Pakistan J. Zool., vol. 48(2), pp. 399-408, 2016.

Life History Traits of the Flying Barb *Esomus danricus* (Hamilton, 1822) (Cyprinidae) in the Ganges River, Northwestern Bangladesh

Md. Yeamin Hossain,[1]* S. M. Abu Naser,[1] Ali H. Bahkali,[2] Khairun Yahya,[3] Md. Alomgir Hossen,[1] Abdallah M. Elgorban,[2] Md. Mahmudul Islam[4] and Md. Mosaddequr Rahman[5]

[1] *Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi 6205, Bangladesh*
[2]*Department of Botany and Microbiology, College of Science, King Saud University, Riyadh, Saudi Arabia*
[3]*School of Biological Sciences and Centre for Marine and Coastal Studies, Universiti Sains Malaysia, Penang 11800, Malaysia*
[4]*Department of Genetic Engineering and Biotechnology, University of Rajshahi, Rajshahi 6205, Bangladesh*
[5]*Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan*

ABSTRACT

The present study describe the first life-history traits of threatened fish *Esomus danricus* from the Ganges River, northwestern Bangladesh. This study also calculates the form factor, size at first sexual maturity and natural mortality of *E. danricus* from world-wide different water bodies using available literature. Sampling was done, using traditional fishing gears including cast net, square lift net and conical trap during January to December 2014. A total of 309 individuals ranging from 2.94-6.10 cm total length and 0.25-1.38 g body weight were analyzed in this study. The length frequency distributions showed that the 4.00-4.99 cm total length size group was numerically dominant and constituted 50.00% of the total population. The allometric coefficient (*b*) of the length-weight relationship indicates negative allometric growth ($b < 3.0$) for *E. danricus* in the Ganges River. The results also indicate that the length-length relationships were highly correlated ($r^2 \geq 0.974$). The allometric condition factor varied from 0.015 to 0.018 and Fulton′s condition factor varied from 0.607-0.985. Also the relative condition factor ranges from 0.923 to 1.127 and minimum and maximum values of relative weight were 92.185-112.727 in the Ganges River. The Fulton′s condition factor is the best index for assessing the wellbeing of *E. danricus* in the Ganges River. According to Wilcoxon signed test the relative weight did not show any significant difference from 100 ($p = 0.295$), indicating the balance habitat for *E. danricus*. The form factor was calculated as 0.0033 and the size at first sexual maturity for combined sexes of *E. danricus* was estimated as 3.98 (~ 4.00) cm total length in the Ganges River, northwestern Bangladesh. In addition, the mean natural mortality was estimated as 2.31 year^{-1}. These results will be useful for sustainable conservation of this threatened fish in the Ganges River and surrounding ecosystem.

Article Information
Received 4 May 2015
Revised 18 August 2015
Accepted 3 September 2015
Available online 1 March 2016

Authors' Contributions
MYH designed the study and wrote the article. SMAN performed the experiments. MAH, MMI and MMR helped in preparation of manuscript. KY performed statistical analysis. AHB and AME provided funds.

Key words
***Esomus danricus*, length-weight relationship, relative weight, form factor, size at first sexual maturity.**

INTRODUCTION

The flying barb, *Esomus danricus* (Hamilton, 1822) belongs to the family Cyprinidae, is a small indigenous fish species (SIS) of Bangladesh. This fish is known as Darkina, Darki, Darkya in Bangladesh (Rahman, 2005). In India it is known as Darkina, Dadhikha, Danrika, Jongia, Chilwa, Jhai, Astapakke, Messaparavi and Meesa-parava (Talwar and Jhingran, 1991). This species is widely distributed throughout the Indian sub-continent including Bangladesh, India, Nepal, Pakistan, Sri-Lanka and some other countries of the world such as Afghanistan and Thailand (Froese and Pauly, 2015). The flying barb, *E. danricus* inhabits ponds, weedy ditches, streams, *beels* and inundated fields (Rahman, 1989; Talwar and Jhingran, 1991). It is an important target species for small-scale fishers (Shafi and Quddus, 1982). Nonetheless, the untamed population of this species is waning due to reckless fishing, habitat destruction and other ecological changes to their surroundings (Hossen *et al.*, 2015; Hossain *et al.*, 2015a, b) and afterward categorized as least concern in Red list (Devi and Boguskaya, 2009). This fish is a major source of animal protein and macronutrients in the diet of rural poor people in fresh and dried condition (Bijen *et al.*, 1990; Lilabati and Vishwanath, 2000). *E. danricus* also used as ornamental fish (Froese and Pauly, 2015).

Length-weight relationships (LWRs) are very helpful in fishery for predicting length distributions into weights for estimation of biomass (Gerritsen and

* Corresponding author: hossainyeamin@gmail.com; yeamin.fish@ru.ac.bd
0030-9923/2016/0002-0399 $ 8.00/0

McGrath, 2007). Additionally, LWRs parameters are important to evaluate fish-stock condition (Gonzalez Acosta *et al*., 2004). Furthermore, condition factors are functional parameters that can be used for determining the possible differences among different stocks of the same species (King, 2007; Soomro *et al*., 2012). Moreover, relative weight (W_R) is one of the most popular indices to know the condition of fishes in the USA since last two decades (Rypel and Richter, 2008) and recently it has been used in Bangladesh for determining the condition of freshwater fishes (Hossain *et al.*, 2012a, 2015c).

