). Also, the parameters (a) and (b) of the LWRs were compared by the analysis of covariance (ANCOVA). All statistical analyses were performed using SPSS v. 16.0 and STATISTICA version 8.0.

3 RESULT

3.1 Length-frequency distribution

A total of 150 specimens of *C. garua* were collected from the entire southern coastal region of Bangladesh. The comparison of morphometric characters between males, females and pooled samples of *C. garua* is presented in Table 1. Univariate ANOVA revealed that females have higher mean values than that of males in all examined morphometric measurements except the head depth, highest body depth, lowest body depth, and height of dorsal fin. The total length varied from 8.60 to 25.20 cm (mean \pm SD=14.37 \pm 3.73) for males and 8.80 to 20.80 cm (mean \pm SD=14.57 \pm 3.44) for females of *C. garua*. Total length frequencies of males and females are shown in Fig.3. The distribution of TL was non-normal (Kolmogorov-Smirnov test, $P<0.001$), and showed two peaks at 11 and 16 cm for both males and females. Moreover, the BW varied between 4.26 and 128.80 g (mean \pm SD=23.99 \pm 19.79) in males and 4.66 and 61.40 g (mean \pm SD=23.42 \pm 15.71)

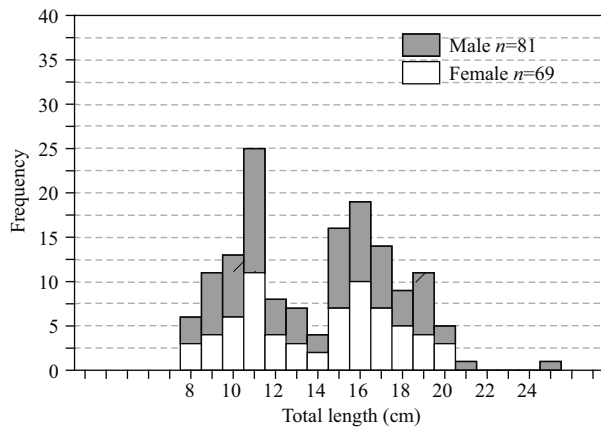


Fig.3 Distribution of the total length frequency of both sexes *C. garua* (Hamilton, 1822) in the waters of Bangladesh

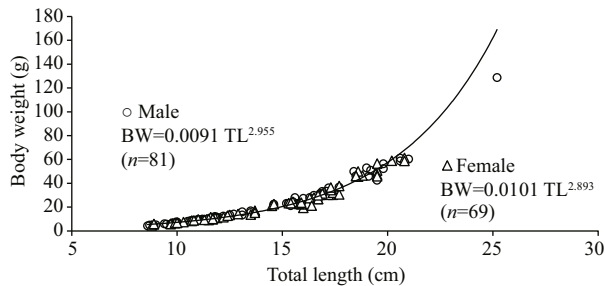


Fig.4 Length-weight relationships of *C. garua* (Hamilton, 1822) of Bangladesh

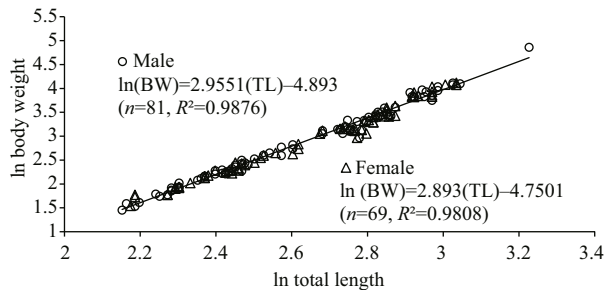


Fig.5 Log-scale visual representation of the length-weight relationship of *C. garua* (Hamilton, 1822) of Bangladesh

in females of *C. garua*. The BW-frequency distribution also showed that the males and females of *C. garua* were not normally distributed (Kolmogorov-Smirnov test, $P < 0.001$).

