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Life-History Traits of the Endangered Carp *Botia dario* (Cyprinidae) from the Ganges River in Northwestern Bangladesh

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MYH designed the study, supervised the work and wrote the article. MAH and MNUP collected samples and data. KY and MMR statistically analyzed the data. FN, SS, DK, AHB and AME helped in preparation of manuscript.

Key words
***Botia dario*, Length-weight relationship,Condition factors, Relative weight, Size at first sexual maturity, Natural mortality.**

ABSTRACT

The threatened (endangered) carp, *Botia dario* (Hamilton, 1822), is an important, nutritionally valuable food fish in south Asian countries *i.e.*, Bangladesh, Bhutan, India and Nepal. The present study describes the first complete, inclusive description on life-history traits of *B. dario,* including ─ sex ratio, length-frequency distributions (LFDs), length-weight relationships (LWRs), length-length relationships (LLRs), condition factors (allometric, K_A; Fulton's, K_F; relative, K_R), relative weight (W_R), form factor ($a_{3.0}$), size at first sexual maturity (L_m) and natural mortality (M_W) in the Ganges River, northwestern (NW) Bangladesh. Samples were collected occasionally using multiples traditional fishing gears, including cast net (mesh size 1.5 – 2.0 cm), square lift net (mesh size ~1.5) and gill net (mesh size 1.8 – 2.2 cm) from July 2013 to June 2014. A total of 142 individuals of *B. dario* were collected, where 42.0% were males and 58.0% were females. The overall sex ratio did not differ significantly from the expected 1:1 ratio ($\chi^2 = 4.06$, $p > 0.05$). Total length was varied from 5.59 to 12.87 cm and body weight ranged from 3.40 to 27.87 g. All LWRs were highly significant ($p < 0.001$), with all r^2 values exceeding 0.97. The calculated allometric coefficient (b) indicated negative allometric growth in male, female, and combined sexes ($b < 3.00$, $p < 0.001$). All LLRs were highly significant ($p < 0.001$), with coefficients of determination (r^2) values exceeded 0.98. Among the condition factors, K_F is the best index for assessing the well-being of this species in the Ganges River. The W_R was not significantly different from 100 for males ($p = 0.298$) and females ($p = 0.650$), indicating that habitat was still in good condition. The calculated $a_{3.0}$ were 0.0120 and 0.0103 for male and female, respectively. The L_m for male and female *B. dario* were 7.32 cm and 7.90 cm in TL, respectively. Moreover, M_W for this population was estimated as 1.09 y^{-1} in the Ganges River, NW Bangladesh. The findings of this study would be very effective for the sustainable management of this threatened carp in Bangladesh and also neighboring countries.

INTRODUCTION

Knowledge of life-history traits of threatened fishes like *Botia dario* is vital for sustainable management strategies to conserve this species in their natural habitats, whose spawning aggregations are heavily depressed by the local anglers (Hossain *et al*., 2009, 2012a). This small indigenous species (SIS), is a freshwater fish in the family Cyprinidae. It is found in Bangladesh, India (Talwar and Jhingran, 1991), Nepal (Shrestha, 2008), and Bhutan (Petr, 1999). This species is commonly known as "Bengal loach". The *B. dario* is also known as Rani or Bou Mach in Bangladesh (Rahman, 1989), Botuk mach in India (Nath and Dey, 1989) and tiger loach in Nepal (Shrestha, 2008). This loach mainly inhabits rivers and streams (Gopalakrishnan and Ponniah, 2000), and is used as a food fish in Bangladesh (Bhuiyan, 1964). However, the natural population of this species is declining due to heavy harvest, and habitat change and loss (Hossain *et al*., 2015a, b, c; Hossen *et al*., 2015), and categorized as endangered in Bangladesh (IUCN Bangladesh, 2000).

