Sains Malaysiana 42(9)(2013): 1207–1218

Life-history Traits of the Freshwater Garfish *Xenentodon cancila* (Hamilton 1822) (Belonidae) in the Ganges River, Northwestern Bangladesh

(Ciri Sejarah Hidup Ikan Todak Air Tawar *Xenentodon cancila* (Hamilton 1822) (Belonidae) di Sungai Ganges, Barat Laut Bangladesh)

MD. YEAMIN HOSSAIN*, MD. ABU SAYED JEWEL, MD. MOSADDEQUR RAHMAN, A.B.M. MOHIDUL HAQUE, HEBA ALLAH M. ELBAGHDADY & JUN OHTOMI

ABSTRACT

The freshwater garfish, Xenentodon cancila *(Hamilton 1822), is one of the commercially important, nutritionally valuable food fish in Asian countries, but the natural populations are seriously decreasing due to high fishing pressure and other factors. This study describes the life history traits, including sex ratio (SR), length-frequency distributions (LFDs), 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* X. cancila *in the Ganges (Padma) River, northwestern Bangladesh. A total of 175 specimens ranging from 10.50-21.00 cm TL (total length) and 1.44-20.67 g BW (body weight) were investigated in this study. Sampling was done using traditional fishing gears from April 2011 to March 2012. The overall sex ratio showed no significant differences from the expected value of 1:1 (df = 1,* $\chi^2 = 0.28$*,* $p<0.05$*), whereas significant difference was found in the LFD (TL) between the sexes (Two tailed,* $p<0.001$*). The allometric coefficient* b *for the LWR indicated positive allometric growth in males, females and combined sexes. The results further indicated that the LLRs were highly correlated. Both* K_R *and* K_F *showed significant variations (Two tailed,* $p<0.001$*) between male and female. 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* X. cancila*. The calculated values of* $a_{3.0}$ *were as 0.0304, 0.0268 and 0.0252 for males, females and combined sexes of* X. cancila*. This study reports the first complete and comprehensive description of life-history traits for* X. cancila *from Bangladeshi waters. The data should be useful for the sustainable conservation of this critically endangered fishery in Bangladesh and neighboring countries.*

Keywords: Bangladesh; Ganges River; Garfish; life-history; Xenentodon cancila

ABSTRAK

Ikan todak air tawar, Xenentodon cancila *(Hamilton 1822), ikan yang penting daripada segi komersial, makanan berkhasiat yang bermutu di negara-negara Asia sedang mengalami masalah penurunan jumlah yang serius akibat daripada tekanan tangkapan yang tinggi dan faktor-faktor lain. Kajian ini menerangkan ciri-ciri sejarah hidup, termasuk nisbah jantina (SR), taburan panjang frekuensi (LFDs), hubungan panjang-berat (LWRs), hubungan panjang-panjang (LLRs), faktor keadaan ('alometrik',* K_A*; Fulton s,* K_F*; keadaan relatif,* K_R*, berat relatif,* W_R*) dan faktor bentuk (*$a_{3.0}$*)* X. cancila *di Sungai Ganges (Padma), barat laut Bangladesh. Sejumlah 175 spesimen yang mempunyai TL (jumlah panjang) 10,50-21,00 cm dan BW (berat badan) 1,44-20,67 g telah dikaji. Persampelan telah dilakukan dengan menggunakan peralatan menangkap ikan tradisi pada bulan April 2011 hingga Mac 2012. Nisbah jantina keseluruhan menunjukkan tiada perbezaan yang ketara daripada nilai yang dijangka 1:1 (df = 1,* $\chi^2 = 0.28$*,* $p<0.05$*), manakala perbezaan yang ketara ditemui dalam LFD (TL) antara jantina (dua ekor,* $p<0.001$*). Pekali alometrik b untuk LWR menunjukkan pertumbuhan alometrik positif dalam sampel jantan, betina dan jantina gabungan. Hasil kajian juga menunjukkan bahawa LLRs mempunyai hubungan yang sangat bererti. Kedua-dua* K_R *dan* K_F *menunjukkan perbezaan yang ketara (dua ekor,* $p<0.001$*) antara jantan dan betina. Selain itu,* W_R *mempunyai perbezaan yang ketara daripada 100 untuk kedua-dua jantina (*$p<0.01$*), menunjukkan ketidakseimbangan habitat dengan adanya makanan berbanding dengan kehadiran pemangsa untuk* X. cancila*. Nilai bagi hasil pengiraan* $a_{3.0}$ *adalah masing-masing 0,0304, 0,0268 dan 0,0252 untuk jantan, betina dan jantina gabungan* X. cancila*. Kajian ini buat pertama kali melaporkan penjelasan yang lengkap dan komprehensif ciri-ciri hidup sejarah bagi* X. cancila *di perairan Bangladesh. Data ini seharusnya berguna untuk pemuliharaan mapan perikanan yang amat terancam di Bangladesh dan negara-negara jiran.*

Kata kunci: Bangladesh; Ikan Todak; sejarah hidup; Sungai Ganga; Xenentodon cancila

INTRODUCTION

Xenentodon cancila (Hamilton 1822) (Beloniformes: Belonidae) is a marine, freshwater and brackish-water species commonly known as 'freshwater garfish'. Freshwater garfish is native in Bangladesh, Bhutan, Cambodia, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand and Viet Nam and Introduced in Hawaii (Froese & Pauly 2012). It is commonly known as *Kaikka* (Rahman 1989), *Kakila* '*Gar'* (Al-Mamun 2003) and *Kankely* (Nath & Dey 1989) in Bangladesh, '*Phtong'* in Cambodia (Poeu & Dubeau 2004), *Sydasiatisk halvgedde* in Denmark (Carl 2003), *Intiannokkakala* in Finland (Varjo et al. 2004), *Silver needlefish* and *Stickfish* in Hawaii, USA (Yamamoto & Tagawa 2000), *Kokila* in India (Nath & Dey 1989), *Pla katung heow mueng* in Thailand (Chuenpagdee 2002), *Freshwater jarfish* in United Kingdom (FAO-FIES 2010), *Cánhói* in Viet Nam (Nghia 2005). Freshwater garfish inhabits large and medium-sized rivers with adults occurring in areas that lack floating vegetation (Pethiyagoda 1991). *X. cancila* occurs primarily in rivers (Talwar & Jhingran 1991) but also found in ponds, canals, *beels* and inundated fields (Rahman 1989) and often found in slow-flowing pools in rivers with a rock or sand substrate (Pethiyagoda 1991). However, *X. cancila* occurs in clear, gravelly, perennial streams and ponds of Terai and Duars, North Bengal, India and is fairly common in the Ganges-Brahmaputra system (Talwar & Jhingran 1991). It is a solitary fish that swims in midwater, usually against the current and is capable of bursts of speed, especially when in pursuit of its prey. The freshwater garfish feeds exclusively on crustaceans, small fishes and insects in the wild; but takes live fish only when in an aquarium (Pethiyagoda 1991; Rainboth 1996). Moreover, *X. cancila* is oviparous and eggs may be found attached to objects in the water by tendrils on the egg's surface (Breder & Rosen 1966).

