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Life History Traits of the Critically Endangered Catfish *Eutropiichthys vacha* (Hamilton 1822) in the Jamuna (Brahmaputra River Distributary) River, Northern Bangladesh

(Ciri Sejarah Hidup Ikan Keli Terancam Kritikal *Eutropiichthys vacha* (Hamilton 1822) di Sungai Jamuna (Anak Sungai Brahmaputra), Bangladesh Utara)

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ABSTRACT

The critically endangered catfish Eutropiichthys vacha *(Hamilton 1822) is one of the commercially high nutritional valuable food fish in Asian countries, but the natural populations are seriously decreasing due to high fishing pressure, leading to an alarming condition and deserving of high conservation importance. Our study describes some biological parameters, including sex ratio, length-frequency distribution (LFD), length-weight relationships (LWRs), length-length relationships (LLRs), condition factors (Allometric,* K_A*; Fulton's,* K_F*; Relative condition,* K_R*; Relative weight,* W_R*) and form factor (*$a_{3.0}$*) of* E. vacha *in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh. A total of 350 specimens ranging from 8.01-16.95 cm TL (total length) and 1.70-30.38 g BW (body weight) were analyzed in this study. Sampling was done using traditional fishing gears during March 2010 to February 2011. The overall sex ratio showed no significant differences from the expected value of 1:1 (*$\chi^2=2.57$*,* $p>0.05$*), and there was no significant difference in the LFD between the sexes (*$p=0.38$*). The allometric coefficient b for the LWR indicated isometric growth (~3.00) in males and combined sexes, but negative allometric growth (<3.00) in females. The results further indicated that the LLRs were highly correlated (*$r^2>0.997$*;* $p<0.001$*).* K_R *showed significant variations (*$F=65.11$*;* $p<0.01$*) between male and female; whereas,* K_F *was not significantly different between the sexes (*$p=0.64$*). Also,* W_R *was significantly different from 100 for both sexes (*$p<0.01$*), indicating the imbalance habitat with food availability relative to the presence of predators for* E. vacha. *The estimated values of* $a_{3.0}$ *were as 0.0060, 0.005 and 0.0054 for males, females and combined sexes of* E. vacha. *This study reported the first complete and comprehensive description of life-history traits for* E. vacha *from Bangladeshi waters. These results should be useful for the sustainable conservation of this critically endangered fishery in Bangladesh and neighboring countries.*

Keywords: Bangladesh; condition factor; Eutropiichthys vacha*; length-weight relationship*

ABSTRAK

Ikan keli terancam, Eutropiichthys Vacha *(Hamilton 1822) adalah salah satu ikan yang menjadi makanan berkhasiat dan bernilai komersial yang tinggi di negara-negara Asia, tetapi kini mengalami pengurangan populasi semula jadi yang serius akibat tekanan penangkapan yang tinggi, menjurus kepada keadaan yang membimbangkan dan wajar menerima kepentingan pemuliharaan yang tinggi. Penyelidikan kami menerangkan beberapa parameter biologi, termasuk nisbah jantina, panjang-frekuensi pengedaran (LFD), panjang-berat hubungan (LWRs), panjang-panjang hubungan (LLRs), faktor keadaan ('allometric, KA itu Fulton, KF; keadaan relatif, KR; faktor berat relatif, WR) dan bentuk (*$a_{3.0}$*)* E. Vacha *dalam Sungai Jamuna (Anak Sungai Brahmaputra) di utara Bangladesh. Sejumlah 350 spesimen yang terdiri daripada 8.01-16.95 cm TL (jumlah panjang) dan 1.70-30.38 g BW (berat badan) telah dianalisis dalam kajian ini. Persampelan telah dilakukan menggunakan peralatan menangkap ikan tradisi pada bulan Mac 2010 hingga Februari 2011. Nisbah jantina keseluruhan menunjukkan tiada perbezaan yang signifikan daripada nilai jangkaan 1:1 (*$\chi^2=2{,}57$*,* $p>0.05$*) dan tidak ada perbezaan yang signifikan dalam LFD antara jantina (*$p=0.38$*). Pekali alometri B untuk LWR menunjukkan pertumbuhan isometrik (~3.00) dalam ikan jantan dan ikan jantina gabungan, tetapi pertumbuhan negatif alometri (<3.00) dalam kalangan ikan betina. Hasil kajian juga menunjukkan bahawa LLRs berkait rapat (*$r^2>0{,}997$*;* $p<0.001$*). KR menunjukkan perbezaan yang signifikan (*$F=65{,}11$*,* $p<0.01$*) antara ikan jantan dan betina, manakala, KF tidak berbeza antara jantina (*$p=0.64$*). Selain itu, WR adalah berbeza dengan ketara daripada 100 untuk kedua-dua jantina (*$p<0.01$*), menunjukkan habitat ketidakseimbangan dengan adanya makanan berbanding dengan kehadiran pemangsa untuk* E. Vacha. *Dianggarkan nilai* $a_{3.0}$ *adalah 0.0060, 0.005 dan 0.0054 untuk jantan, betina dan jantina gabungan* E. Vacha. *Kajian ini merupakan kajian pertama yang lengkap dan komprehensif berkenaan ciri-ciri sejarah hidup* E. Vacha *dari perairan Bangladesh. Keputusan ini amat berguna untuk pemuliharaan mampan ikan terancam di Bangladesh dan negara-negara jiran.*

Kata kunci: Bangladesh; Eutropiichthys vacha*; faktor keadaan; panjang-berat hubungan*

Introduction

The conservation of fish species threatened with extinction is an important issue in modern scientist's society. Knowledge on the life-history traits of threatened fishes is crucial to the implementation of proper management strategies for conserving the critically endangered commercially important fish like *Eutropiichthys vacha* (Hamilton 1822), whose spawning aggregations are heavily exploited by local small- and large-scale fishers (Hossain et al. 2009a).

