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Length-weight relationship and growth of *Labeo bata*

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Abstract. This study was executed to elucidate the length-weight relationship (LWR) yet the annual condition of the *Labeo bata* (Hamilton, 1822), an immensely important fishery of Bangladesh. Overall, 447 specimens employed during this study were collected by using traditional fishing gear (cast net). Total length (TL) of each individual was measured closest to 0.1 cm and whole body-weight (BW) nearest to 0.01 g accuracy, respectively. The values of 'b' indicated negative allometric growth patterns for males (b= 2.913) whilst an isometric value for females (b= 3.038) and both sexes (b= 2.989), respectively. Furthermore, the Fulton condition factor value was highest for males (0.98) over females (0.97). All of these outcomes will bring advanced scientific knowledge and will be helpful for sustainable management of this least concern fish species (*Labeo bata*) in the river ecosystem of Bangladesh.
Keywords: Length-weight relationship, Growth performance, Condition factor

Introduction

Labeo bata (Hamilton, 1822) locally known as 'bata' is a freshwater Indian minor carp known for its taste and fetches a high price in the market (Chakraborty and Mirza 2007, Paul *et al.* 2018) belongs to the family Cyprinidae (Cypriniformes) inhabits water bodies of Bangladesh, India, Pakistan, Myanmar, and Nepal (Froese and Pauly 2015) and is an economically important target species for small and large-scale fisheries in the Indian subcontinent. However, it is registered as least concern fish species in Bangladesh during 2015 (IUCN 2015). Unfortunately, the population of this species is declining day by day as a result of habitat loss, overexploitation, and other ecological changes (Hossain 2014, Hossain *et al*. 2015, Hossen *et al*. 2015). And as the species is least concern fish species in Bangladesh, it is urgent need to assess the commercially important species on different aspects like LWRs, growth rates, age structures, and other components of population dynamics especially in the northern part of Bangladesh.

Length-weight relationship (LWR) is very vital for stabilizing the taxonomic characters (Thomas *et al*. 2003, Pervin and Mortuza 2008) and for proper management and exploitation of the population of fish species (Anene 2005). This information is useful in estimating length, growth rates, age structures, and further components of fish population dynamics (Kolher *et al*. 1995). Subsequently, assessments of LWRs permit fisheries scientists to determine the fish condition (Petrakis and Stergiou 1995), compare life history (Stergiou and Moutopoulos 2001), estimate the weight of fish from length and vice-versa (Morato *et al*. 2001), and calculate biomass from length-frequency distributions (Dulcic and Kraljevic 1996). Moreover, LWRs the of fish are essential for optimizing the production of economically important fish species along with having significant importance in growth studies, the general well-being of the fish population, and also reveal the nutritional status of the species (Sheikh and Ahmed 2018). On the other hand, condition factor is the quantifiable parameter specifying the state of well-being of the fish that will decide present and future population success by its influence on survival, growth, and reproduction (Hossain *et al*. 2006). It is used to compare the inter- and intra-specific "condition" of fish (Oni *et*

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al. 1983). In addition, it also acts as a useful index to assess the status of the aquatic ecosystem (Anene 2005) and influences the reproductive cycle in fish (Welcome, 1979). Nevertheless, there are only a few studies executed including the biology, and breeding performance of *L. bata* available in the literature (Azadi and Naser 1996, Hossain *et al.* 2006, Hossen *et al*. 2018). Despite the importance of condition factor, length-weight relationship, and growth performance in fisheries science, information on *L. bata* fish species in Bangladesh is currently scarce. In this background, the current study is a maiden attempt in Bangladesh aimed at ending the paucity of this basic information about their growth characteristics of this least concern fish species declared by IUCN Bangladesh (2015).

Materials and Methods

The experiment was carried out at the Atrai River (Longitude 24°29'00" N and Latitude 89°03'00" E), the westernmost tributary of the Brahmaputra River which locates at Dinajpur district (Rangpur division) of Bangladesh and linked with the Korotoa River, a distributary of the Brahmaputra River. It originates in West Bengal (India) and after flowing through Bangladesh, it enters India again. The sampling was accompanied for a period of one year from May 2018 to April 2019. Samples of *L. bata* fish were collected monthly during day time (10:00am-4:00pm) from the river usually by using the traditional fishing gear 'cast net' and instantly preserved with ice in the landed area and kept refrigerated upon arrival at the laboratory (Kibria and Ahmed, 2005). All specimens (447) were sexed as male (166) and female (281) by gonad observation and morphometric characteristics under microscopic observation. The specimens were individually measured and weighed moreover, total length (TL) was measured in cm using a measuring scale from the tip of the anterior part of the body to the tip of the caudal fin and the body weight (BW) in gram (g) using a digital balance (Shimadzu, EB-430DW; Shimadzu Seisakusho, Tokyo, Japan) with the nearest 0.1 cm, and 0.01 g accuracy, respectively.