Life-history traits including-length-frequency distributions (LFDs) (Hossain *et al*., 2006a, 2012a, 2013a), length-weight relationships (LWRs) (Hossain *et al*., 2012b,

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c, 2013b, 2015d), length-length relationships (LLRs) (Hossain *et al*., 2006b; Hossain, 2010a, b), condition factor (Hossain *et al*., 2008, 2012a, 2013c), form factor (Hossain *et al*., 2013d, 2014, 2016a), and size at sexual maturity (Hossain *et al*., 2012c, 2012d, 2013d, 2016b) are well documented for of many threatened species of Bangladesh, but there appears to be no available literature on endangered species *B. dario*. Detailed information on the life-history traits of *B. dario* is needed urgently for proper management, and to initiate conservation policies in the Ganges River, NW Bangladesh and adjacent countries. Therefore, this study reports the inclusive and informative description on life-history traits - including sex ratio, LFDs, LWRs, LLRs, condition factors (allometric K_A; Fulton′s K_F; relative K_R), relative weight (W_R), form factor ($a_{3.0}$), size at first sexual maturity (L_m), and natural mortality (M_w) of *B. dario* using individuals of various body sizes from the Ganges River (NW Bangladesh) over a one year study period.

MATERIALS AND METHODS

Study site

This study was conducted in the Ganges River (locally known as Padma River in Bangladesh; Latitude 24°22' N; Longitude 88° 35' E) in Bangladesh. This river is considered an important feeding and spawning ground for freshwater fish species of northwestern Bangladesh (Jones *et al*., 2003; Hossain *et al*., 2012b).

Sampling and laboratory analysis

The samples were collected from the commercial fishers in different locations (Charghat; 24°15' N, 88°44' E; Saheb bazar; 24° 20' N, 88° 34' E and Godagari; 24° 26' N, 88° 19' E) of the Ganges River in the Rajshahi region during July 2013 to June 2014, using different types of traditional fishing gears *i.e.,* cast (mesh size 1.5 – 2.0 cm), square lift (mesh size ~1.5) and gill nets (mesh size 1.8 – 2.2 cm). The fresh samples were immediately chilled in ice upon capture, and then preserved in 10% buffered formalin in the laboratory. Fish were sexed by observing their gonads under a dissecting microscope. Individual lengths including total length (TL), fork length (FL), and standard length (SL) were measured to the nearest 0.01 cm using digital slide calipers and whole body weight (BW) was measured using an electronic balance with 0.01 g accuracy.

Sex ratio and length-frequency distributions (SR and LFDs)

A chi-square test was conducted to determine the sex-ratio deviation from the expected value of 1:1 (male: female). LFDs for males and females were constructed separately using 1.0 cm intervals of TL.

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

LWR was calculated using the equation: $W = a \times L^b$, where, W is body weight (BW, g) and L is body length (cm, see below). The parameters a and b were estimated by linear regression analyses based on natural logarithms: $\ln(W) = \ln(a) + b \ln(L)$. In addition, 95% confidence limits of a and b and the co-efficient of determination (r^2) were estimated. Based to Froese (2006), prior to the regression analyses of ln BW on ln TL, ln-ln plots of length and weight values were performed for visual inspection of outliers, with extremes being omitted from the regression analyses. A t-test was used to confirm whether b values obtained in the linear regression were significantly different from the isometric value (b = 3), (Sokal and Rohlf, 1987). Furthermore, LLRs - including TL *vs*. SL; TL *vs*. FL and SL *vs*. FL relationships were estimated by linear regression (Hossain *et al*., 2006a).

Condition factors

Allometric condition factor (K_A) was calculated using the equation of Tesch (1968): $K_A = W/L^b$, where W is BW in g, L is TL in cm, and b is the LWR parameter. Fulton′s condition factor (K_F) was calculated using the equation: $K_F = 100 \times (W/L^3)$; where, W is BW in g, and L is TL in cm. The scaling factor of 100 was used to bring K_F close to unit. 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 BW in g, L is TL in cm, a and b are the LWR parameters.

Relative weight (W_R)

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

Form factor ($a_{3.0}$)

The $a_{3.0}$ of this species was calculated using the equation of Froese (2006), *i.e.,* $a_{3.0} = 10^{\log a - s(b-3)}$; where, a and b are regression parameters of LWRs and s is the regression slope of *ln a vs. b*. During this study, a mean slope (S) of -1.358 (Froese, 2006) was used to estimate the form factor ($a_{3.0}$), because information on LWRs is unavailable for this species for estimating of the regression of *ln a vs. b.*

Size at first sexual maturity (L_m)

The L_m of *B. dario* in the Ganges River was calculated using the equation of Binohlan and Froese (2009), *i.e.*, log

$(L_m) = -0.1189 + 0.9157 * \log (L_{max})$, for males and females.

Natural mortality (M_W)

M_W of *B. dario* 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 $W = a*L^b$, (where *a* and *b* are regression parameters of LWR).