A number of studies including length-frequency distributions (Hossain *et al.*, 2008; Rahman *et al.*, 2012), length-length and LWRs (Hossain, 2010a; Hossain *et al.*, 2006a,b; 2009a), condition- and form- factors (Hossain, 2010b; Hossain *et al.*, 2010, 2012b) of several fish species have been conducted, but the research on the life history traits of *E. danricus* are evidently lacking from Bangladesh or else. Therefore, this study reports the first complete and comprehensive description on life-history traits of *E. danricus* in the Ganges River, northwestern Bangladesh using a large number of specimens from small to large body sizes.

MATERIALS AND METHODS

Study site

The current study was conducted in the Ganges River (known as Padma in Bangladesh) (24.35′ N; 88.64′ E) northwestern (NW) Bangladesh. It is one of the longest rivers and believed to be an important spawning and feeding ground for riverine fishes (Hossain *et al.*, 2010; Rahman *et al.*, 2012).

Sampling and measurement

The samples of *E. danricus* were collected during daytime from the fishermen at different parts (Charghat; 24°15’ N, 88˚44’ E; Godagari; 24° 26’ N, 88° 19’ E and Saheb bazar; 24° 20’ N, 88° 34’ E) of the Ganges River in Rajshahi region during January 2014 to December 2014. The fishes were caught using cast net, square lift net and box trap. The fresh samples were immediately chilled in ice on site and fixed with 10% buffered formalin upon arrival in the laboratory. For each individual, 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; Mitutoyo Corporation, Tokyo, Japan) and whole body weight (BW) was taken by a digital balance (Shimadzu, EB-430DW; Shimadzu Seisakusho, Tokyo, Japan) with 0.01 g accuracy.

Length-frequency distribution (LFDs)

The LFDs for the *E. danricus* were constructed using 1 cm intervals of TL. The normal distribution was fitted to the TL frequency distribution of *E. danricus* using a computer analysis Microsoft Excell-add-in-solver) based on Hasselblad′s maximum-likelihood method (Hasselblad, 1966).

Length-weight and length-length relationships (LWRs and LLRs)

The LWRs were calculated using the equation: $W= a*L^b$, where the W is the body weight (g) and L is the length (cm). The parameters a and b were estimated by linear regression analysis based on natural logarithms: $\ln(W) = \ln(a) + b \ln(L)$. Additionally, 95% confidence limits of a and b and the coefficient of determination r^2 were estimated. In order to confirm whether b values obtained in the linear regressions were significantly different from the isometric value ($b = 3$), a t-test 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) was applied. Additionally, the data of *E. danricus* from India by Mustafa (1978) and Mercy *et al.* (2008) were used to compare the LWRs with present study s through analysis of co-variance (ANCOVA). Furthermore, the LLRs including TL *vs.* FL; TL *vs.* SL and FL *vs.* SL were estimated by linear regression analysis (Hossain *et al.*, 2006b).

Condition factors (CF)

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

Relative weight (W_R)

For assessing W_R the equation of Froese (2006): $W_R = (W / W_s) \times 100$, were used, where W is the weight of a particular individual and W_s is the predicted standard weight for the same individual as calculated by $W_s = a*L^b$ (a and b values obtained from the composite of LWRs).

Form factor ($a_{3.0}$)

The $a_{3.0}$ of *E. danricus* was calculated using the equation of Froese (2006) as: $a_{3.0} = 10^{\log a - s\,(b\text{-}3)}$, where

a and *b* are regression parameters of LWRs and *s* is the regression slope of *ln a vs. b*. In this study, a mean slope *S* = -1.358, was used for estimating the form factor because information on LWRs is not available for this species for estimation of the regression (S) of *ln a vs. b*.

Size at first sexual maturity (L_m)

The L_m of *E. danricus* was calculated using the empirical equation, log (L_m) = -0.1189 + 0.9157 * log (L_{max}), where L_{max} is the maximum observed length (Binohlan and Froese, 2009).

Natural mortality (M_W)

The M_W of *E. danricus* was calculated using the model, M_W=1.92 year^{-1} *(W)$^{-0.25}$ (Peterson and Wroblewski, 1984), where, M_W = Natural mortality at mass W; and W = a*L^b, *a* and *b* are regression parameters of LWR.

Statistical analysis

For statistical analysis Microsoft® Excel-add-in-DDXL and GraphPad Prism 6.5 (GraphPad Software, Inc., San Diego, CA) were used. Tests for normality was conducted by visual assessment of histograms and box plots, and confirmed using the Kolmogorov-Smirnov test. Where test for normality assumption was not met, then the non-parametric Wilcoxon rank test was used to compare the mean W_R of a population with 100 (Anderson and Neumann, 1996). In addition, the Spearman rank test was used to correlate body measurements (*e.g.*, TL, FL, SL, and BW) with condition factors (K_A, K_F, K_R). Furthermore, the LWRs between waters were compared by the ANCOVA. All statistical analyses were considered significant at 5% (p<0.05).

RESULTS

Length-frequency distribution

A total number of 309 individuals of *E. danricus* were collected from the Ganges River. Table I illustrates the descriptive statistics on the length (cm), weight (g) measurements and 95% confidence limit (CL) of the *E. danricus*. The LFDs of *E. danricus* showed that the smallest and largest individuals were 2.94 cm and 6.10 cm TL, respectively, whereas the BW ranges from 0.25-1.38 g. The 4.00-4.99 cm TL size group was numerically dominant and constituted 50.00% of the total population (Fig. 1). According to Shapiro-Wilk normality test, the LFDs were normally distributed (p = 0.018 for TL and p < 0.001 for BW) in the Ganges River.