Length-weight relationship: The length-weight relationship (LWR) was determined separately using the log-transformed formula described by Le Cren (1951) as $BW = aTL^b$. The values of constants 'a' and 'b' were estimated after logarithmic transformation of the equation using least-square linear regression, ln BW= ln a + b ln TL where BW is the body weight, TL is the total length, a is coefficient related to body form, and b is an exponent indicating isometric growth (b= 3) or allometric (negative allometric: b<3, or positive allometric: b>3) followed by Ricker (1973). To observe the significant differences from isometric values of b, a t-test was applied. Moreover, the parameters a and b of the LWR between sexes were compared by the analysis of covariance. All statistical analyses were considered significant at 5% (p<0.05). Fulton's Condition Factor (CF) for each individual was determined using the formula of $CF = (BW \times 100) / TL^3$ (Fulton 1904).

Growth parameters: The length-frequency data were analyzed with FiSAT software (Gayanilo*et al*. 2002) to estimate population parameters. The growth parameters estimation was based on the von Bertalanffy Growth Function (VBGF) (Gayanilo and Pauly 1997) which is expressed as follows: $L_t = L_\infty [1\text{-exp } \{-K (t-t_o)]$ where L_∞ is the asymptotic length at which an average fish would achieve until their live and grow, K is the growth coefficient, and t_o is the age the fish would have been at zero length. Moreover, length-based frequencies data, 'L_∞' was taken from the Powell-Wetherall plot using the equation as $L_\infty = -a/b$ (Sparre and Venema 1998) where L∞ is the asymptotic length, 'a' and 'b' are regression parameters from LWR. Growth performance index (Ø) (Pauly and Munro 1984) was calculated through the following equation as $(Ø) = \log_{10}K + 2\log_{10}L\infty$ where L∞ is the asymptotic length, and K is the growth coefficient of the fish species

(year^{-1}). The value of asymptotic length L∞ and growth coefficient is obtained by the ELEFAN-1 program based on length frequency data (Pauly and David 1981).

Statistical analysis: Length-weight relationship and condition factor were calculated according to the method mentioned by Le Cren (1951). Statistical analyses of this study were conducted using IBM SPSS (Statistical Package for Social Science) software version 22. The normal distribution of data was checked through the normality test based on Shapiro-Wlk's test. To observe the significant differences from isometric values of b, t-test was applied. Moreover, the parameters a and b of the LWR between sexes were compared by the analysis of covariance. All statistical analyses were considered significant at 5% (p<0.05).

Results

From the total of 447 individuals (male= 166; female= 281) of *L. bata* sampled in the Atrai River, northern Bangladesh during this study period, 37.13% were males and 62.86% were females. The male and female sex ratio of *L. bata* in this study was 1:1.69. The descriptive statistics on sample size (n), minimum and maximum lengths along with measurement of body weight, regression parameters a and b of the LWR, and their 95% confidence limits and coefficients of determination (r^2) for male, and female are demonstrated (Table 1). The total length ranged from 10.7 to 30.7 cm for male fish and 11.4 to 31 cm for female fish. The mean ±SD value of total length for male, female, and both sexes were 23.5±3.7, 24.23±3.8 and 24±3.8, respectively (Table 1). Moreover, the body weight measurement extended from 14.2 to 315.5 g for males and 15 to 355.5 g for females. The mean ± SD value of body weight for male, female, and both sexes were 136.6±56.2, 147.6±58.7 and 143.5±57.6, respectively (Table 1). The mean ± SD value of condition factor obtained in this study for male, female, and both sexes were 0.98± 0.11, 0.97±.0.09, and 0.98±0.10, respectively. Furthermore, the highest CF value recorded was 1.09 ± 0.11 for male in August and the lowest value recorded was 0.9±0.1 for female in June (Table I).