The small fish *E. vacha* (Siluriformes: Schilbeidae) is a freshwater and brackish-water subtropical species which is commonly known as 'river catfish'. This fish is also known as *Bacha* in Bangladesh (Rahman 1989), *Batchwa vacha* in India (Talwar & Jhingran 1991), *Cherki* in Nepal (Shrestha 1994) and *Challi* in Pakistan (Soomro et al. 2007). The conservational status of this fish has been referred as critically endangered in Bangladesh (IUCN Bangladesh 2000) and endangered in India (Lakra et al. 2010). In addition, Mijkherjee et al. (2002) reported *E. vacha* as vulnerable species and predicted that, the species will disappear from their natural habitat in West Bengal. It is a commercially important food fish in Asian countries and has gained popularity among consumers due to its high nutritional value and good taste (Hasan et al. 2002). The river catfish is an important target species for small scale fishermen in Bangladesh, who use a variety of traditional fishing gears (Hossain 2010a). It is also a major source of animal protein and micronutrients in the diet of rural small-scale farmers (Hossain et al. 2009a).

This fish is widely distributed through the Indian sub-continent including Bangladesh, India, Pakistan, Nepal, Myanmar and Thailand (Talwar & Jhingran 1991). The river catfish inhabits standing and running waters, usually in tanks, streams, rivers and lagoon with mostly muddy bottoms (Froese & Pauly 2011). Previously abundant in the rivers, streams, canals, reservoirs, lakes, swampland (*beels*, *haors* and *baors*) and ponds of Bangladesh (ICUN Bangladesh 2000), India and Pakistan (Froese & Pauly 2011), but the populations have seriously declined or verge of extinction due to over exploitation and various ecological changes in its natural habits (Mijkherjee et al. 2002). Furthermore, in a recent study, Mishra et al. (2009) reported that overfishing is a potential major threat as this species is heavily utilized as a food fish and they recorded a mean decline of 29.2% in wild catch in southern West Bengal for the period 1960-2000. However, IUCN Bangladesh (2000) identified habitat loss as a major threat to this species; though, this does not appear to be supported by any empirical data. Moreover, the culture practices of this species do not exist so far and the total demand for this fish in the domestic market is met through the capture from wild populations; thus, the effective management of wild stocks is critical (Mishra et al. 2009).

Sex ratio and size structure constitute basic information in estimating stock size of fish populations (Vazzoler 1996). Deviation from a 1:1 sex ratio is not expected for most aquatic species, although some fish populations may show a strong bias in this ratio. Such variations might be from different causes, including thermal influences on sex determination (Conover & Kynard 1981), selective mortality by sex through differential predation and divergent sexual behavior, growth rate, or longevity expectation (Schultz 1996).

Length-Weight relationships (LWRs) are effective in fishery assessments for predicting length distributions into weights for biomass estimates (Gerritsen & McGrath 2007) and a cost-effective alternative to direct, field-based weight measurements that can be time-consuming (Koutrakis & Tsikliras 2003). Additionally, LWR parameters are important to assess fish-stock condition. (Gonzalez Acosta et al. 2004). Moreover, LLRs are generally more relevant than age, particularly several ecological and physiological factors are more length-dependent than age-dependent (Hossain et al. 2006a). 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).

To the best of our knowledge, life-history traits like sex ratio, length-frequency distribution (LFD), length-weight relationships (LWRs), length-length relationships (LLRs) and condition factors as well as form factor are generally lesser known for critically endangered fishes, nevertheless, a number of studies on biology, life history characteristics and conservation of many threatened species of Bangladesh are well documented (Hossain 2010a, 2010b; Hossain et al. 2006a, 2006b, 2008, 2009a, 2009b, 2009c, 2012a, 2012c, 2012d, 2012e; IUCN Bangladesh 2000). Furthermore, the natural populations of *E. vacha* are seriously decreasing due to high fishing pressure, leading to an alarming condition. Detailed knowledge on the population structure of *E. vacha* is needed immediately to avert the alarming decline and initiate conservation measures for this important fish of the Jamuna River. Hence, the present paper is the first complete and comprehensive description of the sex ratio, LFD, LWRs, LLRs, condition factors (K_A, K_F, K_R, W_R) and form factor ($a_{3.0}$) of *E. vacha* in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh.

Materials and Methods

Study site

This study was conducted in the Jamuna River (Sariakandi, Bogra region: Latitude 24°88' N; Longitude 89°57' E) of Bangladesh. The Jamuna is the main distributary of the Brahmaputra River, Bangladesh and is one of the world's largest rivers, ranked among the top three rivers in terms of sediment and water discharge volumes. The high water and sediment discharge are attributed to the monsoon flooding and tectonic setting which supplies profuse sediment from the Himalayan uplift into the subsiding Bay of Bengal (Best et al. 2007). A large number commercially important species in this river are targeted by both small and large scale fishermen throughout the year. The river is also believed to be an important spawning and feeding ground for many riverine fish species of Bangladesh.

SAMPLING AND LABORATORY ANALYSIS

Samples were collected on a seasonal basis from the commercial catches landed at the Sariakandi fish landing center of Bogra region during March 2010 to February 2011. The main gears used by the commercial fishers include traditional fishing gears; *jhaki jal* (cast net), *tar jal* (square lift net) and *dughair* (conical trap). The fresh samples were immediately chilled in ice on site and fixed with 10% buffered formalin upon arrival in the laboratory. All morphometric measurements were conducted according to Froese and Pauly (2011). 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.