Length-weight relationships

The sample size (*n*), regression parameters of the LWRs, 95% CL of *a* and *b*, the coefficient of determination (r^2) and growth type of *E. danricus* are given in Table II and Figure 2. The calculated allometric coefficient (*b*) of TL *vs.* BW indicate negative allometric growth type in the combined sexes of *E. danricus* (b<3.00, p<0.01). In addition, the FL-BW and SL-BW relationships showed similar pattern of growth (Table II) in the Ganges River, NW Bangladesh. All LWRs relationships were highly significant (p<0.01), with all r^2 values being >0.966. The ANCOVA revealed significant differences on the LWRs of *E. danricus* between Bangladesh and Indian waters (p<0.001) (Table III, Fig.3).

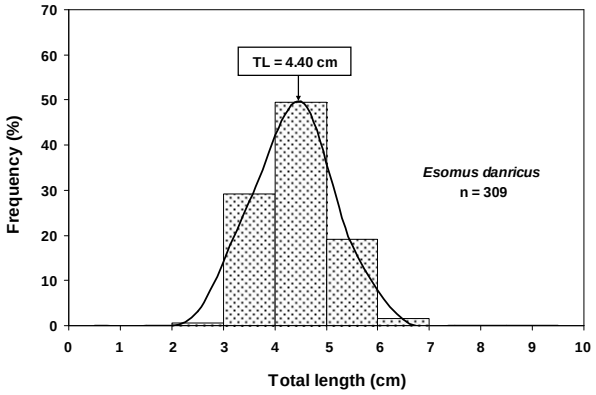

Fig. 1. Total length frequency distribution of *Esomus danricus* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh (Arrow and n value indicate the mean value and sample size, respectively).

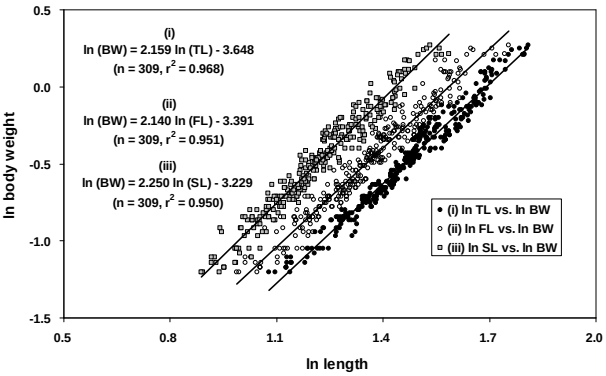

Fig. 2. Relationships (*ln W = ln a + b ln L*) between (i) ln total length vs. ln body weight, (ii) ln fork length vs. ln body weight and (iii) ln standard length vs. ln body weight of *Esomus danricus* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh.

Table I.- Length (cm) and weight (g) measurements with 95% confidence limit of combined sexes of *Esomus danricus* (Hamilton, 1822) (n=309) from the Ganges River (24.35′ N; 88.64′ E), northwestern Bangladesh.

Characteristics	Range (cm)	Mean ± SD	Mode	95% CL
Total length	2.94-6.10	4.40 ± 0.67	3.09	4.33 – 4.48
Fork length	2.68-5.53	3.95 ± 0.60	2.87	3.88 – 4.02
Standard length	2.43-4.79	3.44 ± 0.50	2.59	3.38 – 3.49
Body weight	0.25-1.38	0.67 ± 0.26	0.47	0.64 – 0.70

Table. II.- Descriptive statistics and estimated parameters on the length-weight relationships (BW = $a \times TL^b$) of *Esomus danricus* (Hamilton, 1822) from the Ganges River (24.35′ N; 88.64′ E), northwestern Bangladesh.

Equation	Regression parameters		95% CL		r^2	GT
	a	*b*	*a*	*b*		
Combined sex (n=309)						
$BW=a \times TL^b$	0.0158	2.502	0.015 – 0.016	2.476 – 2.529	0.991	-A
$BW=a \times FL^b$	0.0205	2.509	0.019 – 0.022	2.461 – 2.557	0.972	-A
$BW=a \times SL^b$	0.0253	2.619	0.024 – 0.027	2.563 – 2.674	0.966	-A

n, sample size; *a*, intercept; *b*, slope; CL, confidence limit for mean values; r^2, coefficient of determination; GT, growth type (-A, negative allometric); BW, body weight; TL, total length; FL, fork length; SL, standard length

Table III.- Comparison on length-weight relationships of *Esomus danricus* (Hamilton, 1822) between the Ganges River (24.35′ N; 88.64′ E), northwestern Bangladesh and the Indian waters through analysis of co-variance (ANCOVA)

Water-body	Channel of flowing water, Aligarh, India	Freshwater fish pond, Aligarh, India	Western Ghat, india
Ganges River, NW Bangladesh	*** F = 2883.23, *df* = 614, $p < 0.001$	*** F = 84.64, *df* = 614, $p < 0.001$	*** F = 218, *df* = 614 $p < 0.001$

*** The slopes differ so much; therefore it was assumed that the differences between the intercepts are extremely significant; *df*, degree of freedom

Table IV.- The estimated parameters on the length-length relationships ($Y = a + b \times X$) of *Esomus danricus* (Hamilton, 1822) from the Ganges River (24.35′ N; 88.64′ E), northwestern Bangladesh.

Equation	*n*	Regression parameters		95% CL		r^2
		a	*b*	*a*	*b*	
$FL = a + b \times TL$	309	0.0762	0.880	0.0118 – 0.1460	0.866 – 0.895	0.979
$SL = a + b \times TL$		0.2013	0.735	0.1411 – 0.2616	0.721 – 0.748	0.974
$SL = a + b \times FL$		0.1730	0.826	0.1119 – 0.2341	0.811 – 0.841	0.974

n, sample size; *a*, intercept; *b*, slope; CL, confidence limit for mean values; r^2, coefficient of determination; TL, total length; FL, fork length; SL, standard length

Length-length relationships

The relationships between TL, FL and SL of *E. danricus* including 309 specimens along with the estimated parameters of the LLRs and the coefficient of determination (r^2) are presented in Table IV and Figure 4. All LLRs were highly significant ($p<0.001$) and most of the coefficients of determination values being ≥0.974.