The length-weight relationships of the total length and body weight of male, female and both sexes of the *L. bata* fish is displayed (Fig. 1). The intercept (a) and the slope (b) of the regression analysis for male were 0.0129 and 2.9127 (Fig. 1A), for female were 0.0085 and 3.0387 (Fig. 1B) and for both sexes were 0.01 and 2.989 (Fig. 1C), respectively. Moreover, the 'b' value of male (2.9127) expresses negative allometric growth while female (3.0387) and both sexes (2.989) express isometric growth (Fig. 1). The 'r' value of male (0.97), female (0.96) and both sexes (0.96) showed a high degree of correlation between total length and body weight and its positive value indicates increase of body weight with the increase of total length.

Table I. Correlation factor and length-weight relationship of *Labeo bata*

	Sex	No	TL (cm)		Mean TL/SD	BW (g)		Mean BW/SD	a value	b value	95% CI a	95% CI b	CF (± SD)	r	r^2	Growth
			min	max		Min	Max									
May	M	6	13.4	29	21.8±5.7	20.1	294.6	128.6±101.	0.002	3.412	-6.781 to -4.963	3.115 to 3.709	1±0.13	0.997	0.996	PA
	F	15	11.7	25.6	18.42±4.9	15	183.1	76±56	0.003	3.319	-6.470 to -4.677	3.010 to 3.630	0.97±0.15	0.965	0.976	PA
	Both	21	11.7	29	19.4±5.2	15	294.6	91±73.3	0.003	3.334	-6.245 to -4.996	3.122 to 3.546	0.97±0.14	0.974	0.982	PA
June	M	3	20.3	22	21.1±0.9	81	100	90±9.5	0.031	2.613	-6.427 to -.515	1.644 to 3.583	1±0.2	0.956	0.999	NA
	F	9	15	27.4	20.2±4.6	27	167	85.9±54.7	0.004	3.203	-6.405 to -4.248	2.843 to 3.564	0.9±0.1	0.89	0.984	PA
	Both	12	15	27.4	20.4±4	27	167	86.9±46.9	0.004	3.217	-6.246 to -4.465	2.922 to 3.514	0.91±0.08	0.99	0.983	PA
July	M	7	21.8	22.9	22.6±0.4	29	167	111.1±7.9	0.005	3.18	-6.076 to -4.623	-1.316 to 5.764	0.97±0.06	0.908	0.979	NA
	F	14	17.5	29.9	23.3±3.2	102	127.5	119.1±39.9	0.036	2.56	-6.005 to -.642	2.645 to 3.715	0.92±0.15	0.92	0.78	NA
	Both	21	17.5	29.9	23±2.6	41	177.5	116.4±32.7	0.039	2.535	-5.318 to -1.134	1.867 to 3.203	0.94±0.12	0.87	0.768	NA
Aug.	M	17	10.7	23.9	17.5±4	14.2	159.7	67.4±45.1	0.010	3.021	-5.208 to -3.959	2.802 to 3.241	1.09±0.11	1.09	0.982	IS
	F	20	11.4	25.4	19.3±4.4	15.4	170.5	82.3±46.1	0.010	2.984	-4.834 to -4.287	2.891 to 3.077	1±0.05	0.999	0.996	NA
	Both	37	10.7	25.4	18.5±4.3	14.2	170.5	75.4±45.6	0.011	2.964	-4.800 to -4.128	2.848 to 3.080	1.04±0.09	0.99	0.987	NA
Sep.	M	10	16.3	28.7	25.1±3.5	38.2	228.1	160.5±56.3	0.004	3.214	-6.075 to -4.615	2.988 to 3.442	0.95±0.05	0.954	0.992	PA
	F	20	18	29.7	24.7±3	57.6	268.9	157.7±56.2	0.009	3.011	-5.593 to -3.691	2.714 to 3.308	1±0.08	1.001	0.961	IS
	Both	30	16.3	29.7	24.9±3.1	38.2	268.9	158.6±55.3	0.007	3.092	-5.569 to -4.266	2.889 to 3.295	0.99±0.07	0.98	0.972	IS
Oct.	M	15	23.9	27.7	25.9±1.4	133.8	237	175±29.5	0.030	2.657	-4.296 to -2.208	1.795 to 3.519	1±0.06	1.001	0.773	NA