Table I.- Number of males, females, and sex ratio (male: female = 1:1) of *Botia dario* from the Ganges River, northwestern Bangladesh.

Length class (TL, cm)	Number of specimens			Sex ratio (M/F)	χ^2 (df=1)	Significance
	M	F	Tot			
5.00 – 5.99	12	14	26	1 : 1.17	0.15	NS
6.00 – 6.99	11	7	18	1 : 0.64	0.89	NS
7.00 – 7.99	20	16	36	1 : 0.8	0.44	NS
8.00 – 8.99	6	18	24	1 : 3.0	6.00	*
9.00 – 9.99	7	18	25	1 : 2.57	4.84	*
10.00 – 10.99	0	3	3	-	3.00	NS
11.00 – 11.99	3	2	5	1 : 0.67	0.20	NS
12.00 – 12.99	0	5	5	-	5.00	*
Overall	59	83	142	1 : 1.41	4.06	

M, male; F, female; TL, total length; *df*, degree of freedom; NS, not significant; *, significant.

Statistical analysis

Statistical analyses were performed using GraphPad Prism 6.5 software. The 1- sample t-test was used to compare the mean relative weight (W_R) with 100 (Anderson and Neumann, 1996). The Spearman rank-correlation test was applied to analyze the relationship between the morphometric indices (condition factors) with TL, and BW. Furthermore, LWRs between the sexes were compared by the analysis of covariance (ANCOVA). All statistical analyses were considered significant at 5% ($p < 0.05$).

RESULTS

Sex ratio (SR) and length-frequency distributions (LFDs)

During the study, a total of 142 individuals of *B. dario* were collected from the Ganges River, where 42.0% were males and 58.0% were females, and the overall sex ratio did not differ statistically from the expected 1:1 ratio (df = 1, $\chi 2 = 4.06$, $p > 0.05$) (Table I). However, the variation in sex ratio with length class showed that females were dominated in the 8.00 - 8.99 cm TL and 9.00 - 9.99 cm TL size groups, whereas males were dominated in the 7.00 - 7.99 cm TL range or below and statistically there was no significant differences between these groups ($p > 0.05$).

Table II illustrates the descriptive statistics for length and weight measurements of *B. dario*. The smallest and largest specimens were 5.59 cm and 12.87cm TL and BW ranged from 3.40 to 28.10 g. LFDs showed that, the 7.00 - 7.99 cm TL size group was numerically dominant and constituted 34.0% of the male population, whereas females were dominated in the 8.00 - 10. 99 cm TL size groups that constituted 43.0% of its population (Fig. 1). There was a significant difference for LFD between sexes (Mann-Whitney U-Test, $p = 0.003$). Furthermore, BW for males (mean ± SD =7.75 ± 4.56 g) was significantly different from females (mean ± SD =10.43 ± 5.96 g) (Mann-Whitney U-test, $p = 0.26$).

Table II.- Descriptive statistics and estimated parameters of the length-weight relationships (BW = $a \times L^b$) of *Botia dario* from the Ganges River, northwestern Bangladesh.

Equation	Sex	*n*	Length (cm)		Body weight (g)		Regression parameters		95% CL of a	95% CL of b	r^2	GT
			Min	Max	Min	Max	*a*	*b*				
$BW=a \times TL^b$	M	59	5.70	11.85	3.40	23.87	0.0354	2.655	0.0297–0.0423	2.566 – 2.745	0.98	-A
$BW=a \times FL^b$			4.83	10.51			0.0643	2.532	0.0547–0.0755	2.445 – 2.619	0.98	
$BW=a \times SL^b$			4.05	9.00			0.0910	2.563	0.0746–0.1110	2.446 – 2.680	0.97	
$BW=a \times TL^b$	F	83	4.59	12.87	3.60	28.10	0.0440	2.535	0.0399–0.0486	2.489 – 2.582	0.99	-A
$BW=a \times FL^b$			4.83	11.38			0.0662	2.503	0.0598–0.0732	2.451 – 2.554	0.99	
$BW=a \times SL^b$			4.15	9.50			0.0915	2.526	0.0801–0.1046	2.453 – 2.599	0.98	
$BW=a \times TL^b$	C	142	5.59	12.87	3.40	28.10	0.0422	2.561	0.0385–0.0462	2.517 – 2.605	0.99	-A
$BW=a \times FL^b$			4.83	11.38			0.0675	2.498	0.0619–0.0735	2.453 – 2.543	0.98	
$BW=a \times SL^b$			4.05	9.50			0.0978	2.502	0.0874–0.1094	2.438 – 2.565	0.97	

M, male; F, female; C, combined sex; *n*, sample size; Min, minimum; Max, maximum; *a*, *b* are LWR parameters; slope; CL, confidence limit for mean values; r^2, coefficient of determination; GT, growth type; -A, negative allometric.