LENGTH-WEIGHT AND LENGTH-LENGTH 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), fork length (FL, cm) or standard length (SL, cm), a is the intercept of the regression and b is the slope or regression coefficient. Parameters a and b of the weight-length relationship 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 latter as an indicator of the quality of the linear regressions (Hossain et al. 2009c). The coefficient of determination (r^2) is the square of the correlation coefficient (r). According to King (2007), 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. Although 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 case, 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 ($b \approx 3$), we applied the equation of Sokal and Rohlf (1987): $t_s = (b-3) / s_b$, 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 $b>3$). According to Froese (2006), 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. 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. Furthermore, SL *vs*. TL; SL *vs*. FL; and TL *vs*. FL relationships were estimated by linear regression (Hossain et al. 2006b).

CONDITION FACTORS

Fulton's condition factor (K_F) (Fulton 1904) was calculated using 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. The relative condition factor (K_R) for each individual was calculated via 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. In addition, the allometric condition factor (K_A) was calculated using the equation of Tesch (1968): W/L^b, where W is the BW, L is the TL and b is the LWRs parameter. Furthermore, 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 are 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 log a vs b. During 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*.

STATISTICAL ANALYSES

Statistical analyses were performed using Microsoft® Excel-add-in-DDXL, GraphPad Prism 5 and VassarStats online software (http://faculty.vassar.edu/lowry/VassarStats.html). 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 Spearman rank test was used to correlate body measurements (TL) and condition factors (K_F). Kruskal-Wallis test was used to compare the K_F between sexes. The Mann-Whitney U test was used to compare the length-frequency distributions between the sexes. A Chi-square test was used to identify the sex-ratio divergence from the expected value of 1:1 (male: female). In addition, according to the method reported by Froese (2006), the analysis of covariance (ANCOVA) was used to compare relative condition factor between males and females within the same population. Moreover, the parameters *a* and *b* of the LWRs between sexes were compared by ANCOVA. All statistical analyses were considered significant at 5% (p<0.05).

Results

From the 350 specimens of *E. vacha* collected in the Jamuna River during the study period (March 2010 to February 2011), 46% were males and 54% were females, so the overall sex ratio did not differ statistically from the expected 1:1 ratio (χ^2=2.57, df=1, p>0.05) (Table 1). However, the variation in sex ratio with length class showed that females dominated vaguely for the 10.00-10.99 cm TL to 15.00-15.99 cm TL size groups, whereas males dominated somewhat in the 9.00-9.99 cm TL range, or below, however statistically there were no significance differences among these groups (p>0.05).

Table 2 illustrates the descriptive statistics for length and weight measurements of the river catfish. The length-frequency distribution of *E. vacha* showed that the smallest and largest specimens were 8.01 cm and 16.95 cm TL, respectively (Figure 1). The 9-10 cm TL size group was numerically dominant and constituted 18% of the male population, whereas females were dominated by the 12-13 cm TL size group that constituted 19% of its population. The LFD for males and females did not pass the normality (Kolmogorov-Smirnov test; p<0.05) during the study. In

TABLE 1. Number of male, female and sex ratio (male: female = 1:1) of the *Eutropiichthys vacha* (Hamilton 1822) in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh

Total length class (cm)	Number of specimens			Sex ratio (Male/ Female)	χ^2 (*df*=1)	Significance
	Male	Female	Total			
8.00 – 8.99	11	9	20	1 : 0.82	0.20	NS
9.00 – 9.99	29	28	57	1 : 0.97	0.02	NS
10.00 – 10.99	27	33	60	1 : 1.22	0.60	NS
11.00 – 11.99	25	36	61	1 : 1.44	1.98	NS
12.00 – 12.99	21	20	41	1 : 0.95	0.02	NS
13.00 – 13.99	17	27	44	1 : 1.59	2.27	NS
14.00 – 14.99	14	16	30	1 : 1.14	0.13	NS
15.00 – 15.99	5	11	16	1 : 2.20	2.25	NS
16.00 – 16.99	11	10	21	1 : 0.91	0.05	NS
Overall	160	190	350	1 : 1.19	2.57	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 *Eutropiichthys vacha* (Hamilton 1822) in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh

Measurements	*n*	Min	Max	Mean ± SD	$CL_{95\%}$
Male	160				
TL		8.22	16.94	11.80±2.22	11.46 – 10.21
FL		7.22	15.39	10.60±2.05	8.87 – 9.31
SL		6.37	14.08	9.56±1.97	7.72 – 8.10
BW		2.80	30.80	11.26±6.78	16.40 – 19.26
Female	190				
TL		8.01	16.95	11.99±2.17	11.68 – 12.30
FL		7.15	15.41	10.77±2.01	10.48 – 11.06
SL		6.32	14.09	9.73±1.93	9.45 – 10.01
BW		1.70	29.80	11.62±6.22	10.73 – 12.51
Combined sex	350				
TL		8.01	16.95	11.91±2.19	11.70 – 12.12
FL		7.15	15.41	10.69±2.03	10.48 – 10.91
SL		6.32	14.09	9.65±1.95	9.45 – 9.85
BW		1.70	30.80	11.46±6.48	10.78 – 12.41

