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Size structure of finescale razorbelly minnow, *Salmostoma phulo* (Cyprinidae) inhabiting a coastal river of Bangladesh

Chaklader M.R.[1*]; Siddik M.A.B.[1]; Hanif M.A.[1]; Nahar A.[2]

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Abstract

The aim of this study was to report the size structure of finescale razorbelly minnow, *Salmostoma phulo* in the Payra River, Southern Bangladesh, based on length-frequency distribution (LFD), sex ratio (SR), length-weight relationships (LWR), length-length relationships (LLR), condition factors (allometric K_A; Fulton's, K_F; relative, K_R and relative weight, W_R) and form factor ($a_{3.0}$). A total of 306 individuals ranging from 6.00–10.70 cm in total length and from 1.26-9.20 g in body weight were collected using traditional fishing gear from January 2014 to November 2014. The overall sex ratio of the species did not reveal significant variation from the expected value of 1:1 (χ^2 =0.32, p<0.05). The allometric coefficient *b* calculated for the LWR based on various dimensions indicates both sexes grew allometrically (negative for males: b<3 and positive for females: b>3). Moreover, the values of *b* for LWR, LLR and condition factors did not differ significantly ($p>0.05$) between the sexes of *S. phulo*. The estimated value of W_R was very close to 100 indicating the balanced habitat with available food relative to the presence of predators. To the best of our knowledge, this is the first inclusive and comprehensive explanation on the size structure of *S. phulo* from Bangladesh and it should be crucial for the sustainable management of this SIS fishery not only in southern coastal waters of Bangladesh but also in all of its geographical distributions including India and Myanmar.

Keywords: Length-frequency distribution, Length-weight, Condition factors, Allometric growth, Small indigenous species (SIS)

1-Department of Fisheries Biology and Genetics, Patuakhali Science and Technology University, Patuakhali-8602, Bangladesh
2-Department of Marine Fisheries and Oceanography, Patuakhali Science and Technology University, Patuakhali-8602, Bangladesh
*Corresponding author's email: reazpstu@gmail.com

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Introduction

Bangladesh is endowed with 4.5 million hectares of wetland along inland and coastal water bodies which are considered aquatic biodiversity hotspots across the country (Mustafa and Brooks, 2008; Ahmed and Toufique, 2014).There are 260 species of freshwater fish in Bangladesh, of which 150 species (58%) have been categorised as small indigenous species(SIS) (Hanif *et al.*, 2015a). *Salmostoma phulo* is an important component of SIS which belongs to the order Cypriniformes commonly known as finescale razorbelly minnow, existing throughout the country including the lower reaches of rivers and streams, ponds, rice fields, floodplains, canalsand some mighty river tributaries flowing from India and Myanmar (Talwar and Jhingran, 1991). Among SIS, *S. phulo*is a good source of protein, vitamins and minerals, and plays an important role in providing essential nutrients for the people of Bangladesh. Minnow contains more available vitamin A than any other edible freshwater fish of Bangladesh. Once *S. phulo* was regarded as trash fish and was used as ingredient for fish feed manufacture. But nowadays, this species have been co-cultured with Indian major carps and exotic carps which led to the development of Carp-SIS culture systems that allow simultaneous production of *S. phulo* for the farmer's household consumption and carps as a cash crop (Ahmed and Toufique, 2014).

However, in spite of its nutritional and economic importance, SIS are facing high level of risk of extinction due to indiscriminate exploitation of brood and young SIS by destructive fishing gears (Siddik *et al.*,2014; Hanif *et al.*, 2015b). The *S. phulo*once endemic in the wetlands across the country, is now facing tremendous threat due to over exploitation augmented by various ecological changes and degradation of the natural habitats. IUCN (2014) has categorized the species as endangered in Bangladesh and indicated the urgent need for adequate measures to implement adaptation-centric regulations for sustainable management of small indigenous fishes in the country (Mustafa and Brooks, 2008). Inadequate knowledge with respect to life history traits and conservation status of the species might be one of the significant factors for overexploitation of not only the *S. phulo* but many others species of southern Bangladesh (Chaklader *et al.*, 2014; Sharker *et al.*, 2015)