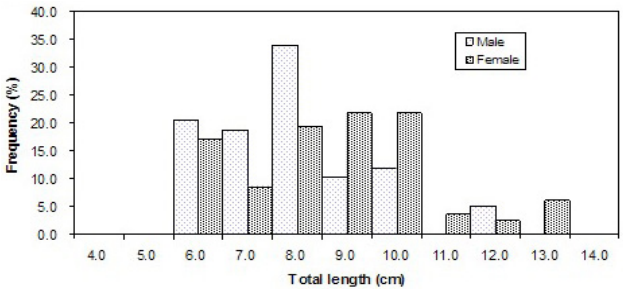

Fig. 1. Length-frequency distributions of male and female *Botia dario* in the Ganges River, northwestern Bangladesh.

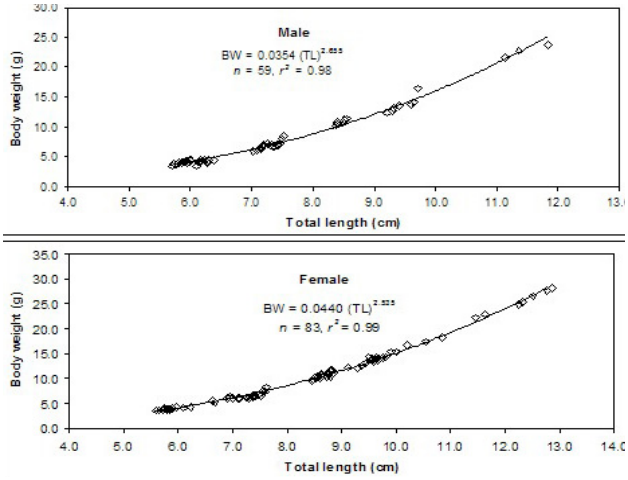

Fig. 2. The length-weight relationships (BW = a * TL^b) of male and female *Botia dario* in the Ganges River, northwestern Bangladesh.

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

The 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 *B. dario* are given in Figure 2 and Table II. The (b) values of the LWRs indicated negative allometric growth (-A) in males, females, and combined sexes ($b < 3.00$, $p < 0.001$) (Table II). All LWRs were highly significant ($p < 0.001$), with r^2 values exceeding 0.97. The ANCOVA revealed significant differences in LWRs between the sexes ($p = 0.012$).

Moreover, the LLRs— including TL *vs.* SL, TL *vs.* FL, and SL *vs.* FL along with the estimated parameters and the coefficient of determination (r^2) are presented in Table III. All LLRs were highly significant ($p < 0.001$), and most coefficients of determination exceeded 0.98.

Condition factors

The K_A values ranged from 0.0318 to 0.0446 for males and 0.0406 to 0.0500 for females (Table IV). According to an unpaired t- test, K_A was significantly different between sexes ($p < 0.001$). The K_F ranged from 1.4344 to 2.1012 for males and 1.3181 to 2.1513 for females, respectively (Table IV), and Mann-Whitney U-test stated that, K_F was significantly different between males and females ($p = 0.001$). In addition, K_R ranged from 0.8178 to 1.1480 for males and 0.8850 to 1.0910 for females (Table IV) and Mann-Whitney U-test, showed significant deviations between sexes ($p = 0.834$) in our study area.Calculated W_R for males were 81.783 to 114.810 and for females were 88.503 to 109.100 (Table IV). According to a 1-sample t-test, W_R showed no significant differences from 100 for both males ($p = 0.298$) and females ($p = 0.650$). The relationship between TL *vs.* W_R is shown in Figure 3, whereas the relationships of different condition factors (K_A, K_F, K_R, and W_R) with TL and BW are shown in Table V. From the above four condition factors only the K_F has very highly significant correlation with TL and BW ($p < 0.001$).