According to Vazzoler (1996), sex ratio and size structure constitute basic information in estimating stock size of fish populations. 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. 2012a).

In addition, length-weight relationships (LWRs) are useful in fishery management for both applied and basic uses (Pitcher & Hart 1982) to convert length distributions into weights for biomass estimates (Gerritsen & McGrath 2007). Moreover, the LWRs are needed to estimate weights from lengths because direct weight measurements can be time consuming in the field (Koutrakis & Tsikliras 2003) and its parameters are important in fish biology and can give information on stocks or organism condition at the corporal level (Ecoutin et al. 2005; Gonzalez Acosta et al. 2004). Furthermore, length-length relationships (LLRs) are generally more relevant than age, particularly several ecological and physiological factors are more length-dependent than age-dependent (Hossain et al. 2006a).

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). Moreover, 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 *X. cancila* including SEM studies on *Bucephalopsis karvei* Bhalerao, 1937, an intestinal parasite of the fish, *X. cancila* (Pandey & Tewary 1984), length-weight relationship (Chandrika & Balasubramonian 1986), reproduction (Yamamoto & Tagawa 2000) and study on *Trichodina cancilae* sp. n. (Mobilina: Trichodinidae) from the gills of a freshwater gar, *X. cancila* (Asmat 2001). However, the LWRs are still scarce for most sub-tropical fish species (Hossain et al. 2006(a), 2006(b)). To the best of the authors' knowledge, there is no previous information on life-history traits including the LWRs, LLRs, condition- and form factors of *X. cancila* from the Ganges River. Detailed knowledge on the population structure of *X. cancila* is needed immediately for proper management and initiate conservation measures for this important fish of the Ganges River. Therefore the present study aimed to focus on the sex ration; length-frequency distributions (LFDs); length-weight (LWRs) and length-length relationships (LLRs); Fulton's, relative, allometric condition factors; relative weight (W_R) and form factor ($a_{3.0}$) of *X. cancila* using a number of specimens with various body sizes from the Ganges River, NW Bangladesh.

MATERIALS AND METHODS

STUDY AREA

The present study was conducted in the lower part of the Ganges (known as Padma River in Bangladesh) River, northwestern Bangladesh, enters Bangladesh from India through the Nawabganj district (Latitude 24° 65' N; Longitude 88° 06' E). A large number of fishes including many commercially important species are fished by both small and large-scale fishermen throughout the year (Hossain et al. 2009). During the year 2007-2008, a total of 9392 metric tons of fish were captured from the Padma River which is 6.87% of the total fish captured from all the rivers in Bangladesh (FRSS 2009).

SAMPLING AND LABORATORY ANALYSES

The samples of *X. cancila* were collected during daytime on a seasonal basis from different fisherman catch landed at Jahajghat, Rajshahi to Godagari, Rajshahi (Padma River: 24°46'N; 88°32'E) during from 2011 to March 2012. *X. cancila* were caught by the traditional fishing gears including *jhaki jal* (cast net), *tar jal* (square lift net) and *dughair* (conical trap). Samples were immediately preserved with ice in the fish landed area and fixed with 5% formalin on arrival in the laboratory, University of Rajshahi, Bangladesh. For each individual, total length (TL), standard length (SL) and head length (HL) were measured to the nearest 0.01 cm using digital slide calipers and whole body weight (BW) was taken on a digital balance with 0.01 g accuracy.

LENGTH-WEIGHT AND LENGTH-LENGTH RELATIONSHIPS

The weight-length relationship was calculated using the expression: $W = aL^b$, where the W is the body weight (g) and L is the total length (cm). Parameters a and b were estimated by linear regression analysis based on natural logarithms: $\ln(W) = \ln(a) + b\ln(L)$. Additionally, 95% confidence limits of b and the coefficient of determination r^2 were estimated. In order to confirm whether b values obtained in the linear regressions were significantly different from the isometric value ($b = 3$), a t-test was applied, expressed by the equation according to Sokal and Rohlf (1987): $t_s = (b\text{-}3) / s_b$, where t_s is the t-test value, b the slope and s_b the standard error of the slope (b). The comparison between obtained values of t-test and the respective tabled critical values allowed for the determination of the b values statistically significant and their inclusion in the isometric range ($b = 3$) or allometric range (negative allometric; b < 3 or positive allometric; b > 3). Furthermore, LLRs including TL vs. SL; TL vs. HL and HL vs. SL relationships were estimated by linear regression (Hossain et al. 2006(a)).

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 LWR parameter.

RELATIVE WEIGHT

The 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 (TL vs. BW) and S is the regression slope of $\ln a$ vs b. During the study, a mean slope S = -1.358 (Froese 2006) was used for estimating the form factor because 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 and GraphPad Prism 5 software. 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 not met, the Spearman rank test was used to correlate body measurements (TL, BW) and condition factors (K_F, K_R, K_A). A chi-square (χ^2) test was applied to check the differences from the expected value of 1:1 for male and female. Also the Unpaired t-test with Welch's corrections was used to compare the LFDs between males and females in case of normal distribution. However, the non-parametric, Mann-Whitney U-test was used to compare the median value between the sexes. Moreover, the regression parameters of the LWR and LLR between sexes were compared by the analysis of covariance (ANCOVA). All statistical analyses were considered significant at 5% (p<0.05).

RESULTS

SEX RATIO

From the 175 specimens (male = 84; female = 91) of *X. cancila* collected at the Ganges River during this study, 48% were males and 52% were females (male: female = 1: 1.08), so the overall sex ratio did not differ statistically from the expected value of 1:1 (df = 1, χ^2 = 0.28, p< 0.05). The total length dependent sex ratio showed that males outnumber females in the lower length classes (10.00 cm to 13.99 cm) while females are dominant in the higher length classes (14 cm to 21.99 cm) (Table 1).