As a population parameter, length-weight relationship is very crucial for the conversion of -growth-in-length equations to growth-in-weight which is useful for the assessment of fish stock, estimation of fish stock from limited sample sizes (Yasemi and Nazari Bejgan, 2014; Chaklader *et al.*, 2015; Siddik *et al.*, 2016a,b,c,d) and management of fisheries resources (Ilkyaz *et al.*, 2008; Pathak *et al.*, 2013; Chaklader *et al.*, 2016). These studies

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are used as a tool with a view to conserving the fish population in several parts of the world providing information on the condition, growth pattern, ontogenic changes and in fish population dynamics (Oscoz *et al.*, 2005; Simon and Mazlan, 2008; Karimzadeh and Gabrielyan 2010). However, no comprehensive information on these aspects of *S. phulo* is available. Therefore, this study presents the first reference of size structure including length-frequency distribution (LFD), sex ratio (SR), length-weight relationship (LWR) and length-length relationships (LLR), condition factors (allometric, K_A; Fulton's, K_F; relative, K_R and relative weight, W_R) and form factor ($a_{3.0}$) of *S. phulo* in the Payra River, Southern Bangladesh.

Materials and methods

Sample collection

The sample collection was conducted between January and November 2014 from eight stations of the Payra River by commercial fishers who used traditional fishing gear and seine nets to catch the fish (Fig. 1). The collected fresh samples were preserved with ice on site and fixed with 10% buffered formalin to save the species from spoilage or any damage upon arrival at the laboratory. All morphometric characters were measured by following Froese (2006) method. Total length (TL), fork length (FL), and standard length (SL) were measured with the help of using digital slide calipers nearest to 0.01cm and weight was measured with the help of using an electronic balance (Shimadzu, EB-430DW; Shimadzu Seisakusho, Tokyo, Japan) with 0.01 g accuracy.

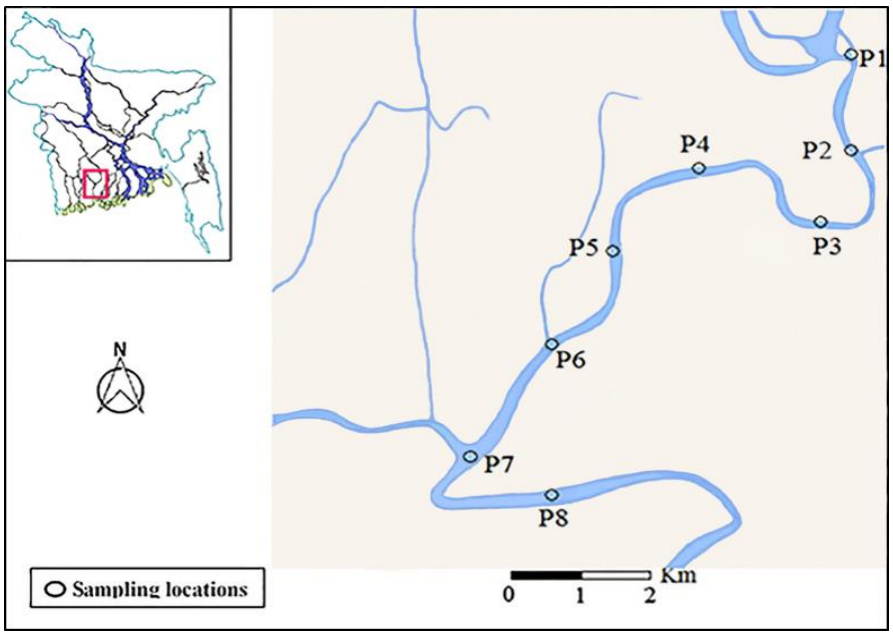

Figure 1: *Salmostoma phulo* sampling sites in the Payra River of southern Bangladesh.

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Length-length relationships

The length-length relationship i.e. (i) TL=p+q×SL, (ii) FL=p+q×TL and (iii) SL=p+q×FL were determined by the method of least squares to fit a simple linear regression model as Y=a+bX, where Y=various body lengths, X=total length, a =proportionality constant and b= regression coefficient.