Condition factors

Allometric condition factor

The K_A varied from 0.015-0.018 (mean±SD = 0.016±0.001) (Table V). According to Spearman rank

correlation test there was no significant relationship among the TL *vs.* K_A (spearman, r = 0.063, p = 0.270), FL *vs.* K_A (spearman, r = 0.060, p = 0.296), SL *vs.* K_A (spearman, r = 0.067, p = 0.240) but significant relationship exist between BW *vs.* K_A (spearman, r = 0.129, p = 0.003) (Table VI).

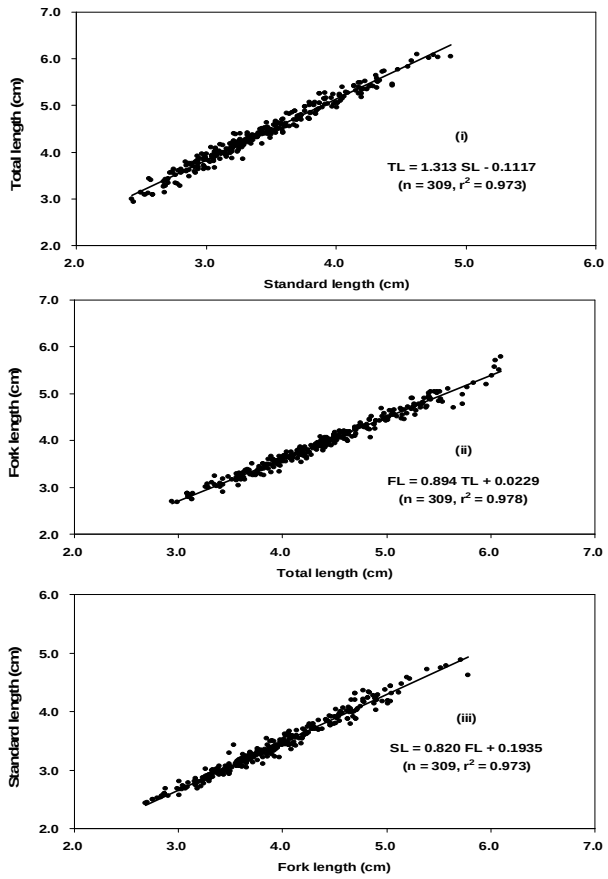

Fig. 3. Relationships ($y = p + q \times x$) between (i) standard length (SL) and total length (TL), (ii) total length (TL) and fork length (FL), and (iii) fork length (FL) and standard length (SL) of *Esomus danricus* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh

Fulton's condition factor

In our study K_F ranged from 0.607 to 0.985 (mean ± SD = 0.762 ± 0.065) (Table V). Spearman rank correlation test revealed that there was strong correlation among the TL *vs.* K_F (spearman, r = -0.854, p< 0.001), FL *vs.* K_F (spearman, r = -0.846, p<0.001), SL *vs.* K_F (spearman, r = -0.842, p<0.001) and BW *vs.* K_F (spearman, r = -0.814, p<0.001) (Table VI). Based on the spearman rank correlation test, the K_F is the best condition factor for assessing the well-being of *E. danricus* during the study.

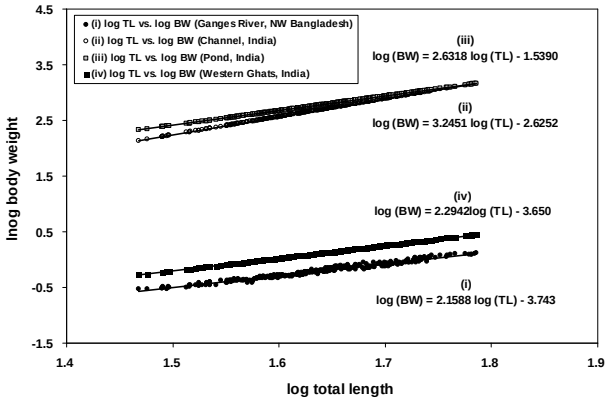

Fig. 4. Total length (mm) and body weight (g) relationships (log W = log a + b ln L) of *Esomus danricus* in the (i) Ganges River, NW Bangladesh (Present study), (ii) Channel of flowing water, Aligarh, India (Mustafa, 1978), (iii) freshwater fish pond, Aligarh, India (Mustafa, 1978) and Western Ghats, India (Mercy et al., 2008).

Relative condition factor

In the present study the K_R ranged from 0.923-1.127 (mean±SD = 0.998±0.038) (Table V). Spearman rank correlation test indicated that there was no significant relationship among the TL *vs.* K_R (spearman, r = 0.063, p=0.269), FL *vs.* K_R (spearman, r = 0.060, p=0.296), SL *vs.* K_R (spearman, r = 0.067, p=0.240). But there exist significant correlation between BW *vs.* K_R (spearman, r = 0.129, p=0.023) (Table VI).

Relative weight

The calculated minimum and maximum W_R were 92.184 and 112.727, with a mean values of 99.808±3.755 (Table V) which was not significantly different from 100 (Wilcoxon signed rank test, p=0.295) indicating a balance population in presence of prey and predators for *E. danricus* in the Ganges River. According to spearman rank correlation test there was no significant relationship between TL and W_R (spearman, r = 0.063, p=0.269). Also the spearman rank correlation test specify that there was significant association between BW *vs.* W_R (spearman, r= 0.129, p=0.023) for *E. danricus* in the Ganges River. The relationship between TL *vs.* W_R was also shown in the Figure 5.