LENGTH-FREQUENCY DISTRIBUTIONS

A total of 175 (male = 84; female = 91) specimens *X. cancila* were collected from the Ganges River, northwestern Bangladesh during the study. The sample size, minimum and maximum length and body weight, standard deviation (SD), 95% confidence limit (CL) for male, female and combined sex are presented in Table 2 and Figures 1 & 2. The total length of male *X. cancila* ranged from 10.50 cm to 18.90 cm, while body weight ranged from 1.44 g to 16.72 g. In case of female, the total length (TL) ranged from 11.00 cm to 21.00 cm and body weight varied from 2.30 g to 20.67 g. However, the TL frequency distribution for males (KS distance = 0.08) and females (KS distance = 0.05) passed the normality (Kolmogorov-Smirnov test, p>0.05). The Unpaired t-test with Welch's corrections (df

TABLE 1. The sex ratio (male: female = 1:1) of the total length dependent for *Xenentodon cancila* in the Ganges (Padma) River, northwestern Bangladesh

Length class (TL, cm)	Number of specimens			Sex ratio	χ^2	Significance
	Male	Female	Total	(Male/ Female)	(df=1)	
10.00 – 10.99	2	0	2	-	2.00	Ns
11.00 – 11.99	8	1	9	1 : 0.13	5.44	*
12.00 – 12.99	11	6	17	1 : 0.55	1.47	Ns
13.00 – 13.99	12	6	18	1 : 0.50	2.00	Ns
14.00 – 14.99	12	10	22	1 : 0.83	0.18	Ns
15.00 – 15.99	19	15	34	1 : 0.79	0.47	Ns
16.00 – 16.99	11	19	30	1 : 1.73	2.13	Ns
17.00 – 17.99	7	12	19	1 : 1.71	1.32	Ns
18.00 – 18.99	2	10	12	1 : 5.00	5.33	*
19.00 – 20.99	0	7	7	-	7.00	**
20.00 – 20.99	0	4	4	-	4.00	*
21.00 – 21.99	0	1	1	-	1.00	Ns

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

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

Measurements	*n*	Min	Max	Mean ± SD	$CL_{95\%}$
Male	84				
TL		10.50	18.90	14.47 ± 1.90	14.05 – 14.88
SL		9.80	17.60	13.50 ± 1.78	13.11 – 13.89
HL		3.80	6.60	5.23 ± 0.64	5.09 – 5.37
BW		1.44	16.72	5.52 ± 2.83	4.91 – 6.14
Female	91				
TL		11.00	21.00	16.31 ± 2.15	15.87 – 16.76
SL		10.10	19.70	15.25 ± 2.03	14.83 – 15.68
HL		3.99	7.40	5.84 ± 0.70	5.69 – 5.98
BW		2.30	20.67	8.82 ± 4.15	7.95 – 9.68
Combined sex	175				
TL		10.50	21.00	15.43 ± 2.23	15.10 – 15.76
SL		9.80	19.70	14.40 ± 2.11	14.09 – 14.71
HL		2.30	8.90	5.53 ± 0.83	5.41 – 5.65
BW		1.44	20.67	7.31 ± 4.03	6.71 – 7.91

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; HL, head length

= 172, t = 6.03) showed significant differences in the TL-frequency distributions between males and females (Two tailed, p<0.001). Furthermore, the results showed that BW of females was significantly higher (Mann-Whitney *U*-test, Two tailed, p<0.001) than that for males.

LENGTH-WEIGHT AND LENGTH-LENGTH RELATIONSHIPS

Values of regression parameter *b* for male and female *X. cancila* were 3.868 and 3.695, respectively. The calculated *b* values for the LWR indicated positive allometric growth (> 3.00) in males and females (> 3.00) and there was no significant differences in the intercepts (F = 1.051, df = 172, p = 0.307) and slopes (F = 1.119, df = 171, p = 0.292) between the sexes of *X. cancila* in the Ganges River. The regression models showed that there were significant differences between observation and prediction growth patterns in both sexes (ANCOVA, p<0.05). The sample size (*n*), regression parameters *a* and *b* of the LWR, 95% confidence intervals of *a* and *b*, the coefficient of determination (r^2) and growth type of *X. cancila* are given in Table 3 and Figures 3 to 8.

All the length-length relationships including TL vs. SL, SL vs. HL and TL vs. HL for male, female and combined

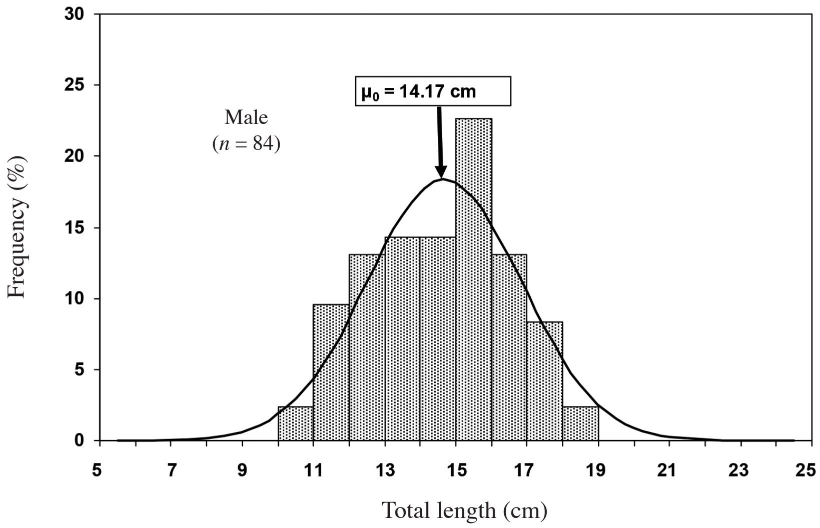

FIGURE 1. The length-frequency distribution of the male *Xenentodon cancila* in the Ganges River, northwestern Bangladesh. Here, μ_0 indicates the mean value

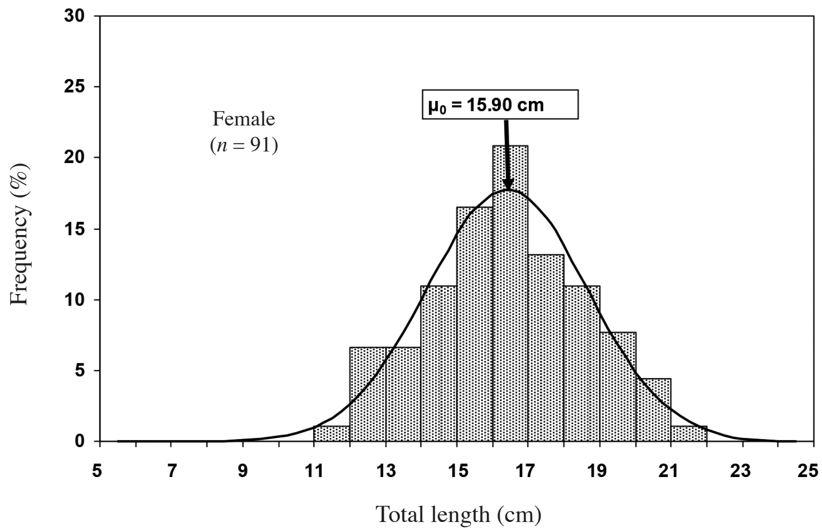

FIGURE 2. The length-frequency distribution of the female *Xenentodon cancila* in the Ganges River, northwestern Bangladesh. Here, μ_0 indicates the mean value

sexes of *X. cancila* are highly correlated. The LLRs are as follows:

For Males

TL = 1.062 (SL) + 0.1319, r^2 = 0.995, *n* = 84
HL = 0.328 (TL) + 0.4930, r^2 = 0.945, *n* = 84
SL = 2.710 (HL) - 0.6763, r^2 = 0.945, *n* = 84

For Females

TL = 1.058 (SL) + 0.1830, r^2 = 0.994, *n* = 91
HL = 0.316 (TL) + 0.7161, r^2 = 0.778, *n* = 91
SL = 2.781 (HL) - 0.9729, r^2 = 0.921, *n* = 91

All these LLRs between males and females revealed no significant differences for slopes and intercepts (ANCOVA, $p>0.05$) during this study.

FULTON'S CONDITION FACTOR

Fulton's condition factor of *X. cancila* ranged from 0.10 to 0.25 for both male and female (Table 4). The Spearman rank test revealed that K_F was strongly correlated with TL for males (Two tailed, r_s = 0.643, $p<0.001$) and females (Two tailed, r_s = 0.455, $p<0.001$). In addition, there was also highly correlation between K_F and body weight for males (Spearman rank test, Two tailed, r_s = 0.794, $p<0.001$) and females (Spearman rank test, Two tailed, r_s = 0.633,

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

Sex	*a*	*b*	$CL_{95\%}$ of a	$CL_{95\%}$ of b	r^2	t_s	GT
Male (*n* = 84)	0.0002	3.868	0.0001 – 0.0003	3.653 – 4.083	0.940	8.04	A+
Female (*n* = 91)	0.0003	3.695	0.0002 – 0.0005	3.453 – 3.936	0.912	5.74	A+
Common gender (*n* = 175)	0.0002	3.811	0.0001 – 0.0003	3.665 – 3.957	0.938	10.87	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: $t_s = (b-3) / s_b$, where t_s is the *t*-test value, *b* the slope and s_b the standard error of the slope (*b*)

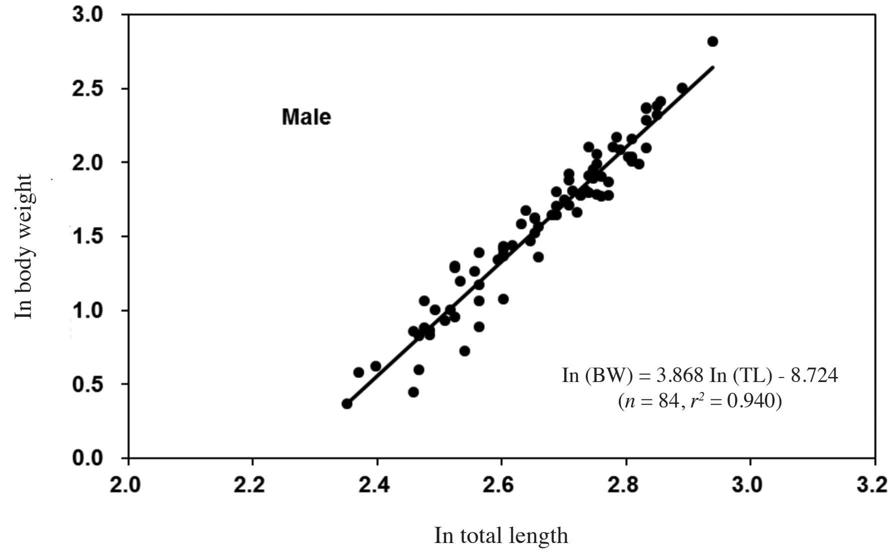

FIGURE 3. Relationships between ln total length (ln TL) and ln body weight (ln BW) of the male *Xenentodon cancila* in the Ganges River, northwestern Bangladesh

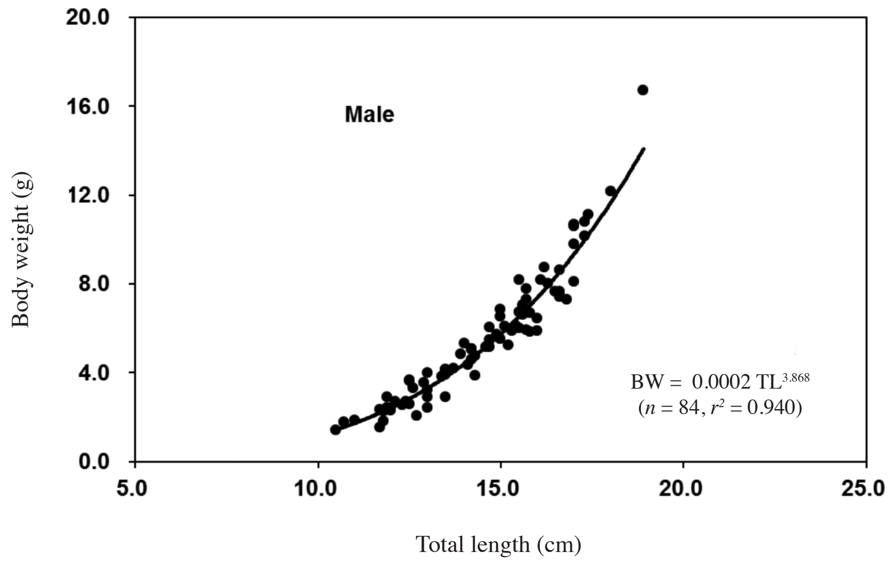

FIGURE 4. Relationships between total length (TL) and body weight (BW) of the male *Xenentodon cancila* in the Ganges River, northwestern Bangladesh