3.2 Sex ratio

In the study, 54% were males and 46% were females among the 150 specimens (male=81; female=69; male:female=1: 0.85) of *C. garua* collected during the study. However, the overall sex ratio did not show significant difference from the expected value of 1:1

Table 2 The sex ratio of the total length dependent for *C. garua* in the waters of southern Bangladesh

Length class (TL, cm)	No. of fish	Male No.	Female No.	Ratio		χ^2 (df=1)	Significance
				Male	Female		
8.00–8.99	6	3	3	1	1	0.00	NS
9.00–9.99	11	7	4	1	0.57	0.82	NS
10.00–10.99	13	7	6	1	0.86	0.08	NS
11.00–11.99	25	14	11	1	0.79	0.36	NS
12.00–12.99	8	4	4	1	1	0.00	NS
13.00–13.99	7	4	3	1	0.75	0.14	NS
14.00–14.99	4	2	2	1	1	0.00	NS
15.00–15.99	16	9	7	1	0.78	0.25	NS
16.00–16.99	19	9	10	1	1.11	0.06	NS
17.00–17.99	14	7	7	1	1	0.00	NS
18.00–18.99	9	4	5	1	1.25	0.12	NS
19.00–19.99	11	7	4	1	0.57	0.82	NS
20.00–20.99	5	2	3	1	1.50	0.20	NS
21.00–21.99	1	1	0	-	-	1.00	NS
22.00–22.99	0	0	0	-	-	0.00	NS
23.00–23.99	0	0	0	-	-	0.00	NS
24.00–24.99	0	0	0	-	-	0.00	NS
25.00–25.99	1	1	0	-	-	1.00	NS
Overall	150	81	69	1	0.85	0.96	NS

NS=not significant.

(df=1, $\chi^2=0.96$, $P > 0.05$) (Table 2).

3.3 Length-weight relationships

The statistics and parameters of the length-weight relationships (LWR), form factor ($a_{3,0}$) and growth types of *C. garua* are shown in Figs.4 and 5, and Table 3. The calculated b in the LWR for males, females and combined gender of *C. garua* were 2.955 (2.881 to 3.029), 2.893 (2.794 to 2.992) and 2.927 (2.867 to 2.987), respectively and indicated negative allometric growth as b was less than 3. However, there were no statistical differences in the intercepts and in the slopes between the sexes. The coefficient of determination (R^2) estimated from the length-weight relationship for all male, female and combined was greater than 0.9 and was significant.

3.4 Condition factors and form factor

K_F ranged from 0.47 to 0.80 (mean \pm SD=0.67 \pm 0.06) in males and from 0.47 to 0.84 (mean \pm SD=0.65 \pm 0.07) in females (Table 4). K_R for males and females *C. garua* varied between 0.982 and 1.310 (mean \pm SD=

Table 3 Estimated parameters of the length-weight relationships ($BW=a \times TL^b$) and form factor ($a_{3.0}$) of *C. garua* (Hamilton, 1822) in the waters of southern Bangladesh

Sex	Linear regression equation	SE(b)	CL95% of b	t_s	GT	$a_{3.0}$
Male (n=81)	$\ln BW = -4.893 + 2.955 \ln TL$, $R^2 = 0.988$	0.037	2.955	-1.22	A-	0.006
Female (n=69)	$\ln BW = -4.750 + 2.893 \ln TL$, $R^2 = 0.981$	0.049	2.893	-2.18	A-	0.006
Combined sample (n=150)	$\ln BW = -4.829 + 2.927 \ln TL$, $R^2 = 0.984$	0.030	2.927	-2.43	A-	0.010

n: sample size; BW: body weight; TL: total length; a: intercept; b: slope; SE(b): standard error of slope; CL: confidence limits; R^2 : coefficient of determination; GT: growth type (A-: negative allometric growth based on: $t_s = (b-3)/s_b$, where t_s is the t-test value; b the slope and s_b the standard error of the slope (b); $a_{3.0}$: form factor.