Form factor

The $a_{3.0}$ was calculated as 0.0033 for combined sexes of *E. danricus* from the Ganges River, NW

Table V.- Condition factors of combined sexes of *Esomus danricus* (Hamilton, 1822) (n=309) from the Ganges River (24.35′ N; 88.64′ E), northwestern Bangladesh.

Condition factor	Range	Mean ± SD	95% CL
K_A	0.015-0.018	0.016 ± 0.001	0.0157 – 0.0158
K_F	0.607-0.985	0.762 ± 0.065	0.7542 – 0.7688
K_R	0.923-1.127	0.998 ± 0.038	0.9939 – 1.0023
W_R	92.184-112.727	99.808 ± 3.755	99.389 – 100.228

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

Table VI.- Estimation of correlation for Allometric (K_A), Fulton's (K_F) and Relative (K_R) condition factor with total length (TL, cm), fork length (FL, cm), standard length (SL, cm) and body weight (BW, g) of *Esomus danricus* (Hamilton, 1822) from the Ganges River (24.35′ N; 88.64′ E), northwestern Bangladesh

Condition factor	r_S value	95% CL of r_S	P value	Degree of significance
Allometric condition factor				
TL *vs.* K_A	0.063	-0.052 to 0.176	$P = 0.269$	*ns*
FL *vs.* K_A	0.060	-0.056 to 0.173	$P = 0.296$	*ns*
SL *vs.* K_A	0.067	-0.048 to 0.180	$P = 0.240$	*ns*
BW *vs.* K_A	0.129	0.015 to 0.240	$P = 0.023$	*
Fulton's condition factor				
TL *vs.* K_F	-0.854	-0.882 to -0.820	$P < 0.001$	***
FL *vs.* K_F	-0.846	-0.876 to -0.810	$P < 0.001$	***
SL *vs.* K_F	-0.842	-0.872 to -0.805	$P < 0.001$	***
BW *vs.* K_F	-0.814	-0.849 to -0.771	$P < 0.001$	***
Relative condition factor				
TL *vs.* K_R	0.063	-0.052 to 0.176	$P = 0.269$	*ns*
FL *vs.* K_R	0.060	-0.056 to 0.173	$P = 0.296$	*ns*
SL *vs.* K_R	0.067	-0.048 to 0.180	$P = 0.240$	*ns*
BW *vs.* K_R	0.129	0.015 to 0.240	$P = 0.023$	*

r_S, coefficient of spearman rank correlation test; *ns*, not significant; *, significant; ***, highly significant

Table VII.- The calculated form factor ($a_{3.0}$), size at first sexual maturity (L_m) and natural mortality (M_W) of Esomus danricus in world-wide different water-bodies

Water-bodies	*a*	*b*	Maximum TL	Reference	$a_{3.0}$	L_m *cm*	M_W year^{-1}
Western Ghats of India	0.0441	2.294	7.2 cm	Mercy *et al.* (2008)	0.0048	4.64	1.91
Ponds, India	0.0663	2.632		Mustafa (1978)	0.0210		1.51
Water channel, India	0.0051	3.245		Mustafa (1978)	0.0110		2.42
Nageshwari water, Bangladesh	0.0505	2.812	6.8 cm	Ferdaushy and Alam (2015)	0.0281	4.40	1.48
Ganges River, Bangladesh	0.0158	2.502	6.1 cm	Present study	0.0033	3.98	2.31

a and *b* are regression parameters of length-weight relationships; TL, total length; $a_{3.0}$, form factor; L_m, size at first sexual maturity; M_W, natural mortality

Bangladesh and also our study calculate the $a_{3.0}$ of *E. danricus* from world-wide different water bodies using available literature (Table VII).

Size at first sexual maturity

The size at first sexual maturity (L_m) for the *E. danricus* was estimated as 3.98 (~ 4.00) cm TL (95% CL

= 3.30 - 4.86 cm TL) in the Ganges River, NW Bangladesh. In addition, our study calculates the L_m of *E. danricus* from world-wide different water bodies using available literature (Table VII).

Natural mortality

The mean natural mortality was estimated as 2.31 year^{-1} for the *E. danricus* in the Ganges River, NW Bangladesh.

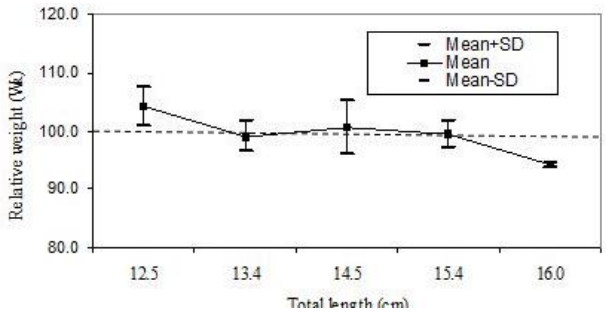

Fig. 5. The relationship between TL and W_R of *Esomus danricus* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh

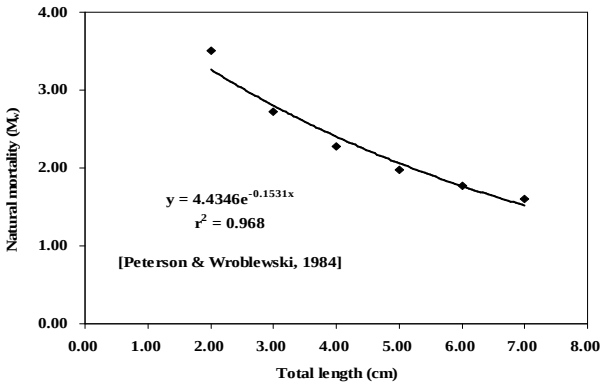

Fig. 6. The natural mortality of *Esomus danricus* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh

DISCUSSION

Information on life-history traits of *E. danricus* from Bangladesh is not available in the literature, but some studies on LWRs were conducted by Hossain *et al.* (2009b, 2015d); Sani *et al.* (2010); Naeem *et al.* (2012) from Indian sub-continent. However, this study collected a total number of 309 individuals with various body sizes using traditional fishing gears from the Ganges River, NW Bangladesh. This study focuses on LWRs, LLRs, CF (K_A, K_F, K_R), W_R, $a_{3.0}$ and L_m and M_W of *E. danricus* from the Ganges River. Also comparison on LWRs between two water-bodies, which would be effective for further study and sustainable conservation of this species in different geographical locations.

In our study, it was not possible to collect the *E. danricus* smaller than 2.94 cm, which can be attributed that, the fishermen did not go where the smaller size exist or selectivity of fishing gears (Hossain *et al.*, 2012 c, d). The maximum length of *E. danricus* found in the present study 6.10 cm in TL which is lower than the maximum recorded value of 7.2 cm TL in the Western Ghats of India, Mercy *et al.* (2008). In addition, maximum BW of *E. danricus* found in the present study was 1.38 g, which is lower than by Mercy *et al.* (2008) as 1.72 g in the Western Ghats. Information on maximum length is necessary to estimate the asymptotic length and growth coefficient of fishes (Hossain, 2010c), which is vital for fisheries resource planning and management (Ahmed *et al*., 2012; Hossain *et al*., 2012e).

The present study revealed that the calculated *b* values lies between 2.5 to 2.6 for different LWRs of *E. danricus* from the Ganges River. However, the *b* values ranging from 2.5 to 3.5 are more common (Carlander, 1969; Froese, 2006). In general *b* values close to 3, indicating that fish grow isometrically and different from 3.0 indicate allometric growth (>3 positive allometric and <3 negative allometric) (Tesch, 1971). In the present study, *b* values ranges from 2.5-2.6 that indicate negative allometric growth for *E. danricus* in the Ganges River, NW Bangladesh. In a recent study by Mercy *et al.* (2008) recorded the isometric growth for *E. danricus* from the Western Ghats, India. In addition, Mustafa (1978) described the growth of this flying barb as negatively allometric in two freshwaters including a pond and a running channel, Aligarh, India, which is accordance with the present study. However, ANCOVA revealed significant differences on the LWRs between Bangladesh and Indian waters (p<0.001). Such differences may be ascribed due to observed length ranges of the specimen caught, preservation techniques, health of the stocks, seasonal effect or geographic condition (Hossain *et al*., 2010).

All the LLRs for the combined sexes of *E. danricus* were highly correlated with all r^2 values ≥ 0.974. Since the current study is the first assessment on LLRs of *E. danricus*, so lack of references dealing with LLRs restrains the comparison of the present results with early literature on the same population/ species.

Although most of the studies deal with single condition factor, however we have worked on four condition factors (allometric, K_A; Fulton′s, K_F; (2004) relative, K_R and relative weight, W_R) to assess the health and habitat condition of *E. danricus* in the

Ganges River. Spearman rank correlation test stated that the K_F was more significantly correlated with TL, FL, SL and BW than other factors. Therefore, it can be postulated that, the Fulton′s condition factor (K_F) is the best biometric index for assessing the well-being of this *E. danricus* in the Ganges River and surrounding ecosystem.

Additionally, the Wilcoxon signed rank test indicates W_R was not significantly different from 100 (p=0.295) indicating a balance population with the availability of food and lower predators for *E. danricus* in the Ganges River ecosystem. Moreover, the W_R can use to evaluate the overall health and fitness as well as population-level responses to ecosystem disturbance (Rypel and Richter, 2008). However, there is no available information in literature dealing with the W_R of this species restrains the comparison with our present findings.

The calculated form factor ($a_{3.0}$) was 0.0033 for *E. danricus* in the Ganges River. The $a_{3.0}$ can be used to verify whether the body shape of individuals in a given population or species is significantly different from others (Froese, 2006). There is no reference regarding the form factor of this species in the literature and this is the first study for the estimation of $a_{3.0}$ for *E. danricus* in different water-bodies which will provide the foundation for future studies.

The size at first sexual maturity (L_m) for *E. danricus* was 3.98 (~ 4.00) cm in TL. Studies on L_m for the fishes of Bangladeshi waters are very rare (except Hossain *et al.*, 2010; 2012f). This study presents the first attempt to determine the size at first sexual maturity and natural mortality for *E. danricus* from different waters of Indian sub-continent. Therefore, this study presented the basis for more detailed studies to provide combination of factors affecting the size at first sexual maturity and natural mortality in different populations of *E. danricus* in the Indian sub-continent.

CONCLUSIONS

The present findings describe the life history traits of *E. danricus* including, length-frequency distribution, growth pattern based on LWRs, best fitted condition factor, relative weight, form factor, size at first sexual maturity and natural mortality. The results of this study would be an effective tool for fishery managers, fish biologists and conservationists to initiate early management strategies and regulations for the sustainable conservation of the remaining stocks of this species in the Ganges River and surrounding ecosystem. 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 neighboring countries.

ACKNOWLEDGEMENTS

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

REFERENCES

Ahmed, Z.F., Hossain, M.Y. and Ohtomi, J., 2012. Modeling the growth of Silver hatchet chela *Chela cachius* (Cyprinidae) from the Old Brahmaputra River in Bangladesh using multiple functions. *Zool. Stud.*, **51**: 336-344.