	F	28	24.1	29.7	26.4±1.5	144.3	237	183.1±29.5	0.030	2.657	-4.791 to -2.208	2.263 to 3.052	0.99±0.06	0.987	0.880	NA
	Both	43	23.9	29.7	26.2±1.4	133.8	237	180.3±27.2	0.031	2.645	-4.574 to -2.339	2.303 to 2.986	0.99±0.06	0.92	0.856	NA
Nov.	M	11	20.3	27.4	24.5±2.6	81	200	152.3±38.6	0.063	2.428	-5.596 to .075	1.540 to 3.316	1.03±0.16	1.02	0.809	NA
	F	14	21.6	30.2	26.3±2	97.5	270.5	176.7±40.2	0.012	2.915	-5.952 to -2.793	2.432 to 3.399	0.96±0.06	0.958	0.935	NA
	Both	25	20.3	30.2	25.5±2.4	81	270.5	166±40.6	0.041	2.556	-4.571 to -1.801	2.128 to 2.984	0.99±0.12	0.932	0.869	NA
Dec.	M	11	25.6	28.9	27.2±1.2	144.5	232.5	186.9±29.1	0.001	3.732	-10.168 to -	2.797 to 4.668	0.95±0.06	0.94	0.9	PA
	F	19	19.6	29.7	27±1.8	144	355.5	144.9±46.4	355.5	2.998	-4.835 to -4.289	3.374 to 2.622	1±0.14	1.00	0.943	IS
	Both	30	22.2	31.2	27.1±4	144	355.5	194.9±41.1	0.029	2.662	-5.777 to -1.264	1.978 to 3.347	0.98±0.12	0.83	0.693	NA
Jan.	M	22	24.9	30.7	26.6±1.3	139.5	315.5	176.6±37.7	0.001	3.671	-8.381 to -5.393	3.216 to 4.126	0.98±0.08	0.92	0.934	PA
	F	29	24.9	31	27.6±1.6	158	355.5	207.5±37.1	0.012	2.93	-6.38 to -2.40	2.33 to 3.530	0.98±0.08	0.97	0.788	NA
	Both	51	24.9	31	27.2±4	139.5	315.5	194.2±60.3	0.004	3.202	-6.573 to -4.071	2.823 to 3.581	0.95±0.07	0.92	0.854	PA
Feb.	M	14	21.8	27.4	24±2.1	100	222.5	142.3±41.8	0.003	3.32	-6.070 to -4.612	2.932 to 3.711	1.02±0.23	0.95	0.966	NA
	F	39	21.3	28.7	25.5±2.2	95.5	228.5	159.4±39.5	0.021	2.745	-5.008 to -2.677	2.385 to 3.105	0.94±0.08	0.94	0.865	NA
	Both	53	21.3	28.7	25.1±3.6	95.5	228.5	154.9±54.1	0.029	2.654	-4.729 to -2.346	2.285 to 3.025	0.97±0.14	0.89	0.802	NA
Mar.	M	20	20.1	28.9	24.1±3.2	78.5	248.5	144.2±58.6	0.007	3.092	-5.551 to -4.304	2.896 to 3.288	0.97±0.05	0.97	0.983	IS
	F	32	19.3	28.2	24.4±2.7	61.5	236.5	146.9±49.1	0.004	3.215	-5.929 to -4.720	3.026 to 3.405	0.97±0.07	0.97	0.975	PA
	Both	52	19.3	28.9	24.3±2.9	61.5	248.5	145.8±52.4	0.005	3.158	-5.559 to -4.719	3.026 to 3.290	0.97±0.06	0.98	0.978	PA
April	M	30	15.5	24.9	21.5±2	34	151.5	98.8±26.4	0.006	3.137	-5.592 to -4.544	2.967 to 3.308	0.96±0.04	0.95	0.980	PA
	F	42	19.3	27.4	22.6±1.8	65.5	220	114.9±31.7	0.008	3.033	-5.633 to -3.829	2.744 to 3.323	0.98±0.07	0.98	0.918	IS
	Both	72	15.5	27.4	22.1±2	34	220	107.9±30.5	0.006	3.109	-5.480 to -4.471	2.947 to 3.273	0.97±.06	0.97	0.953	PA
Overall	M	166	10.7	30.7	23.5±3.7	14.2	315.5	136.6±56.2	0.012	2.913	-4.673 to -4.229	2.871 to 3.013	0.98±0.11	0.97	0.942	NA
	F	281	11.4	31	24.23±3.8	15	355.5	147.6±58.7	0.008	3.038	-4.986 to -4.585	2.983 to 3.109	0.97±.0.1	0.96	0.936	IS
	Both	447	10.7	31	24±3.8	14.2	355.5	143.5±57.6	0.009	2.989	-4.802 to -4.502	2.958 to 3.053	0.98±0.10	0.96	0.938	IS