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 and BW, body weight

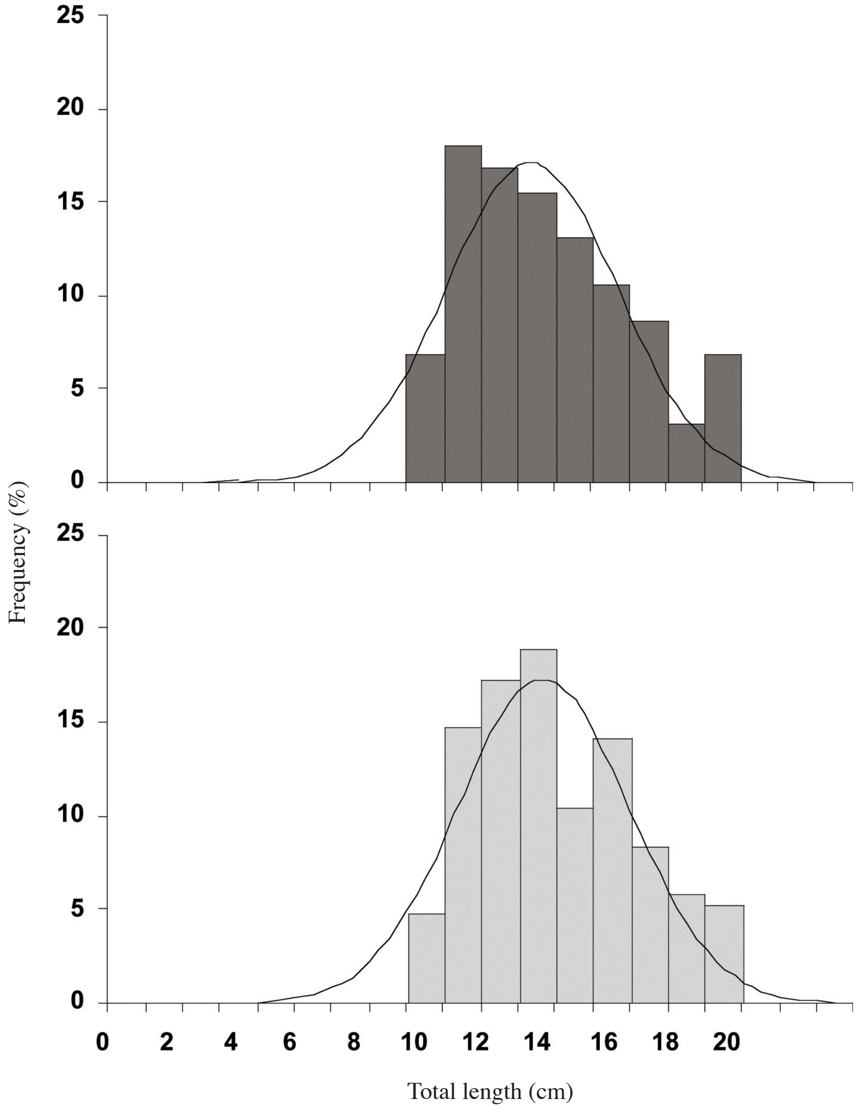

FIGURE 1. Length-frequency distribution of the *Eutropiichthys vacha* (Hamilton 1822) in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh

addition, the Mann-Whitney U-test showed no significant differences in the LFDs between sexes (Mann-Whitney U-test, p=0.38). Furthermore, the results showed that BW of males (11.26±6.78 g, range 2.80-30.80 g) was not significantly varied (Mann-Whitney U-test, p=0.26) from females (11.62±6.22 g, range 1.70-29.80 g).

Sample sizes (n), regression parameters and 95% confidence intervals for a and b of the LWRs, coefficients of determination (r^2) and growth type of *E. vacha* are given in Figures 2 and 3 and in Table 3. The calculated allometric coefficient (b) indicated isometric growth in males (b≈3.03) and combined sexes (b≈2.92), but negative allometry in females (b≈2.81), as the latter t-test for b was significantly different from 3 (b<3.00, p<0.01). In addition, the FL-BW and SL-BW relationship showed similar pattern of growth in males, females and combined sexes (Table 3). All LW relationships were highly significant (p<0.01), with all r^2 values exceeding 0.900. The analysis of covariance (ANCOVA) revealed significant differences between sexes for the intercepts (a) and slopes (b) of the regression lines (Figure 3) (F=4.56, df=346, p=0.03).

Moreover, the relationships between TL, FL and SL of *E. vacha* including 350 specimens along with the estimated parameters of the LLRs and the coefficient of determination (r^2) are presented in Table 4. All LLRs were highly significant (p<0.001) and most of the coefficients of determination values being >0.997.

The different condition factors including allometric, Fulton's, relative and relative weight of *E. vacha* in the Jamuna River are shown in Table 5. All condition factors of this catfish in the Jamuna River passed normality (Kolmogorov-Smirnov test; p>0.10). Minimum and maximum K_A values for males were 0.003 and 0.009, respectively, with a mean value 0.006±0.001. The K_F ranged from 0.38 to 0.96 for males and 0.33 to 0.94 for females, with mean values calculated as 0.62±0.11 and 0.63±0.11 for males and females, respectively. The unpaired t-test showed that K_F had no significant difference