Anderson, R.O. and Neumann, R.M., 1996. Length, weight and associated structure indices. In: *Fisheries techniques* (eds. B.R. Murphy and W.D. Willis), 2nd ed. American Fisheries Society, Bethesda, MD, pp. 447-482.

Bijen, M., Ch, S. and Vishwanath, W., 1990. Nutritive value of sun-dried *Esomus danricus* and smoked *Lepidocephalus guntea*. *Fd. Chem.*, **36:** 89-96.

Binohlan, C. and Froese, R., 2009. Empirical equations for estimating maximum length from length at first maturity. *J. appl. Ichthyol.*, **25:** 611-613.

Carlander, K.D., 1969. *Handbook of freshwater fishery biology*. vol.1. The Iowa State University Press. Ames, IA, 752 pp.

Devi, R. and Boguskaya, N., 2009. *Esomus danrica*. The *IUCN red list of threatened species.* Version 2014.2. <www.iucnredlist.org>. Downloaded on 21 July 2014.

Ferdaushy, M.H. and Alam, M.M., 2015. Length-length and length-weight relationships and condition factor of nine freshwater fish species of Nageshwari, Bangladesh. *Int. J. aquat. Biol.*, **3:** 149-154.

Froese, R., 2006. Cube law, condition factor and weight length relationship: history meta-analysis and recommendations. *J. appl. Ichthyol.*, **22:** 241-253.

Froese, R. and Pauly, D., (Eds). 2015. *Fish base 2015*. World Wide Web electronic publication. Available at: http://www.fishbase.org (accessed on 21 July 2015).

Fulton, T.W., 1904. *The rate of growth of fishes. Twenty-second Annual Reports*, Part III. Fisheries Board of Scotland, Edinburgh, pp. 141-241.

Gerritsen, H.D. and McGrath, D., 2007. Precision estimates and suggested sample sizes for length-frequency data. *Fish. Bull.*, **105:** 116-120.

Gonzalez-Acosta, A. F., De La Cruz-Aguero, G. and De La Cruz-Aguero, J., 2004. Length–weight relationships of fish species caught in a mangrove swamp in the Gulf of California (Mexico). *J. appl. Ichthyol.*, **20:** 154–155.

Hasselblad, V., 1966. Estimation of parameters for a mixture of

normal distributions. *Techno-metrics,* **8:** 431-444.

Hossain, M.Y., 2010a. Morphometric relationships of length-weight and length-length of four Cyprinid small indigenous fish species from the Padma River (NW Bangladesh). *Turk. J. Fish. aquat. Sci.,* **10:** 213-216.

Hossain, M.Y., 2010b. Length-weight, length-length relationships and condition factor of three Schibid catfishes from the Padma River, Northwestern Bangladesh. *Asian Fish. Sci.,* **23:** 329-339.

Hossain, M.Y., 2010c. New maximum size recorded for the Goonch *Bagarius yarelli* (Sykes, 1839) (Siluriformes: Sisoridae) from the Ganges River. *Sains Malay.,* **39**: 157-159.

Hossain, M.Y., Ohtomi, J., Ahmed, Z.F., Ibrahim, A. H.M. and Jasmine, S., 2009b. Length-weight and morphometric relationships of the Tank Goby *Glossogobius giuris* (Hamilton, 1822) (Perciformes: Gobiidae) in the Ganges of Northwestern Bangladesh. *Asian Fish. Sci.,* **22**: 961-969.

Hossain, M.Y., Ahmed, Z.F., Islam, A.B.M.S., Jasmine, S. and Ohtomi, J., 2010. Gonadosomatic index-based size at first sexual maturity and fecundity indices of the Indian River shad *Gudusia chapra* (Clupeidae) in the Ganges River (NW Bangladesh). *J. appl. Ichthyol.,* **26:** 550-553.

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

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

Hossain, M.Y., Hossen, M.A., Ahmed, Z.F., Yahya, K., Rahman, M.M., Ahmed, F. and Ohtomi, J., 2015a. Threatened fishes of the world: *Botia dario* (Hamilton, 1822) (Cypriniformes: Cobitidae). *Croatian J. Fish.,* **73:** 86-88.

Hossain, M.Y., Islam, R., Hossen, M.A., Rahman, O., Hossain, M.A., Islam, M.A. and Alam, M.J., 2015b. Threatened fishes of the world: *Mystus gulio* (Hamilton, 1822) (Siluriformes: Bagridae). *Croatian J. Fish.,* **73:** 43-45.

Hossain, M.Y., Jahan, S., Jewel, M. A.S., Rahman, M.M., Khatun, M.M. and Jasmine, S., 2015c. Biological aspects of the critically endangered fish, *Labeo boga* in the Ganges River, Northwestern Bangladesh. *Sains Malay.,* **44:** 31-40.

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

Hossain, M.Y., Leunda, P.M., Ohtomi, J., Ahmed, Z.F., Oscoz, J. and Miranda, R., 2008. Biological aspects of the Ganges River sprat *Corica soborna* (Clupeidae) in the Mathabhanga River (SW Bangladesh). *Cybium,* **32:** 241-246.

Hossain, M.Y., Ohtomi, J. and Ahmed, Z.F., 2009a. Morphometric, meristic characteristics and conservation of the threatened fish, *Puntius sarana* (Hamilton 1822) (Cyprinidae) in the Ganges River, northwestern Bangladesh. *Turk. J. Fish. aquat. Sci.,* **9:** 223-225.