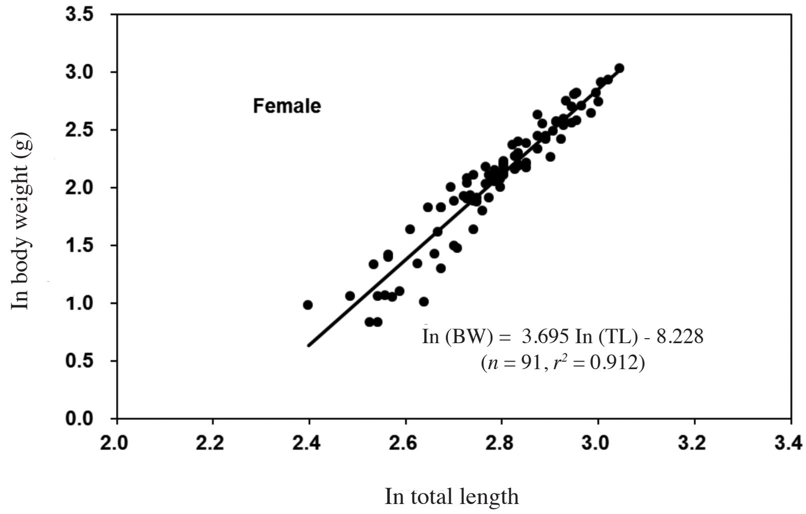

FIGURE 5. Relationships between ln total length (ln TL) and ln body weight (ln BW) of the female *Xenentodon cancila* in the Ganges River, northwestern Bangladesh

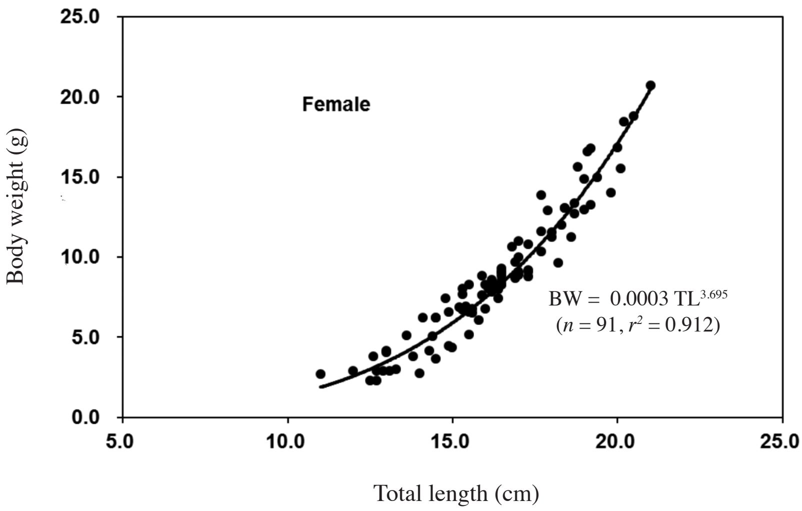

FIGURE 6. Relationships between total length (TL) and body weight (BW) of the female *Xenentodon cancila* in the Ganges River, northwestern Bangladesh

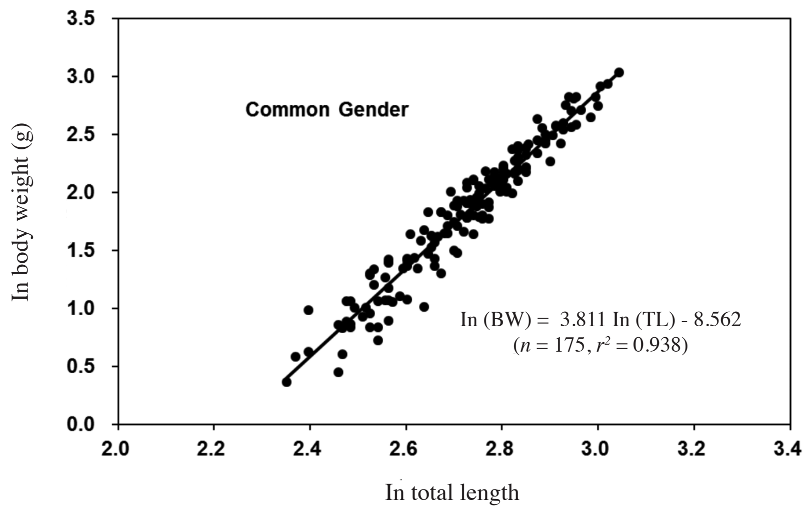

FIGURE 7. Relationships between ln total length (ln TL) and ln body weight (ln BW) of the combined gender *Xenentodon cancila* in the Ganges River, northwestern Bangladesh

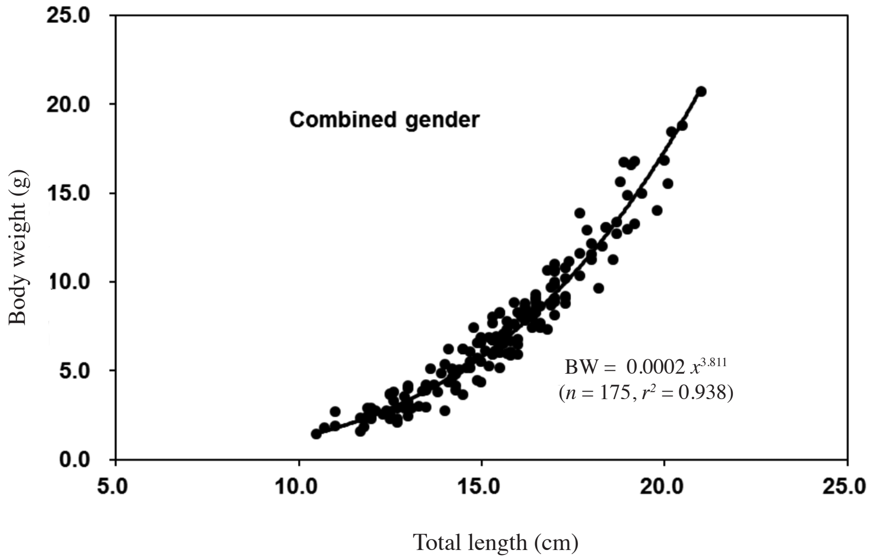

FIGURE 8. Relationships between total length (TL) and body weight (BW) of the combined gender *Xenentodon cancila* in the Ganges River, northwestern Bangladesh

p<0.001). Furthermore, the Mann-Whitney *U*-test showed significant differences in the Fulton's condition factors between males and females (Two tailed, p<0.001) of *X. cancila*.

RELATIVE CONDITION FACTOR

The relative condition factor for male and female *X. cancila* varied from 0.55 to 1.05 and 0.53 to 1.26 for male and female, respectively (Table 4). However, the Mann-Whitney *U*-test showed significantly differences in the relative condition factor between males and females (Two tailed, p<0.001).