*(TL) total length, (BW) body weight, (min) minimum, (max) maximum, (a) intercept, (b) slope, (CF) condition factors, (r) correlation coefficient, (r^2) coefficient of determination, (NA) negative allometric, (IS) isometric, (PA) positive allometric, (SD) standard deviation, (M) male, (F) female, (B) both sexes

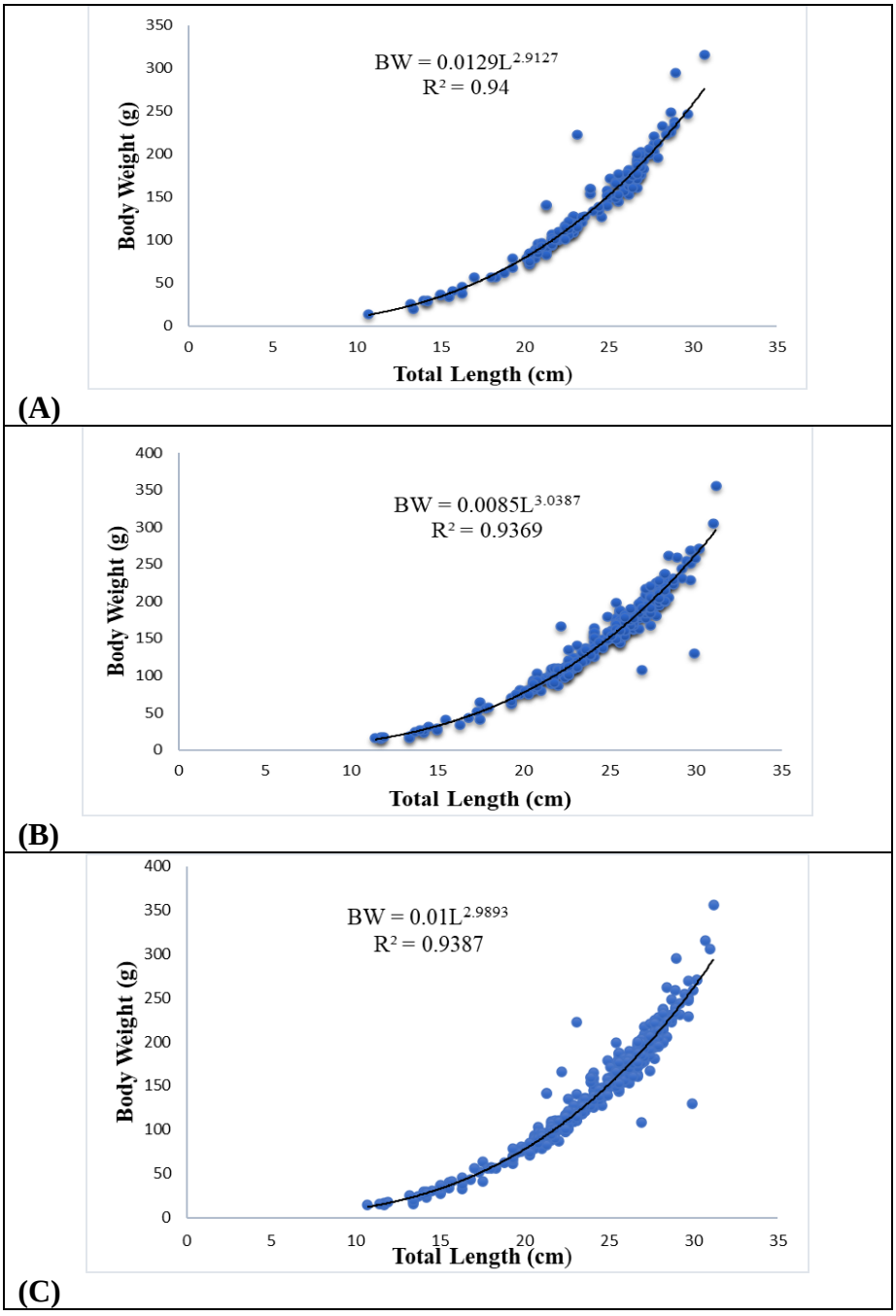


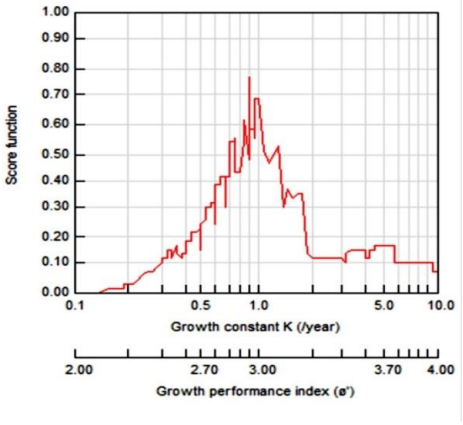
Fig. 1. The relationship between total length (cm) and body weight (g) for (A) male (B) female and (C) both sexes of *L. bata*.

In the present study, the value of L_∞ for male, female and both sexes were 32.03 cm, 32.02 cm and 32.03 cm, respectively. The values of K were also obtained 0.92 y^{-1}, 1.30 y^{-1}, and 1.30 y^{-1} for male, female and both sexes, respectively (Table