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

Hossain, M.Y., Rahman, M.M. and Abdallah, E.M., 2012c. Relationships between body size, weight, condition and fecundity of the threatened fish *Puntius ticto* (Hamilton, 1822) in the Ganges River, Northwestern Bangladesh. *Sains Malay.,* **41:** 803-814.

Hossain, M.Y., Rahman, M.M., Fulanda, B., Jewel, M.A.S., Ahamed, F. and Ohtomi, J., 2012a. Length–weight and length–length relationships of five threatened fish species from the Jamuna (Brahmaputra River tributary) River, northern Bangladesh. *J. appl. Ichthyol.,* **28:** 275-277.

Hossain, M.Y., Rahman, M.M., Jewel, A.S., Ahmed, Z.F., Ahmed, F., Fulanda, B., Abdallah, E.M. and Ohtomi, J., 2012b. Conditions- and form-factor of the five threatened fishes from the Jamuna (Brahmaputra River distributary) River, Northern Bangladesh. *Sains Malays.,* **41:** 671-678.

Hossain, M.Y., Rahman, M.M., Miranda, R., Leunda, P.M., Oscoz, J., Jewel, M.A.S., NAIF, A. and Ohtomi, J., 2012d. Size at first sexual maturity, fecundity, length–weight and length–length relationships of *Puntius sophore* (Cyprinidae) in Bangladeshi waters. *J. appl. Ichthyol.,* **28:** 818-822.

Hossain, M.Y., Sayed, S. R. M., Rahman, M.M., Ali, M.M., Hossen, M.A., Elgorban, A.M., Ahmed, Z.F. and Ohtomi, J., 2015d. Length-weight relationships of nine fish species from the Tetulia River, southern Bangladesh. *J. appl. Ichthyol.,* **31**: 967-969.

Hossen, M.A., Hossain, M.Y., Yahya, K. and Pramanik, M.N.U., 2015. Threatened fishes of the world: *Labeo bata* (Hamilton, 1822) (Cypriniformes: Cyprinidae). *Croatian J. Fish.,* **73:** 89-91.

King, M., 2007. *Fisheries biology, assessment and management*. Second Edition. Blackwell Scientific Publications, Oxford, pp. 1-381.

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

Lilabati, H. and Vishwanath, W., 2000. Biochemical, nutritional and microbiological quality of six smoked fishes from Manipur, pp. 89-94.

Mercy, T.V.A., Jacob, E. and Bashak, R.K., 2008. Length-

weight relationship of sixteen species of indigenous ornamental fishes of the Western Ghats of India. *Indian J. Fish.,* **55:** 337-339.

Mustafa, S., 1978. Length-weight relationship and condition factor of common minnow, *Esomus danricus* (Ham.) from different freshwater environments. *Zool. J. Linn. Soc*., **62:** 349-354.

Naeem, M., Zuberi, A., Khan, N. A., Rasool, S. A., Ismail, H.F. and Qamar, A., 2012. Some morphometric relationship traits of *Labeo bata* (Hamilton, 1822) from Head Panjnad, Pakistan. *Afr. J. Biotechnol.,* **11:** 15465-15468.

Peterson, I. and Wroblewski, J.S., 1984: Mortality rates of Fishes in the pelagic ecosystem. *Can. J. Fish. aquat. Sci.,* **41:** 1117–1120.

Rahman, A.K.A., 1989. *Freshwater fishes of Bangladesh.* Zoological Society of Bangladesh. Department of Zoology, University of Dhaka, Dhaka 1000, pp. 364.

Rahman, A.K.A., 2005. *Freshwater fishes of Bangladesh,* 2nd edition, Zoological Society of Bangladesh, Department of Zoology, University of Dhaka, Dhaka 1000, pp. 1-263.

Rahman, M.M., Hossain, M.Y., Jewel, M.A.S., Rahman, M.M., Jasmine, S., Abdallah, E.M. and 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 Malay.,* **41:** 795-802.

Rypel, A.L. and Richter, T.J., 2008. Empirical percentile standard weight equation for the blacktail redhorse. *N. Am. J. Fish. Manage.,* **28:** 1843-1846.

Sani, R., Gupta, B. K., Sarkar, U. K., Pandey, A., Dubey, V. K. and Lakra, W. S., 2010. Length–weight relationships of 14 Indian freshwater fish species from the Betwa (Yamuna River tributary) and Gomti (Ganga River tributary) Rivers. *J. appl. Ichthyol*., **26**: 456–459.

Shafi, M. and Quddus, M.A.A., 1982. *Bangladesher Matshya Sampad* (in Bengeli), Bangla Academy, Dhaka, pp. 1-444.

Sokal, R.R. and Rohlf, F.J., 1987. *Introduction to biostatistics*, 2nd edn. Freeman Publication, New York, pp. 225-227.

Soomro, A.N., Baloch, W.A., Chandio, T.J., Achakzai, W.M. and Saddozai, S., 2012. Condition factor and length-weight relationship of monsoon river prawn *Macrobrachium malcolmsonii malcolmsonii* (H. Milne-Edwards, 1844) (Palaemonidae) in lower Indus River. *Pakistan J. Zool.,* **44**: 1279-1283.

Talwar, P.K. and Jhingran, A.G., 1991. *Inland fishes of India and adjacent countries*, vol. 2. A.A. Balkema, Rotterdam, pp. 541.

Tesch, F.W., 1968. Age and growth. In: *Methods for assessment of fish production in fresh waters* (ed. W. E. Ricker). Blackwell Scientific Publications, Oxford, pp. 93-123.

Tesch, F.W., 1971. Age and growth. In: *Methods for assessment of fish production in fresh waters* (ed. W.E. Ricker) Blackwell Scientific Publications, Oxford, pp. 99-130.