Length-weight relationships

Length-weight relationship was calculated based on the exponential equation by Le Cren (1951) as $W=aL^b$ where, where *W* is the body weight (g) and *L* is the total length (cm) or fork length (cm) or standard length (cm), *a* is a coefficient related to body form and *b* is an exponent indicating isometric growth when equal to 3 and indicating allometric growth when significantly different from 3(Simon and Mazlan, 2008).The parameters *a* and *b* were estimated by linear regression analysis using log-transformed equation expressed as log *W* = *log a* + *b log L*. The values of the constant *a* and *b* of the linear regression was determined by following Rounsefell and Everhart (1953) and Lagler (1966).

Condition factors

A number of condition factors such as Fulton's (Fulton, 1904), relative (Le Cren, 1951), allometric (Tesch, 1971), and relative weight (Froese, 2006) are used to determine the overall health and productivity of freshwater fish populations (Rypel and Richter,2008; Muchlisin *et al*., 2010). The Fulton's condition factor K_F was calculated using the equation given by (Fulton, 1904) as $K_F=100\times$ (W/L3), where W is the body weight (BW), and *L* is the total length (TL). The relative condition factor (K_R) for each individual was calculated using the equation $K_R=W/a\times L^b$ (Le Cren, 1951), where W is the BW, L is the TL and a and b are the LWR parameters. Also, the allometric condition factor (K_A) was calculated by using a formula developed by (Tesch, 1971) $K_A = W/L^b$, where *W* is the BW, *L* is the TL and *b* is the LWR parameter. Furthermore, relative weight (W_R) was determined by using a formula given by Froese (2006) as $W_R=(W/Ws)\times100$, where W is the body weight of a particular individual and W*s* is the predicted standard body weight for the same individual as calculated by $W_S= aL^b$(*a* and *b* values obtained from the composite of LWRs).

Form factor

Based on Froese (2006), the form factor ($a_{3.0}$) for *S. phulo* was estimated by using the equation as: $a_{3.0}= 10 \log^{a-s(b-3)}$, where *a* and *b* are regression parameters of LWRs, and *S*= -1.358 is the regression slope of log *a* vs *b*.

Statistics analyses

A $\chi 2$ goodness-of-fit test was used to assess the sex-ratio divergence from the expected value of 1:1 (male: female). An analysis of covariance (ANCOVA) was used to compare relative condition factor between males and females within the same population. Since the length-weight relationships were

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curvilinear, data sets were transformed by natural logarithms to linearise before each analysis. The normality tests for each group were conducted by the Kolmogorov-Smirnov test. The statistical package SPSS Version 15 was used for all statistical procedures at 5% (p<0.05).

Results

Length-frequency distributions

Descriptive statistics for length and weight measurements of male and female *S. phulo* are presented in Table 1. The smallest and largest samples of *S. phulo* were 6.00 cm and 10.70 cm TL, respectively according to the length-frequency distribution (LFD). Numerically the size group was dominant in 7.85-8.30 cm TL and constituted 28.10% of the total population (Fig. 2 and Table 2). The total length were ranged from 6.10 to 10.70 cm (mean±SD=8.24±0.81) for males and 6.00 to 10.60cm (mean ±SD = 8.34±0.80) for females *S. phulo*. The TL-frequency distribution showed that the males and females *S. phulo* were not normally distributed in the Payra River during this study. Furthermore, the BW of *S. phulo* varied between 1.44 and 7.21g (mean±SD =3.26±1.01) in males and 1.26 and 9.20g (mean±SD=3.42±1.15) in females. Nonetheless, the BW-frequency distribution showed that the males and females *S. phulo* were not normally distributed (Kolmogorov-Smirnov test, p<0.001) in the study area.

Table 1: Descriptive statistics on the length (cm) and weight (g) measurements of the *Salmostoma phulo* in the Payra River, Southern Bangladesh.