Table 4 Condition factors and relative growth (W_R) of *C. garua* (Hamilton, 1822) in the waters of southern Bangladesh

	Conditions factors			Relative growth
	K_F	K_R	K_A	W_R
Male (n=81)				
Min	0.47	0.982	0.002 3	98.27
Max	0.80	1.310	0.043 3	131.02
Mean±SD	0.67±0.06 ^a	1.093±0.103 ^a	0.011 7±0.013 0 ^a	109.31±10.32 ^a
CL _{95%}	0.06–0.68	1.007–1.179	0.000 8–0.022 6	100.68–117.94
Female (n=69)				
Min	0.47	0.999	0.006 3	99.95
Max	0.84	1.418	0.012 9	141.80
Mean±SD	0.65±0.07 ^a	1.156±0.144 ^a	0.009 5±0.002 8 ^a	114.12±15.32 ^a
CL _{95%}	0.64–0.67	1.023–1.289	0.007 0–0.012 1	99.96–128.29
Combined sample (n=150)				
Min	0.47	0.982	0.002 3	98.27
Max	0.84	1.418	0.043 3	141.80
Mean±SD	0.66±0.06 ^a	1.122±0.124 ^a	0.010 7±0.009 5 ^a	111.56±12.65 ^a
CL _{95%}	0.65–0.67	1.054–1.191	0.005 4–0.015 9	104.55–118.56

K_F , Fulton's condition factor; K_R , relative condition factor; K_A , allometric condition factor. Mean values in each row bearing same superscripts are not significantly different ($P > 0.05$).

1.093±0.103) and between 0.999 and 1.418 (mean±SD=1.156±0.144), respectively. K_A ranged from 0.002 3 to 0.043 3 (mean±SD=0.011 7±0.013 0) for males and from 0.006 3 to 0.012 9 (mean±SD=0.009 5±0.002 8) for females. W_R for male and female *C. garua* ranged from 98.27 to 131.02 (mean±SD=109.31±10.32) and from 99.95 to 141.80 (mean±SD=114.12±15.32), respectively (Table 4). The calculated form factor was 0.006 and 0.006 for males and females, respectively (Table 3).

4 DISCUSSION

The results reveal that females have higher mean values in all morphometric dimensions than males

except for the head depth, highest body depth, lowest body depth, and height of dorsal fin. The minimum size (TL) of *C. garua* was 8.60 cm and the maximum size was 25.20 cm TL, which is less than the maximum reported value of 36.6 cm in Betwa and Gomti rivers, Karnataka, Uttar Pradesh, India (Sani et al., 2010) and 33 cm in Gomti Rivers, India (Kumar et al., 2014). The maximum body weight of *C. garua* recorded in this study was 128.80 g. In this study, the absence of larger individuals in the sampling areas might be due to over exploitation in the coastal waters of Bangladesh (Hossain et al., 2012). Furthermore, local fishers used particular fishing gear with similar mesh size resulting in similar catch composition, unlike in previous studies, in which different fishing techniques caused biased estimation of the various population parameters including the maximum size (Hossain et al., 2012).

The male and female ratio may vary between 1:1 and 1:1.3 in a typical population reported by Dias et al. (2014) but in the study the ratio was 1:0.85 and it was not significantly different from 1:1. There are a variety of factors, including biased sex determination (Conover and Kynard, 1981), divergent sexual behavior, growth rate, varying climate and regional conditions, that could cause such variation (Dias et al., 2014).

In this study, the b values calculated from the TL-BW relationship were 2.955 for males and 2.893 for females, indicating negative allometric growth of *C. garua* in the study i.e. the body does not increase in all dimensions in the same proportion to growth (Jobling, 2008) which were within the limit (2.5–3.5) reported by Oscoz et al. (2005), Esmaeili and Ebrahimi (2006) and by Arshad et al. (2008) in various fishes. Sani et al. (2010) stated that the b value of *C. garua* was 3.10 in Gomti Rivers, India, while in the same river Kumar et al. (2014) found the b value is 2.69. It is widely recognized that there are a number of factors that influence the length-weight relationship in fish, including growth phase, sex, season, food (quantity, quality and size), stage of maturity, and

health and general fish condition, preservation techniques and differences in the observed length ranges of the specimen caught (Tesch, 1971; Hossain et al., 2012), all of which were not investigated in the present study. Moreover, the samples of *C. garua* were collected over an extended period irrespective of any particular season, so these data should be treated only as mean-annual values for comparative purposes.