Table III.- The estimated parameters of the length-length relationships ($y = a + b \times x$) of *Botia dario* from the Ganges River, northwestern Bangladesh.

Equation	Sex	Regression parameters		95% CL of *a*	95% CL of *b*	r^2
		a	*b*			
TL = $a + b \times$ SL	M	0.1937	1.309	-0.0279 to 0.4155	1.269 – 1.348	0.98
TL = $a + b \times$ FL		0.4000	1.084	0.2726 to 0.5275	1.065 – 1.103	0.99
SL = $a + b \times$ FL		0.2323	0.817	0.0303 to 0.4377	0.786 – 0.847	0.98
TL = $a + b \times$ SL	F	-0.1435	1.349	-0.3459 to 0.0589	1.317 – 1.380	0.98
TL = $a + b \times$ FL		0.1262	1.127	-0.0007 to 0.2531	1.110 – 1.144	0.99
SL = $a + b \times$ FL		0.2647	0.826	0.0971 to 0.4324	0.804 – 0.848	0.98
TL = $a + b \times$ SL	C	0.0496	1.324	-0.0975 to 0.1968	1.300 – 1.348	0.98
TL = $a + b \times$ FL		0.2172	1.113	0.1272 to 0.3072	1.101 – 1.126	0.99
SL = $a + b \times$ FL		0.1949	0.831	0.0679 to 0.3218	0.813 – 0.848	0.98

TL, total length; FL, fork length; SL, standard length; M, male; F, female; C, combined sex; a, intercept; b, slope ; CL, confidence limit for mean values; r^2, coefficient of determination.

Table IV.- Allometric (K_A), Fulton′s (K_F), and relative condition factors (K_R) and relative weight (W_R) of *Botia dario* from the Ganges River, northwestern Bangladesh.

Condition factors	Sex	n	Min	Max	Mean ± SD	95% CL
K_A	M	59	0.0318	0.0446	0.0392±0.0025	0.0385 – 0.0398
K_F			1.4344	2.1012	1.7984±0.1654	1.7443 – 1.8415
K_R			0.8178	1.1480	1.0088±0.0644	0.9920 – 1.0256
W_R			81.783	114.810	100.880±6.446	99.200 – 102.560
K_A	F	83	0.0406	0.0500	0.0457±0.0021	0.0453 – 0.0462
K_F			1.3181	2.1513	1.6741±0.1953	1.6314 – 1.7167
K_R			0.8850	1.0910	0.9976±0.0464	0.9874 – 1.0078
W_R			88.503	109.100	99.767±4.646	98.752 – 100.781
K_A	C	142	0.0318	0.0446	0.0385±0.0022	0.0381 – 0.0389
K_F			1.3181	2.1513	1.7257±0.1929	1.6937 – 1.7577
K_R			0.8178	1.1480	0.9914±0.0574	0.9819 – 1.0010
W_R			81.783	114.810	99.147±5.740	98.195 – 100.100

M, male; F, female; C, combined sex; *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 V.- Relationships of condition factor with total length (TL) and body weight (BW) of *Botia dario* from the Ganges River, northwestern Bangladesh.

Relationships	Sex	r_s values	95% CL of r_s	p values	Significance
TL *vs.* K_A	M	0.0810	-0.1864 to 0.3371	$p = 0.542$	ns
TL *vs.* K_F		-0.6742	-0.7960 to -0.4981	$p < 0.001$	***
TL *vs.* K_R		0.0762	-0.1910 to 0.3329	$p = 0.566$	ns
TL *vs.* W_R		0.0817	-0.1857 to 0.3378	$p = 0.539$	ns
BW *vs.* K_A		0.2661	0.0030 to 0.4948	$p = 0.042$	*
BW *vs.* K_F		-0.5120	-0.6835 to -0.2878	$p < 0.001$	***
BW *vs.* K_R		0.2615	-0.0020 to 0.4911	$p = 0.045$	*
BW *vs.* W_R		0.2660	0.0031 to 0.4949	$p = 0.042$	*
TL *vs.* K_A	F	0.3310	0.1178 to 0.5151	$p = 0.002$	**
TL *vs.* K_F		-0.8713	0.9160 to -0.8047	$p < 0.001$	***
TL *vs.* K_R		0.1140	-0.1108 to 0.3276	$p = 0.305$	ns
TL *vs.* W_R		0.0983	-0.1270 to 0.3129	$p = 0.379$	ns
BW *vs.* K_A		0.3782	0.1706 to 0.5536	$p = 0.002$	**
BW *vs.* K_F		-0.8310	-0.8890 to -0.7468	$p < 0.001$	***
BW *vs.* K_R		0.1838	-0.0397 to 0.3898	$p = 0.096$	ns
BW *vs.* W_R		0.1682	-0.0558 to 0.3760	$p = 0.127$	ns
TL *vs.* K_A	C	-0.2015	-0.3588 to -00331	$p = 0.016$	*
TL *vs.* K_F		-0.8470	-0.8888 to -0.7909	$p < 0.001$	***
TL *vs.* K_R		-0.2022	-0.3594 to -0.0338	$p = 0.015$	*
TL *vs.* W_R		-0.2031	-0.3603 to -0.0348	$p = 0.015$	*
BW *vs.* K_A		-0.0698	-0.2366 to 0.1009	$p = 0.409$	ns
BW *vs.* K_F		-0.7645	-0.8265 to -0.6830	$p < 0.001$	***
BW *vs.* K_R		-0.0706	-0.2373 to 0.1001	$p = 0.404$	ns
BW *vs.* W_R		-0.0718	-0.2384 to 0.0990	$p = 0.396$	ns