Sex	Statistics	Measurements			
		TL	FL	SL	BW
Male (n:158)	Min	6.10	5.40	4.90	1.44
	Max	10.70	9.90	8.90	7.21
	Mean ± SD	8.24±.81	7.29±.72	6.62±.67	3.26±1.01
	LCL-UCL	8.11-8.37	7.17-7.40	6.52-6.73	3.10-3.42
Female (n:148)	Min	6.00	5.40	4.90	1.26
	Max	10.60	9.30	8.50	9.20
	Mean ± SD	8.34±.80	7.43±.71	6.75±.65	3.42±1.15
	LCL-UCL	8.21-8.47	7.31-7.54	6.64-6.86	3.23-3.60
Combined (n:306)	Min	6.00	5.40	4.90	1.26
	Max	10.70	9.90	8.90	9.20
	Mean ± SD	8.29±.81	7.36±.72	6.68±.66	3.34±1.08
	LCL-UCL	8.19-8.38	7.28-7.44	6.61-6.76	3.21-3.46

Note: *n*, sample size; Min, minimum; Max, maximum; SD, standard deviation; LCL; lower confidence limit, UCL; upper confidence limit; TL, total length; FL, fork length; SL, standard length; BW, body weight

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Table 2: The sex ratio (male: female = 1:1) by total length category for *Salmostoma phulo* in the Payra River, Southern Bangladesh.

Length class (TL, cm)	No. of Fish	Male No.	Female No.	Ratio		χ^2 (df=1)	Significance
				Male	female		
6.00-6.45	6	4	2	1	0.50	0.66	ns
6.46-6.91	2	0	2	1	-	2.00	ns
6.92-7.37	21	9	12	1	1.3	0.43	ns
7.38-7.83	65	40	25	1	0.63	3.46	ns
7.85-8.30	86	44	42	1	0.95	0.04	ns
8.31-8.76	60	29	31	1	1.07	0.06	ns
8.77-9.22	23	8	15	1	1.88	2.14	ns
9.23-9.68	26	15	11	1	0.73	0.62	ns
9.69-10.14	11	7	4	1	0.57	0.82	ns
10.15-10.60	4	1	3	1	3.00	1.00	ns
10.61-11.06	2	1	1	1	1	0.00	ns
overall	306	158	148	1	0.94	0.32	ns

Note: ns, not significant; *, significant at 5% level ($\chi^2_{t\ 1,\ 0.05}$ = 3.84), **, 1% level ($\chi^2_{t\ 1,\ 0.01}$ = 6.63) and ***, 0.1% level ($\chi^2_{t\ 1,\ 0.001}$ = 10.83)

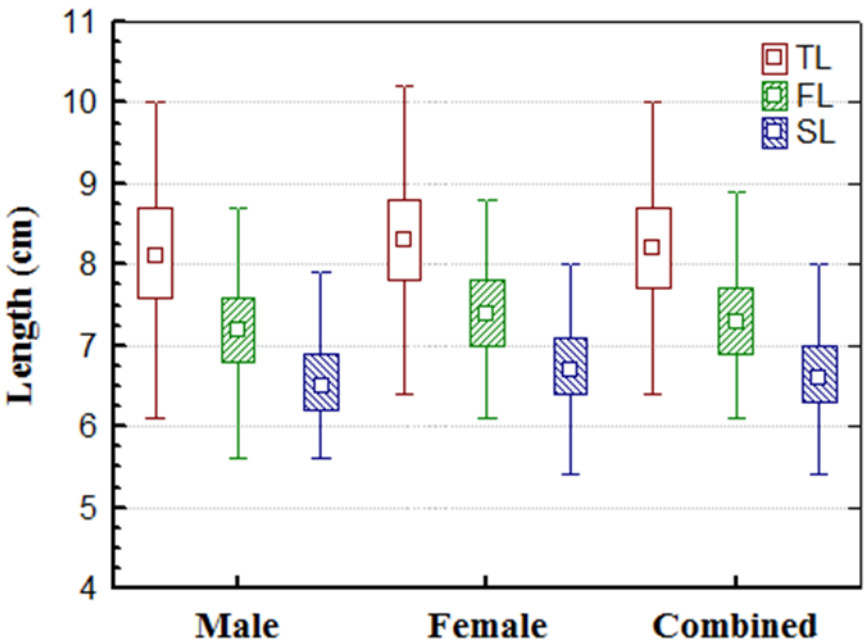

Figure 2: The length-frequency distribution in regard to total length (TL), fork length (FL) and standard length (SL) of *Salmostoma phulo* in the Payra River, southern Bangladesh.