ALLOMETRIC CONDITION FACTOR

Allometric condition factor ranges from 0.00011 to 0.00021 (Mean ± SD = 0.00016 ± 0.00002) for males and 0.00016 to 0.00038 (Mean ± SD= 0.00027±0.00004) for females, respectively (Table 4). Nonetheless, the Mann-Whitney *U*-test showed no significant differences in the relative condition factor between males and females (Two tailed, p= 0.666) of *X. cancila*.

RELATIVE WEIGHT

Relative weight (W_R) ranged from 55.38 to 104.90 for male and 53.17 to 125.85 for female *X. cancila* (Table 5). However, the W_R (actual median = 82.52) showed significantly differences from 100 for males (p= 0.029) and females (Wilcoxon rank test, Two tailed, p< 0.001) in this study, indicating the habitat was not in good condition for *X. cancila*. Furthermore, the results showed that W_R was significantly differences between males and females (Mann-Whitney *U*-test, Two tailed, p < 0.001) in the Padma River.

TABLE 4. Condition factors of the *Xenentodon cancila* (Hamilton 1822) in the Ganges (Padma) River, northwestern Bangladesh

Condition factor	*n*	Min	Max	Mean ± SD	$CL_{95\%}$
Male	84				
K_F		0.10	0.25	0.17 ± 0.03	0.16 – 0.17
K_R		0.55	1.05	0.82 ± 0.10	0.80 – 0.84
K_A		0.00011	0.00021	0.00016 ± 0.00002	0.00016 – 0.00017
Female	91				
K_F		0.10	0.25	0.19 ± 0.03	0.18 – 0.19
K_R		0.53	1.26	0.90 ± 0.13	0.87 – 0.93
K_A		0.00016	0.00038	0.00027 ± 0.00004	0.00026 – 0.00 028

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

TABLE 5. The relative weight, $W_R = (BW/ a\times TL^b)$ and form factor, $a_{3.0} = 10^{loga-S\,(b-3)}$ for the freshwater gar, *Xenentodon cancila* (Hamilton 1822) in the Ganges (Padma) River, northwestern Bangladesh

Sex	Relative weight (W_R)				$a_{3.0}$
	Min	Max	Mean ± SD	95% CL	
Male	55.38	104.90	81.92 ± 10.34	79.68-84.17	0.0304
Female	53.17	125.84	89.91 ± 13.49	87.10-92.72	0.0268

TL, total length; BW, body weight; $a_{3.0}$, form factor; S, slope = 1.358 according to Froese (2006); *a* and *b* are coefficients of LWRs (Table 3); Min, Minimum; Max, maximum; SD, standard deviation; CL, confidence limit of mean

FORM FACTOR

The calculated form factor ($a_{3.0}$) was 0.0.0304, 0.0268 and 0.0252 for male, female and combined sex of *X. cancila* in the Padma River, northwestern Bangladesh (Table 5).

DISCUSSION

Information on biological aspects of *X. cancila* from Bangladesh is quite inadequate, however, this study described the sex ration, length-frequency distributions, length-weight relationships, length-length relationships, Fulton's relative, allometric condition factors, relative weight and form factor of *X. cancila* using a number of specimens with various body sizes from the Ganges River, NW Bangladesh.

Deviation 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. 2012a). During this study, out of the 175 specimens of *X. cancila* sampled, the male-female sex ratio was 1:1.08. The overall sex ratio showed no significant differences from the expected value of 1:1. Avşar (1998) pointed out that in a typical population, female to male ratio will vary between 1:1 and 1:1.3. The values obtained in current study were within the reasonable range expected for a natural population. However, lack of adequate information on sex ratio of this species restrains the comparison with other studies.

No earlier records of length frequency distribution of this species could be traced from the related literature, inhibiting the comparison with previous result. 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 *X. cancila* smaller than 10.50 cm TL during the sampling period, which was attributed to either the absence of small sized fishes (< 10.50 cm TL) in the populations or selectivity of the fishing gears. The maximum size of *X. cancila* observed in this study within the Padma River was 21.00 cm TL which is far less than the maximum reported value of 40 cm TL (Talwar & Jhingran 1991). In Chi River, northeastern Thailand, Satrawaha and Pilasamorn (2009) recorded the maximum TL for *X. cancila* as 23.00 cm and in Vellayani freshwater lake, Trivandrum, India, Chandrika and Balasubramonian (1986) also recorded maximum TL for *X. cancila* as 23.00 cm which are all higher than that recorded in the present study. Nonetheless, Shrestha (1994) reported the maximum TL of *X. cancila* as 20 cm TL in Nepal which is lower than that recorded in the present study. However, the decline in the recorded maximum sizes of individuals of *X. cancila* in the Padma River in this study might be attributed either to the absence of larger-sized individuals in the populations in fishing grounds (Hossain et al. 2012a) and/or shrinkage in body size of the formalin-preserved specimens. In addition, numerous types of fishing gear are employed by the traditional fishers. Consequently, 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. 2012b). Nonetheless, the decrease in the maximum sizes of individuals of *X. cancila* landed within the Padma 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 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 despite 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). In the present study, *b* values were within the limit (2 and 4) reported by Tesch (1971) for most fishes. The value of regression parameter *b* showed that growth of both male and female *X. cancila* was positively allometric. Satrawaha and Pilasamorn (2009) reported the *b* value of *X. cancila* as 3.4896 in Chi River northeastern Thailand which is in accordance with the present study. Though, in Vellayani freshwater lake in Trivandrum, India, Chandrika and Balasubramonian (1986) reported the *b* values for male and female *X. cancila* as 2·9014 and 2·8333 which are different than that found in the present study. Such 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 2010), all of which were not accounted in this study. Because the samples of *X. cancila* 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.

All LLRs were highly correlated and they were compared with the data available in the literature. Satrawaha and Pilasamorn (2009) recorded the length-length relationships of *X. cancila* as FL= -0.240+ 0.935TL, SL= -0.783+ 0.761TL and SL= -0.522+ 0.810TL for combined sex in the Chi River, northeastern Thailand which 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.

A number of condition factors including Fulton's (Fulton 1904), Relative (Le Cren 1951) and Allometric (Tesch 1968) condition factor and Relative weight (Froese 2006) were used to assess the overall health and productivity of *X. cancila* in this study. However, Froese (2006) recommended the relative condition factor for comparison of the health status between males and females within the same sample or same population. Nonetheless, he did not allow for comparison across populations unless they have equivalent underlying length-weight relationship. Moreover, the Fulton's condition might be applicable because it is free from parameters *a* and *b* of the LWR. The K_F values between the sexes were significantly different in this study. Similarly, the mean relative-condition factor showed significant differences between sexes in this study based on the methodology described by Froese (2006). No references dealing with the condition factors of *X. cancila* are available in the Padma River, preventing the comparison with previous results. 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.