TL, total length; BW, body weight; K_A, allometric condition factor; K_F; Fulton′s condition factor; K_R, relative condition factor; W_R, relative weight; M, male; F, female; C, combined sex; r_S, Spearman rank-correlation values; CL, confidence limit; *p*, shows the level of significance; *ns*, not significant; * significant ($p \leq 0.005$); ** highly significant ($p \leq 0.01$); *** very highly significant ($p \leq 0.001$).

Table VI.- The calculated form factor, ($a_{3.0}$) and size at first sexual maturity (L_m) of *Botia dario* from the Ganges River, northwestern Bangladesh.

Sex	*n*	Length (cm)			*a*	*b*	$a_{3.0}$	L_m	95% CL of L_m
		Type	Min	Max					
Male	59	TL	5.7	11.85	0.0354	2.655	0.0120	7.32	5.90 – 9.11
Female	83	TL	5.59	12.87	0.0440	2.535	0.0103	7.90	6.34 – 9.85

n, sample size; TL, total length; Min, minimum; Max, maximum; *a*, intercept; *b*, slope; $a_{3.0}$, form factor; L_m size at first sexual maturity; CL, confidence limit

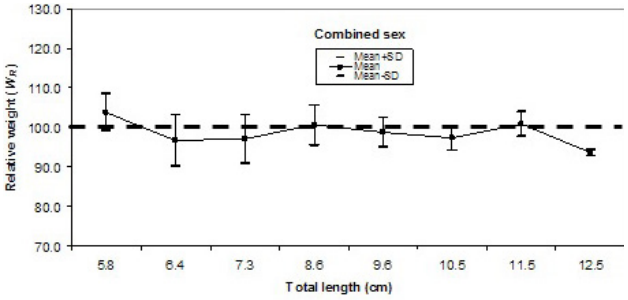

Fig. 3. The relationships between total length and relative weight of *Botia dario* in the Ganges River, northwestern Bangladesh.

Form factor ($a_{3.0}$)

The calculated $a_{3.0}$ were 0.0120, 0.0103, and 0.0107 for males, females, and combined sexes of *B. dario,* respectively, in the Ganges River (Table VI).

Size at first sexual maturity (L_m)

The calculated L_m for males and females were 7.32 cm (95% CL = 5.90 – 9.11 cm TL), 7.90 cm TL (95% CL=6.34 – 9.85 cm TL), respectively (Table VI).

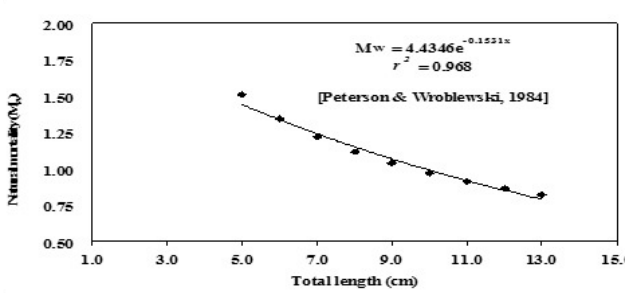

Fig. 4. The relationships between natural mortality and total length of *Botia dario* in the Ganges River, northwestern Bangladesh.