II). Furthermore, the growth performance index (Ø) value was calculated as 2.974, 3.124, and 3.125 for male, female and both sexes, respectively (Table 2). The growth coefficient and growth performance index of male, female, and both sexes are represented (Fig. 2), respectively.

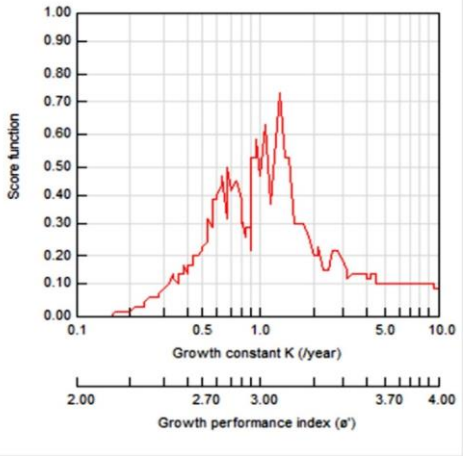
Table II. Growth parameters of *L. bata* for male, female and both sexes

Sex	L∞ (cm)	K (y^{-1})	Ø
Male	32.03	0.92	2.974
Female	32.02	1.30	3.124
Both sexes	32.03	1.30	3.125

*L∞ = asymptotic length, K = growth coefficient and Ø = growth performance indices



(A)



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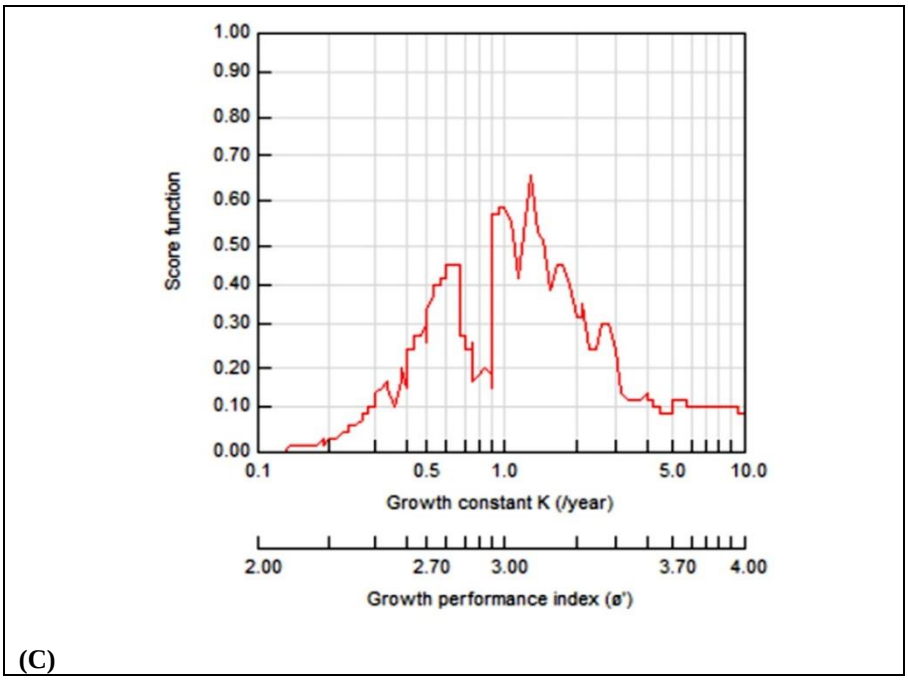

Fig. 2. Growth coefficient and growth performance index for (A) male (B) female and (C) both sexes of *L. bata*.