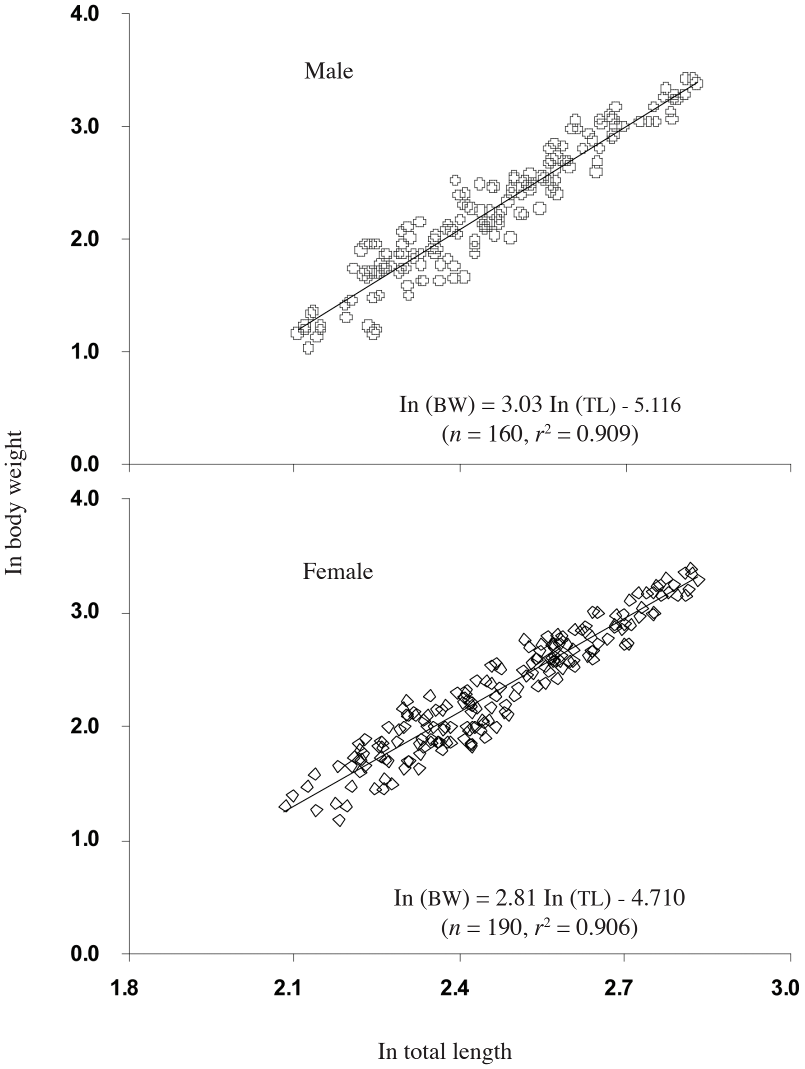

FIGURE 2. Length-weight relationships (*ln W = ln a + b ln L*) of the *Eutropiichthys vacha* (Hamilton 1822) in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh

TABLE 3. Descriptive statistics and estimated parameters of the length-weight relationships of the *Eutropiichthys vacha* (Hamilton 1822) from the Jamuna (Brahmaputra River distributary) River, northern Bangladesh

Equation	*a*	*b*	$CL_{95\%}$ of a	$CL_{95\%}$ of b	r^2	t_s	GT
Male, *n*=60							
$BW = a \times TL^b$	0.006	3.03	0.004 to 0.008	2.88 to 3.18	0.909	0.396	I
$BW = a \times FL^b$	0.010	2.93	0.015 to 0.028	2.78 to 3.08	0.904	-0.907	-A
$BW = a \times SL^b$	0.020	2.75	0.015 to 0.028	2.61 to 2.89	0.905	-3.585	-A
Female, *n*=190							
$BW = a \times TL^b$	0.009	2.81	0.007 to 0.014	2.68 to 2.94	0.906	-2.779	-A
$BW = a \times FL^b$	0.016	2.72	0.012 to 0.022	2.59 to 2.85	0.900	-4.182	-A
$BW = a \times SL^b$	0.031	2.56	0.023 to 0.042	2.44 to 2.68	0.899	-7.016	-A
Combined, *n*=350							
$BW = a \times TL^b$	0.007	2.92	0.006 to 0.010	2.82 to 3.02	0.914	-1.625	I
$BW = a \times FL^b$	0.013	2.82	0.010 to 0.016	2.73 to 2.92	0.901	-3.519	-A
$BW = a \times SL^b$	0.025	2.65	0.021 to 0.31	2.56 to 2.74	0.901	-7.468	-A

n, sample size; *BW*, body weight; *TL*, total length; *FL*, fork length; *SL*, standard length; *a*, intercept; *b*, slope ; CL, confidence limits; r^2, coefficient of determination; GT, growth type (I, isometric growth and 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*)

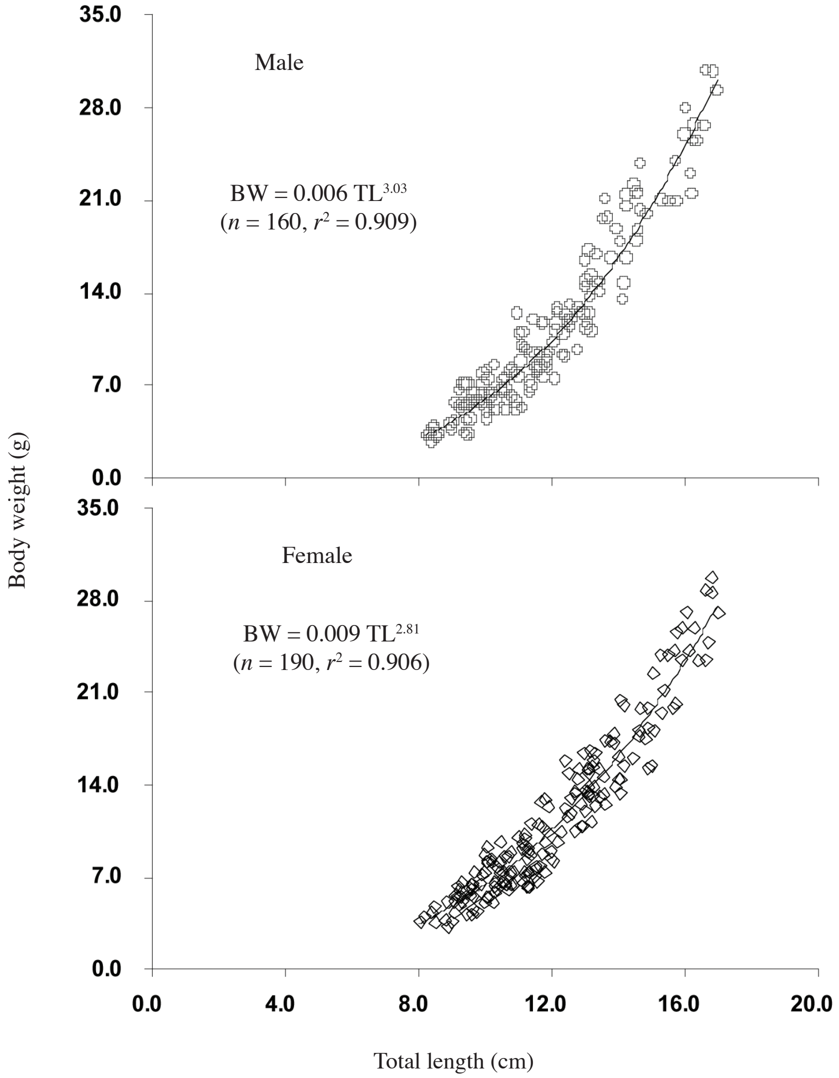

FIGURE 3. Length-weight relationships ($W = a \times L^b$) of the *Eutropiichthys vacha* (Hamilton 1822) in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh

TABLE 4. Descriptive statistics and estimated parameters of the length-length relationships ($y = a + b \times x$) of the *Eutropiichthys vacha* (Hamilton 1822) in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh

Sex	*n*	Equation	*a*	*b*	95% CL of *a*	95% CL of *b*	r^2
Male	160	SL = *a* + *b* × TL	- 0.950	0.89	- 0.975 to - 0.924	0.89 – 0.89	0.999
		SL = *a* + *b* × FL	- 0.626	0.96	- 0.653 to - 0.560	0.96 – 0.96	0.998
		TL = *a* + *b* × FL	0.365	1.08	0.332 to 0.398	1.08 – 1.08	0.998
Female	190	SL = *a* + *b* × TL	- 0.918	0.89	- 0.945 to - 0.890	0.89 – 0.89	0.999
		SL = *a* + *b* × FL	- 0.601	0.96	- 0.625 to - 0.577	0.96 – 0.96	0.999
		TL = *a* + *b* × FL	0.359	1.08	0.330 to 0.387	1.08 – 1.08	0.997
Combined	350	SL = *a* + *b* × TL	- 0.933	0.89	- 0.952 to - 0.914	0.89 – 0.89	0.999
		SL = *a* + *b* × FL	- 0.613	0.96	-0.631 to -0.595	0.96 – 0.95	0.999
		TL = *a* + *b* × FL	0.362	1.08	0.340 to 0.383	1.08 – 1.08	0.997

n, sample size; *a*, intercept; *b*, slope ; TL, total length; FL, fork length; SL, standard length; CL, confidence limit and r^2, coefficient of determination between males and females (p=0.64) during the study. In addition, K_R ranged from 0.59 to 1.48 for males and 0.54 to 1.16 for females. According to the method by Froese (2006), K_R showed significant variations between sexes (ANCOVA, F=65.11, p<0.001) (Figure 4). Furthermore, the mean W_R showed significantly differences from 100 for males (p=0.03) and females (p<0.001) in this study, indicating the habitat was not in good condition for *E. Vacha*. Moreover, Spearman rank test revealed that K_R was not strongly correlated with TL for males (r_s=0.03, p=0.95) and females (r_s= -0.13, p=0.74).

The calculated form factor ($a_{3.0}$) was 0.0066, 0.0050 and 0.0054 for male, female and combined sexes of *E. vacha*, respectively, in the Jamuna River (Table 6).

DISCUSSION

Information on biometrics of the critically endangered fishes, particularly *E. vacha* from Bangladesh has been quite insufficient (Hossain et al. 2009b, 2012a, 2012b). Nevertheless, a number of studies have been conducted on different species within the Asian countries (Gupta et al. 2011; Muchlisin et al. 2010; Naeem et al. 2010, 2011; Patiyal et al. 2010; Sani et al. 2010; Sarkar et al. 2009; Yousaf et al. 2009). In this study, a number of specimen with small to large body sizes were sampled using traditional fishing gears, however it was not possible to catch *E. vacha* smaller than 8.00 cm TL during the sampling period, which was attributed to either the absence

TABLE 5. Condition factors of the *Eutropiichthys vacha* (Hamilton 1822) in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh

Condition factor	n	Min	Max	Mean ± SD	$CL_{95\%}$
Male	160				
K_F		0.38	0.96	0.62±0.11	0.60 – 0.63
K_R		0.59	1.48	0.95±0.17	0.93 – 0.98
K_A		0.003	0.009	0.006±0.001	0.005 – 0.007
W_R		59.35	148.08	95.34±17.29	92.64 – 98.04
Female	190				
K_F		0.33	0.94	0.63±0.11	0.61 – 0.64
K_R		0.54	1.16	1.11±0.18	1.08 – 1.13
K_A		0.005	0.014	0.010±0.001	0.009 – 0.01
W_R		54.37	161.08	110.61±18.14	108.02 – 113.21
Combined sex	350				
K_F		0.33	0.96	0.62±0.11	0.61 – 0.63
K_R		0.56	1.67	1.09±0.19	1.07 – 1.11
K_A		0.004	0.012	0.008±0.001	0.007 – 0.009
W_R		56.18	167.10	109.12±18.89	107.14 – 111.11

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 and W_R, relative weight

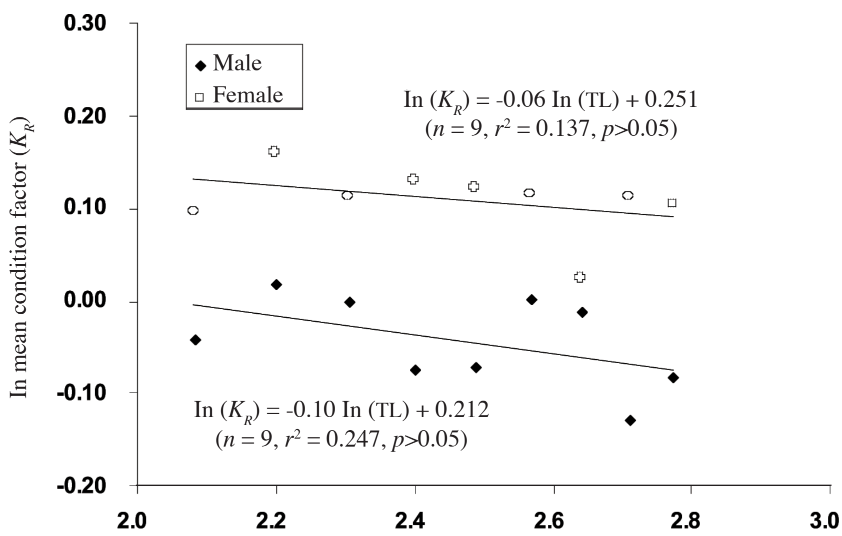

FIGURE 4. ln-ln plot of mean relative condition factor (K_R) in respective total length for male (rectangle) and female (open circle) of the *Eutropiichthys vacha* (Hamilton 1822) in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh

TABLE 6. The calculated form factor, $a_{3.0} = 10^{\log a - s(b-3)}$ for the *Eutropiichthys vacha* (Hamilton 1822) of different habitats using available length-weight relationship (LWR) parameters in the worldwide

Location	Sex	n	Length (cm)			a	b	r^2	Reference	Calculated form factor ($a_{3.0}$)
			Type	Min	Max					
Indus River, Pakistan	M	270	TL	12.30	31.50	0.0039	3.16	0.955	Soomro et al. (2007)	0.0064
	F	270	TL	13.90	34.00	0.0072	2.96	0.976		0.0063
	C	540	TL	12.30	21.50	0.0054	3.05	0.964		0.0064
Gomti River, India	C	23	TL	8.40	21.50	0.0138	2.73	0.970	Sani et al. (2010)	0.0059
Jamuna River, Bangladesh	M	160	TL	8.22	16.94	0.0060	3.03	0.905	Present study	0.0066
	F	190	TL	8.01	16.95	0.0090	2.81	0.901		0.0055
	C	350	TL	8.01	16.95	0.0070	2.92	0.914		0.0054

n, sample size; Min, minimum, Max, maximum; a, intercept; b, slope; s=-1.358 according to Froese (2006); r^2, coefficient of determination; M, male; F, female; C, combined sexes and TL, total length of small sized fishes (<8.00 cm TL) in the populations or the selection of the fishing gears (Hossain et al. 2012d). The maximum size of *E. vacha* observed in this study within the Jamuna River was 16.95 cm TL. The size is far less than the half of the maximum recorded value of 34.00 cm TL in the Indus River at Sindh, Pakistan (Soomro et al. 2007). In Uttar Pradesh, India, Sani et al. (2010) reported the maximum TL for *E. vacha* as 21.50 cm from the Gomti River (Ganges River tributary). In a recent study from the Ganges River, Bangladesh, Hossain et al (2009b) recorded the maximum TL for this catfish as 25.80 cm. Nevertheless, Hora (1941) reported that the maximum length (SL) of *E. vacha* as 40.2 cm based on a specimen collected from the Salween River (known as the Nu in Chinese) system. However, Ferraris and Vari (2007) indicated that *E. vacha* is limited to the region of southern Asia from eastern Pakistan through Bangladesh and some, or all of the reports of *E. vacha* from the Salween River might be based on *E. salweenensis* or *E. burmannicus*. The decrease in the maximum sizes of individuals of *E. vacha* landed within the Jamuna River system signaling the need for urgent measures to conduct extensive studies on these species to provide more information for their management and conservation.

The regression parameter b of LWRs for males was larger than that of females, which indicates that male fish increase in body weight at a more rapid rate than females. The similar results have been reported for the same species from the Indus River, Sindh, Pakistan (Soomro et al. 2007), where males obtained greater b value than females. The LWRs was significantly difference between females and males in this study (p<0.05). Such variations in the same habitat may be attributed to differences in the physiology of the animals (Le Cren 1951), gonadal development (Hossain et al. 2006b), feeding rate (Tarkan et al. 2006) and behavior (Muchlisin et al. 2010). In addition, Mbaru et al. (2010) reported that the LWRs regression parameters, particularly a, may vary daily, seasonally, and/or between habitats, unlike the parameter b, which does not vary significantly throughout the year. Since samples of each species included individuals collected over several seasons, the parameters a and b would be treated as mean annual values. However, the values of a and b for *E. vacha* in this study were within the limits reported by Hossain et al. (2006a, 2009b) and Froese (2006), although these parameters varied significantly between the sexes. The LWRs 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 the respective size range such LWRs should be used only within these size ranges (with caution for sample-size inadequacy). Because data were collected for *E. vacha* over an extended period of time and data were not representative of any particular season, so it should be treated only as mean-annual values for comparative purposes. Thus, body weights of *E. vacha* across sizes can be estimated from the present LWRs, including asymptotic weights (W_∞) for males and females of any river catfish population based on the asymptotic total length (L_∞).

Due to the lack of references dealing with LWRs and LLRs for this species from Jamuna River, it was not possible to compare the present results with early literature on the same population. However, the LWR parameters obtained in the present work may be compared with those of earlier researchers (Table 6) from different populations; Soomro et al. (2007) in the Indus River, Sindh, Pakistan; Hossain et al. (2009b) in the Ganges River, Bangladesh; Hossain (2010a) in the Padma River (main tributary of the Ganges River) and Sani et al. (2010) in the Gomti River, India. In the Indus River, Sindh, Pakistan, Soomro et al. (2007) estimated the positive allometric growth in males (b=3.159), negative allometric growth in females (b=2.958) and isometric growth in combined sexes (b=3.053) of *E. vacha*, although they did not include the 95% confidence intervals in their studies. Hossain at al. (2009c) and Hossain (2010a) recorded negative allometric growth in *E. vacha* from the Padma (lower Ganges River) River, Bangladesh. Similarly, Sani et al. (2010) reported the negative allometric growth for this fish from the Gomti River (Ganges River tributary), India, which is in accordance with the present study. Nevertheless, the length range of the specimens and sampling period of these studies were not similar to the present study. In this study, sex-specific differences were observed, namely a higher slope for males than females that is consistent with the study by Soomro et al. (2007) on the same species. However, the differences in b values can be attributed to the combination of one or more 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 (Hossain 2010a), which were not accounted in this study.