The most popular index (relative weight, W_R) was used to focus the present status of this gar fish in Padma River (Froese 2006). 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 indicate a prey surplus or low predator density (cf. Rypel & Richter 2008). In recent times, several studies have encouraged the use of W_R for supporting in the management and conservation of nongame fishes, particularly those that are threatened or endangered (Muchlisin et al. 2010; Richter 2007). The mean relative weight (W_R) value was significantly different from 100 for males and females in this study, indicating an imbalance habitat with food availability relative to the presence of predators (Anderson & Neumann 1996) for *X. cancila* in the Padma River. In addition, it might be indicated that the water quality of Padma River is not good enough for *X. cancila* fishery. 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 the 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 managers can use to evaluate the overall health and fitness as well as population-level responses to ecosystem disturbance (cf. Rypel & Richter 2008). However, there is no information available in literature dealing with the relative weight of this species restrains the comparison with previous results. Nonetheless, Rahman et al. (2012) studied the relative weight of *Puntius sophore* in the Chalan *beel*, north-central Bangladesh and found balance habitat with food availability relative to the presence of predators.

The present study revealed the values of form factor as 0.0304, 0.0268 and 0.0252 for male, female and combined sex, respectively. The form factor ($a_{3.0}$) can be applied to verify whether the body shape of individuals in a given population or species is significantly different from others (Froese 2006). However, no reference dealing with the $a_{3.0}$ of this species is available in the literature and the present results provide an important basis for future comparisons. Nonetheless, Rahman et al. (2012) studied the form factor of *Puntius sophore* in the Chalan *beel*, north-central Bangladesh as 0.0138 (TL) for combined sex.

CONCLUSION

This study provides an important baseline study on the length-weight relationships, length-length relationships, condition factors and form factor of *X. cancila* 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 Ganges River ecosystem. Furthermore, the information on length-weight relationships, length-length relationships, condition factors and form factor for *X. cancila* 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 Ganges River and surrounding ecosystems. Further studies are suggested to infer a relationship between conditions and gonad cycles and the seasonal variations in stomach contents.

ACKNOWLEDGEMENTS

We express our gratitude to local fishers (Rajshahi, Bangladesh) for collecting the samples, Andrew L. Rypel (University of Alabama, USA) and Alex D. Robertis (Natural Marine Fisheries Service, Washington, USA) for sending us some of the cited articles, the Department of Fisheries, University of Rajshahi (Bangladesh) for laboratory facilities and Bernerd Fulanda (Kagoshima

University, Japan) for critical reading of the manuscript. Also we would like to express our acknowledgement to the anonymous referee for their useful and constructive comments.

REFERENCES

Al-Mamun, A. 2003. *A Hand Guide for Identification of Inland Fishes of Bangladesh*. WorldFish Centre-Bangladesh.

Anderson, R.O. & Neumann, R.M. 1996. Length, weight and associated structural indices. In *Fisheries Techniques*. 2nd ed., edited by Murphy, B.R. & Willis, D.W. American Fisheries Society, Bethesda, Maryland.

Asmat, G.S.M. 2001. *Trichodina cancilae* sp. n. (Mobilina: Trichodinidae) from the Gills of a Freshwater Gar, *Xenentodon cancila* (Hamilton) (Belonidae). *Acta Protozoologica* 40: 141-146.

Avşar, D. 1998. *Fisheries Biology and Population Dynamics*. University of Çukurova, Faculty of Fisheries, Adana, Turkey, (in Turkish).

Breder, C.M. & Rosen, D.E. 1966. *Modes of Reproduction in Fishes*. Neptune City, New Jersey: T.F.H. Publications.

Carl, H. 2003. *Danish Fish Names*. Zoological Museum of Copenhagen (Unpublished).

Carlander, K.D. 1969. *Handbook of Freshwater Fishery Biology*. Vol.1. Ames, IA: The Iowa State University Press.

Chandrika, B. & Balasubramonian, N.K. 1986: Length-weight relationship of *Xenentodon cancila* (Ham.) (Teleostei: Belonidae). *Proceedings of Indian Academy of Science (Animal Science)* 95(2): 187-190.

Chuenpagdee, R. 2002. *Checklist of Thai Names and Scripts*. Personal communication, April 2002.

Ecoutin, J.M., Albaret, J.J. & Trape, S. 2005. Length-weight relationships for fish populations of a relatively undistributed tropical estuary: The Gambia. *Fisheries Research* 72: 347-351.

FAO-FIES, 2010. *Aquatic Sciences and Fisheries Information System (ASFIS) Species List*. Retrieved from http://www.fao.org/fishery/collection/asfis/en, March 2010.

Froese, R. & Pauly, D. 2012. Fishbase 2012. World Wide Web electronic publication. Available at: http://www.fishbase.org (accessed on 26 March 2012).

Froese, R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. *Journal Applied Ichthyology* 22: 241-253.

FRSS. 2009. Fisheries Statistical Yearbook of Bangladesh 2007-2008. Department of Fisheries, Ministry of Fisheries and Livestock, Dhaka, Bangladesh. 25(1): 1-42.

Fulton, T.W. 1904. *The Rate of Growth of Fishes*. *Twenty-second Annual Report,* Part III. Fisheries Board of Scotland, Edinburgh.

Gerritsen, H.D. & McGrath, D. 2007. Significance differences in the length-weight relationships of neighbouring stocks can result in biased biomass estimates: Examples of haddock (*Melanogrammus aeglefinus*, L.) and whiting (*Merlangius merlangus*, L.). *Fisheries Research* 85: 106-111.

Gonzalez Acosta, A.F., De La Cruz Aguero, G. & De La Cruz Aguero, J. 2004. Lengthweight relationships of fish species caught in a mangrove swamp in the Gulf of California (Mexico). *Journal of Applied Ichthyology* 20: 154-155.

Hossain, M.Y. 2010. Length-weight, length-length relationships and condition factors of three schibid catfishes from the Padma River, Northwestern Bangladesh. *Asian Fisheries Science* 23: 329-339.

Hossain, M.Y., Jewel, M.A.S., Nahar, L., Rahman, M.M., Naif, A. & Ohtomi, J. 2012b. Gonadosomatic index-based size at first sexual maturity of the catfish *Eutropiichthys vacha* (Hamilton 1822) in the Ganges River (NW Bangladesh). *Journal of Applied Ichthyology* 28(4): 601-605.