Discussion

The length-weight relationship (LWR) of fish is one of the vital tools because it allows the estimation of the average weight (Mirzaei *et al*. 2015) and population size of fish stock for its rational exploitation (Dulcic and Kraljevic 1996, Froese 2006). Subsequently, fish specimens of a given length, exhibiting higher weight are said to be in better condition (Bolger and Connolly 1989, Anyanwu *et al*. 2007). In this study, females are found comparatively weighty than males of the same length probably because of differences in fatness and gonadal development (Le Cren 1951). Moreover, growth is alleged to be positive allometric when the weight of an organism increases quite higher than length (b>3) and negative allometric when length increases further than weight (b<3) (Wootton 1992). The 'b' value of females and both sexes in LWR proposed an isometric growth (b = 3), although it suggested negative allometric growth for males. The accepted range of the 'b' value of this species is 2.5-3.5 (Froese 2006). Furthermore, the 'b' value stated from the current study is almost similar to the earlier reports for *L. bata*in open water body of the Indian subcontinent (Chatterji *et al*. 1997, Khan *et al*. 2012, Das *et al.* 2015, Hossain *et al*. 2016, Sarkar *et al*. 2017). However, any variation in slope (b) may be attributed to the sample size variation, different water bodies, life stages, and environmental factors (Kleanthids *et al*. 1999).

The coefficient of determination (r^2) states goodness of fit measures for experimental models based on the proportion of variance. Moreover, the 'r^2' value of this study has compliance with the previous study performed in West Bengal of India where the finding indicates a proper fit model

of growth (Sarkar *et al*. 2017). In addition, the coefficient of determination also suggested that the variation in body weight and shape was observed due to the variation in total length (Pauly 1984). On the other hand, condition factor (CF) is used as an index of growth and feeding intensity and compares the wellbeing of the fish based on the hypothesis that heavier fish of a given length are in better condition (Bagenal and Tesch 1978, Adebiyi 2013). Findings of the present effort revealed that CF was highest for males (0.98) over females (0.97), this result may be due to the physico-chemical characters of the environment, sex of the individual, spawning, onset of maturity, environmental conditions, breeding, feeding etc. (Gowda *et al*. 1987, Dhanze and Dhanse 1997, Sandhya and Shameem 2003, Rao *et al*. 2005). The CF value of this study indicates that *L. bata* are in good condition and healthy, suitable for thriving and can sustain livability in the river because CF values close to 1 are a sign of the overall fitness of fish species (Blackwell *et al*. 2000).

Asymptotic length (L∞) is the highest theoretical length that individual species can grow in its length (Rosli *et al*. 2015). In the present study, L∞ value (32.03) for both sexes is lower than the results observed by Dwivedi (2013) who obtained asymptotic length (L∞) of *L. bata* as 40.2 cm. in Ganga River, India. The growth coefficient (K) of fish is the speed towards its final size (Rosli *et al.* 2015). In the present study, K value was high for females (1.30 y^{-1}) compared to males (0.92 y^{-1}) indicates a faster growth rate of females than males (Gomez-Marquez *et al.* 2008). Furthermore, the growth performance index (Ø) of the females (3.124) was also higher than males (2.974) because of ecological characteristics, environmental parameters, and types of food (Mirzaei *et al*. 2015). Nevertheless, studies about growth performance index (Ø) of this important species are so rare therefore further studies are required to carry out the growth performance indices of *L. bata* species.

Overall the present investigation concluded that *L. bata* follows isometric growth pattern for males and females, respectively. The findings of LWRs and condition factors from the study will support a judicious utilization of resources because of significant importance in terms of food value and biodiversity. Considering the stress on rivers and successive threats to the aquatic biodiversity the baseline information will be employed by policy-makers for the long-term conservation of this endangered fish species in Bangladesh. Subsequently, a more detailed study on species composition is essential to help in the sustainable utilization of the resources in this water body. To assess the biology of economically important other fish species and aquatic fauna, further studies are recommended for a better overview of knowledge of growth and population dynamics.

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