Natural mortality (M_W)

Mean M_W for the population of *B. dario* was estimated as 1.09 year^{-1} in the Ganges River, NW Bangladesh. However, M_W was very high for individuals under 5.00 cm TL in the Ganges River, but it was decreased with larger body sizes (Fig. 4).

DISCUSSION

Information on life-history traits of *B. dario* from Bangladesh was lacking in the literature; until our study. We collected 142 individuals of various body sizes using traditional fishing gears in the lower Ganges River, NW Bangladesh. We examined life-history traits, including length-weight relationships using several length measurements (*e.g.*, TL, FL, SL) and various condition factors (K_A, K_F, K_R, and W_R), which could be compared to linear dimensions of other populations from other locations.

Departure from 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.*, 2012e). In our study of 142 individuals of *B. dario*, the male and female sex ratio was 1:1.41. The overall sex ratio did not differ significantly from the expected value of 1:1. No sexual dimorphism (all male or all female) was found in the present study. However, lack of adequate information on sex ratio of this species restrains the comparison with other studies.

Here we did not catch *B. dario* smaller than 5.59 cm TL during the sampling period, which can be attributed either to the absence of smaller fishes (< 5.59 cm TL) in the population or selectivity of fishing gears (Hossain *et al.*, 2012f). The maximum length of *B. dario* in our study was 12.87 cm TL, which is lower than the maximum recorded value of 15.1 cm TL (Rahman, 1989) and is an alarming for decreasing the size. Maximum length is necessary to estimate population parameters, including asymptotic length and growth coefficient of fishes, which are important for fisheries resource planning and management (Hossain *et al.*, 2012d).

The regression parameter *b* of LWRs for males (2.655) was larger than that of females (2.535), indicating that male fish add body weight more rapidly than females.

However, *b* value for male, female, and combined sexes of *B. dario* were all less than 3.00. Thus, the growth of *B. dario* indicates negative allometry in the Ganges River, NW Bangladesh, which means faster growth in length than in weight. There was no available literature on this species, so it was impossible to compare with our study. Our data for *B. dario* were collected over an extended period of time, and data were not representative of any particular season, and should be treated only as mean-annual values for comparative purposes. All the LLRs for male, female, and combined sexes of *B. dario* are highly correlated.

In our study, there were four condition factors: K_A, K_F, K_R and W_R. Spearman rank– correlation test stated that among these condition factors; only K_F has very highly significant correlation with TL and BW than other condition factors (Table V) and K_F can be used for assessing wellbeing of this species in the Ganges River and surrounding ecosystems. In addition, based on a 1-sample t-test, the relative weight W_R showed no significant differences from 100 for males (p = 0.298) and females (p=0.650). This suggests that habitat was in suitable condition, with good food availability and a balance of the prey-predator relationships for *B. dario* in the Ganges River.

The $a_{3.0}$ were 0.0120 and 0.0103 for males, females of *B. dario* in the Ganges River. The $a_{3.0}$ can assess whether the body shape of individuals in a given population or species is considerably different from others (Froese, 2006). Unfortunately, there are no literature data on the form factor for this species, so our study of *B. dario* provides the foundation for future studies.

The L_m for males and females of *B. dario* were 7.32 cm, and 7.90 cm in TL, respectively. Studies on L_m for Bangladeshi fresh water fishes are very rare (except Hossain *et al*., 2010, 2012d, 2013d). Our study is the first attempt to determine the size of first sexual maturity for *B. dario* from the Ganges River. Therefore, our study will provide the basis for more detailed studies to ascertain the factors affecting the sizes of first sexual maturity and spawning for different populations of *B. dario.*

The natural mortality (M_w) for the population of *B. dario* were estimated as 1.09 year^{-1} in the Ganges River, NW Bangladesh. This is the first study on natural mortality for this species and it was not possible to compare with other literature. It would be useful to find out the reasons for fish mortality in our study area.

CONCLUSION

The present study describe the life history traits of *B. dario,* including length-frequency distribution, length-weight and length-length relationships, condition factors (allometric, Fulton′s, and relative factors), relative weight, form factor, size at sexual maturity, and natural mortality rate. The results of this study should be an effective tool for fishery managers, biologists, and conservationists to initiate proactive management strategies and regulations for the sustainable management of the remaining stocks of this species in the Ganges River and surrounding ecosystems.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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