Hossain, M.Y., Ahmed, Z.F., Leunda, P.M., Islam, A.K.M.R., Jasmine, S., Oscoz, J., Miranda, R. & Ohtomi, J. 2006b. Length-weight and length-length relationships of some small indigenous fish species from the Mathabhanga River, southwestern Bangladesh. *Journal of Applied Ichthyology* 22(4): 301-303.

Hossain, M.Y., Ahmed, Z.F., Leunda, P.M., Jasmine, S., Oscoz, J., Miranda, R. & Ohtomi, J. 2006a. Condition, length–weight and length–length relationships of the Asian striped catfish *Mystus vittatus* (Bloch 1794) (Siluriformes: Bagridae) in the Mathabhanga River, southwestern Bangladesh. *Journal of Applied Ichthyology* 22: 304-307.

Hossain, M.Y., Jasmine, S., Ibrahim, A.H.M., Ahmed, Z.F., Rahman, M.M. & Ohtomi, J. 2009. Length-weight and length-length relationships of 10 small fish species from the Ganges, Bangladesh. *Journal of Applied Ichthyology* 25: 117-119.

Hossain, M.Y., Ohtomi, J., Ahmed, J., Jasmine, S. & Vadas, R.L. 2012a. Life-history traits of the Monsoon River prawn *Macrobrachium malcolmsonii* (Milne-Edwards 1844) (Palaemonidae) in the Ganges (Padma) River, northwestern Bangladesh. *Journal of Freshwater Ecology* 27(1): 131-142.

Koutrakis, E.T. & Tsikliras, A.C. 2003. Length-weight relationships of fishes from three northern Aegean estuarine systems (Greece). *Journal of Applied Ichthyology* 19: 258-260.

Le Cren, E.D. 1951. The length-weight relationships and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *Journal of Animal Ecology* 20: 201-219.

Muchlisin, Z.A., Musman, M. & Siti Azizah, M.N. 2010. Length-weight relationships and condition factors of two threatened fishes, *Rasbora tawarensis* and *Poropuntius tawarensis*, endemic to Lake Laut Tawar, Aceh Province, Indonesia. *Journal of Applied Ichthyology* 26: 949-953.

Nath, P. & Dey, S.C. 1989. *Fish and Fisheries of North East India*. Arunachal Pradesh Vol. 1: 1- 143.

Nghia, N.V. 2005. Fishes of Viet Nam. Compilation of Nguyen Viet Nghia (Unpublished).

Pandey, K.C. & Tewary, S.K. 1984. SEM studies on *Bucephalopsis karvei* Bhalerao, 1937, an intestinal parasite of the fish, *Xenetodon cancila* (Ham.). *Proceedings of Indian Academy of Science (Animal Science)* 93(6): 527-533.

Pethiyagoda, R. 1991. *Freshwater Fishes of Sri Lanka*. The Wildlife Heritage Trust of Sri Lanka, Colombo.

Pitcher, T.J. & Hart, P.J. 1982. *Fisheries Ecology*. London: Chapman and Hall.

Poeu, O. & Dubeau, P. 2004. Value of floodplain fisheries in Kompong Traolach district, Kompong Chhnang province. In *Wetlands Management in Cambodia: Socioeconomic, Eecological and Policy Perspectives,* edited by Torell, M. Salamanca A. & Ratner B. WorldFish Technical Report 64.

Rahman, A.K.A. 1989. *Freshwater Fishes of Bangladesh*. Zoological Society of Bangladesh. Department of Zoology, University of Dhaka.

Rahman, M.M., Hossain, M.Y., Jewel, M.A.S., Rahman, M.M., Jasmine, S., Abdallah, E.M. & Ohtomi, J. 2012. Population structure, length-weight and length-length relationships and condition and form-factor of the pool barb *Putius sophore* (Hamilton 1822) (Cyprinidae) from the Chalan *Beel*, North-central Bangladesh. *Sains Malaysiana* 41(7): 795-802.

Rainboth, W.J. 1996. *Fishes of the Cambodian Mekong*. FAO Species Identification Field Guide for Fishery Purposes. FAO, Rome. p.265.

Richter, T.J. 2007. Development and evaluation of standard weight equations for bridgelip sucker and large scale suckers. *North American Journal of Fisheries Management* 27: 936-939.

Rypel, A.L. & Richter, T.J. 2008. Empirical percentile standard weight equation for the blacktail redhorse. *North American Journal of Fisheries Management* 28: 1843-1846.

Satrawaha, R. & Pilasamorn, C. 2009. Length–weight and length–length relationships of fish species from the Chi River, northeastern Thailand. *Journal of Applied Ichthyology* 25: 787-788.

Shrestha, J. 1994. *Fishes, Fishing Implements and Methods of Nepal*. Smt. M.D. Gupta, Lalitpur Colony, Lashkar (Gwalior), India.

Sokal, R.R. & Rohlf, F.J. 1987. *Introduction to Biostatistics*. 2nd ed. New York: Freeman Publication.

Talwar, P.K. & Jhingran, A.G. 1991. *Inland Fishes of India and Adjacent Countries*. Volume 2. Rotterdam: A.A. Balkema.

Tesch, F.W. 1968. Age and Growth. In *Methods for Assessment of Fish Production in Fresh Waters*, edited by Ricker, W.E. Oxford: Blackwell Scientific Publications.

Tesch, F.W. 1971. Age and Growth. In *Methods for Assessment of Fish Production in Fresh Waters*, edited by Ricker, W.E. Oxford: Blackwell Scientific Publications.

Varjo, M., Koli, L. & Dahlström, H. 2004. *Kalannimiluettelo* (versio 10/03). Suomen Biologian Seura Vanamo Ry.

Vazzoler, A.E.A.M. 1996. *Reproduction Biology of Teleostean Fishes: Theory and Practice*. Maringá, EDUEM, Brazilian Society of Ichthyology.

Yamamoto, M.N. & Tagawa, A.W. 2000. *Hawai'i's Native and Exotic Freshwater Animals*. Honolulu, Hawaii: Mutual Publishing.

Md. Yeamin Hossain*, Md. Abu Sayed Jewel,
Md. Mosaddequr Rahman & A.B.M. Mohidul Haque
Department of Fisheries
Faculty of Agriculture
University of Rajshahi
Rajshahi 6205
Bangladesh

Md. Yeamin Hossain* & Jun Ohtomi
Faculty of Fisheries
Kagoshima University, 4-20-50 Shimoarata
Kagoshima 890-0056
Japan

Heba Allah M. Elbaghdady
Department of Zoology
Faculty of Science
Mansoura University
Egypt

*Corresponding author; email: yeamin2222@yahoo.com

Received: 28 December 2012
Accepted: 15 February 2013