Condition factors are indices reflecting interactions between biotic and abiotic factors in the physiology of fish, which reflects the well-being of their populations during various stages of the life cycle (Hossain et al., 2012). Several condition factors, including Fulton's condition factor (K_F), the relative condition factor (K_R) and the allometric condition factor (K_A) were employed during this study in order to evaluate the general health and productivity of *C. garua*. These condition factors revealed no significant differences between sexes. Several studies conducted on population dynamics have revealed that high condition factor values indicate favorable environmental conditions such as habitat suitability and prey availability, while low values indicate more unfavorable environmental conditions (Blackwell et al., 2000). Table 4 shows Fulton's condition factor (K_F) for males, females and pooled samples were 0.67, 0.65 and 0.66, respectively. The fluctuation of condition factor occurs due to interaction between feeding conditions, parasitic infections, and physiological factors (Le Cren, 1951). Differences in condition factor have been considered to indicate various biological features, such as fatness or suitability of the environment (Le Cren, 1951). The temporal decrease in K_F between the sexes in the present study could be considered indicative of degradation in feeding conditions. However, no references dealing with the condition factors of the *C. garua* are available in the coastal waters of Bangladesh.

Relative weight (W_R), used in this study, is an index frequently used to compare the condition of species. The estimated values of W_R less than 100 for an individual, size group or population suggest problems such as low prey availability or high predator density, while values greater than 100 indicate a prey surplus or low predator density (Rypel and Richter, 2008). Recently, a number of studies have used W_R to provide assistance in the management and conservation of non-game fishes, especially those that are threatened or endangered (Richter, 2007; Muchlisin et al., 2010).

During the present study, the relative weight (W_R) showed no significant differences for either male (109.31 ± 10.32) or female (114.12 ± 15.32) *C. garua*, and W_R values were close to 100 in this study indicating a habitat with a balance between food availability and the presence of predators (Anderson and Neumann, 1996). Moreover, it might suggest that the water quality of southern waters is still auspicious for these fisheries. However, *C. garua* is categorized as critically endangered in Bangladeshi waters by IUCN (2015) which might be due to various causes other than water quality (Rahman et al., 2012). Nevertheless, this information would aid in urgent detection of any long-term deterioration in condition that may occur. However, no research concerning the relative weight of *C. garua* is available in the literature thus preventing any comparison of this finding with previous results, although it will provide baseline information to compare with future investigations.

Only a few studies on form factor of fish are available in Bangladeshi waters (Hossain et al., 2012; Rahman et al., 2012). Froese 2006 reported that the estimated value of $a_{3,0}$ is 0.01, indicating an elongate body shape of the fish. The form factor of *C. garua* was 0.006 and 0.006 for male and female, respectively indicating elongate body shape which is characteristic of many riverine fishes. Nonetheless, there is no information available concerning the form factor of this species in the literature, so this study is the first report on it in *C. garua*, which again will be helpful for future studies.

5 CONCLUSION

This study provides basic information on the sex ratio, LFD, LWRs, and condition factors of *C. garua* in the waters of the southern coastal region of Bangladesh, which should be useful for the fishery scientists and conservationists to initiate early management strategies and regulations for the sustainable conservation of the remaining stocks of this species. Furthermore, no length-weight, length-length data or condition-factor data currently exist in the FishBase for this species. So our results may contribute to this invaluable electronic database. Research in more detail is necessary to answer several questions about body-size range and the spawning periodicity of this fishery.

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