All LLRs were highly correlated and they were compared with the available literature. In Soomro et al. (2007) study, the LLRs of *E. vacha* were reported as TL = 0.923 SL + 1.017 (r^2=0.971), SL = 1.036 FL + 0.934 (r^2=0.986) and FL = 1.012 TL + 0.940 (r^2=0.977) for combined sexes from the Indus River, Pakistan. Furthermore, Hossain et al. (2009b) recorded the LLRs as TL =1.212 SL + 0.185 (r^2= 0.995), FL =0.899 TL + 0.249 (r^2=0.994) and SL = 0.918 FL + 0.023 (r^2=0.995) for *E. vacha* from the Ganges River, Bangladesh. These results were different from the present study and such differences may be attributed to the differences in ecological conditions of the habits or variation in the physiology of animals or both (Le Cren 1951). Nevertheless, the length ranges and the sampling period were not similar to the present study.

Several condition factors including: Fulton's (Fulton 1904), Relative (Le Cren 1951); Allometric (Tesch 1968) and Relative weight (Froese 2006) were used to assess the overall health and productivity of *E. vacha* in this study. Among these factors, Froese (2006) recommended the relative condition factor for the health status comparison between males and females within the same sample or same population. However, no comparison across populations is allowed unless they have equivalent underlying length-weight relationship. In addition, the Fulton's condition might be applicable because it is free from parameters *a* and *b* of the LWRs. The K_F values between the sexes were not significantly different in this study, likely indicating the absence of mature females. This might be attributed to either the absence of mature females in the sampling site or the selection of the fishing gears. In contrast, the mean relative-condition factor showed significant differences between sexes in this study based on the methodology described by Froese (2006) (Figure 4). No references dealing with the condition factors on the river catfish are available in the Jamuna River (Hossain 2010a), preventing the comparison with previous results. But, the condition factors recorded on the same species from the Padma River might be compared with the population of Jamuna River. Hossain (2010a) recorded the mean Fulton's and relative condition factors as 0.671±0.071 (range: 0.537-0.864) and 1.002±0.106 (range: 0.818-1.293), respectively, from the Padma River, northwestern Bangladesh. The condition factor based on the LWR is an indicator of the changes in food reserves and the general fish condition. In general, the seasonal cycle in the condition of the fishes suggested a relationship with gonadal development. According to Hossain et al. (2006b), the condition factor of *Mystus vittatus* (Bloch 1794) (Siluriformes: Bagridae) was constant during the pre-spawning period, decreased in the period of spawning and was lowest immediately after spawning. However, only the seasonal data were used during this study, thus it is difficult to compare among the condition of fishes throughout the year.

Based on Froese (2006), the most popular index (relative weight, W_R) was used to focus the present status of this river catfish in Jamuna River. The values of W_R falling below 100 for an individual, size group or population suggest problems such as low prey availability or high predator density; whereas values above 100 indicates a prey surplus or low predator density (Rypel & Richter 2008). Recently, a number of studies have promoted the use of W_R for assisting in the management and conservation of nongame fishes, particularly those that are threatened or endangered (Muchlisin et al. 2010; Richter 2007). However, to the best of the authors' knowledge, the present paper conducts the first comprehensive description of W_R for the sub-tropical freshwater fishes of Bangladesh (except Hossain et al. 2012c; Rahman et al. 2012). The mean relative weight (W_R) value was significantly different from 100 for males, females and combined sexes in this study, indicating an imbalance habitat with food availability relative to the presence of predators (Anderson & Neumann 1996) for *E. vacha* in the Jamuna River. In addition, it might be indicated that the water quality of Jamuna River is not enough for *E. vacha* fishery. However, according to IUCN Bangladesh (2000), the populations in Bangladesh have been seriously declined due to various ecological changes in its natural habitats. Additionally, in a recent study, Mishra et al. (2009) reported that populations of this catfish have been declined or on the verge of extinction due to over exploitation. The results of this study provide the much needed information and are important to allow for urgent detection of any long-term declines in condition that may have occurred. Such changes may be attributed to environmental degradation because the relative condition integrates key physiological components of fish life history such as lipid storage and growth. Moreover, the relative weight is a strong, handy metric that can be used to evaluate the overall health and fitness as well as population-level responses to ecosystem disturbance (Rypel & Richter 2008).

According to Froese (2006), 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. In this study, the estimated values of $a_{3.0}$ were as 0.006, 0.0050 and 0.0054 for males, females and combined sexes (Table 6) suggesting that *E. vacha* can be classified as relatively elongate which is characteristic of many riverine fishes. The $a_{3.0}$ of *E. vacha* from three different habitats including Indus River, Pakistan and Gomti River, India (Table 6) were within the limits 0.00775 to 0.00906 reported by Froese (2006) and Treer et al. (2009). No references dealing with the $a_{3.0}$ are available in the literature for tropical or sub-tropical freshwater species and the present results provide an important basis for future comparisons.

CONCLUSIONS

This study provides an important baseline study on the LWRs, LLRs, condition- and form-factors of the critically endangered catfish *E. vacha* from Bangladesh. The results of the study would be an effective tool for fishery biologists, managers and conservationists to initiate early management strategies and regulations for the sustainable conservation of the remaining stocks of this species in the Brahmaputra River ecosystem. Moreover, information on LWRs, LLRs, condition factors and form factor for *E. vacha* are clearly lacking from literature and data bases including FishBase. Therefore, the results of this study provide invaluable information for the online FishBase database, as well as providing an important baseline for future studies within the Brahmaputra River and surrounding ecosystems.

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