Sex ratio

There were 158 males and 148 females (male: female=1: 1.05) in the 306 specimens of *S. phulo* collected from Payra River; 51.63% males and 48.37% females. However, the overall sex ratio did not show significant variation from the expected value of 1:1 (df = 1, $\chi 2$ =

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0.32, p<0.05). Males were dominant in the 7.38 to 8.30 TL groups while females were dominant in the 8.31 to 9.32 TL groups according to the TL dependent sex ratio (Table 2).

Length-weight and length-length relationships

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 *S. phulo* are shown in Figs. 3, 4 and Table 3. The coefficients of correlation (r^2) were highly significant (p<0.001) in all cases. The estimated allometric coefficient was 2.82 for males and 3.05 for females based on BW vs TL, 2.84 for male and 3.09 for female based on BW vs FL respectively, whereas the *b* was 2.79 for male and 3.00 for females based on BW vs SL in the Payra River. The coefficient *b* of the LWR indicated negative allometric growth with pool population in the Payra River of Bangladesh, as the t-test revealed that the *b* value was significantly different from 3 (b<3.00, p<0.01) (Table 2). Furthermore, the relationships between TL, FL and SL of males, females and common gender of *S. phulo* including 306 specimens along with the estimated parameters of the LLR and the coefficient of determination (r^2) are presented in Table 4. The coefficients of determination (r^2) estimated from length-length relationship for all males, females and combined gender were greater than 0.9 revealing a highly significant difference (p< 0.0001).

Table 3: Descriptive statistics and estimated parameters of the length-weight relationships, and form factor ($a_{3.0}=10^{loga-S\ (b-3)}$) of *Salmostoma phulo* in the Payra River, Southern Bangladesh.

Sex	Equation	SE (a)	SE(b)	(LCL_a-UCL_a)	(LCL_b-UCL_b)	r^2	GT	$a_{3.0}$
Male	$BW = 0.008 \times TL^{\mathbf{2.82}}$	0.14	0.07	0.006-0.011	2.69-2.95	0.920	A-	0.0046
(n:158)	$BW = 0.011 \times FL^{\mathbf{2.84}}$	0.12	0.06	0.009-0.014	2.72-2.97	0.930	A-	0.0066
	$BW = 0.016 \times SL^{\mathbf{2.79}}$	0.10	0.05	0.013-0.020	2.68-2.89	0.949	A-	0.0081
Female	$BW = 0.005 \times TL^{3.05}$	0.21	0.10	0.003-0.008	2.85-3.25	0.864	A+	0.0059
(n:148)	$BW = 0.007 \times FL^{3.09}$	0.18	0.09	0.005-0.009	2.92-3.37	0.892	A+	0.0093
	$BW = 0.011 \times SL^{3.00}$	0.19	0.10	0.007-0.016	2.81-3.20	0.863	A+	0.0110
Combined	$BW = 0.007 \times TL^{2.93}$	0.13	0.06	0.005-0.008	2.85-3.01	0.890	A-	0.0056
(n:306)	$BW = 0.009 \times FL^{2.95}$	0.11	0.05	0.007-0.011	2.85-3.06	0.908	A-	0.0078
	$BW = 0.014 \times SL^{\mathbf{2.88}}$	0.10	0.05	0.011-0.017	2.77-2.99	0.902	A-	0.0095

Note: n, sample size; BW, body weight; TL, total length; FL, fork length; SL, standard length; *a*, intercept; *b*, slope ; Bold numbers indicate significant differences from b = 3, LCL; lower confidence limit, UCL; upper confidence limit; r^2, coefficient of determination; GT, growth type (A+, positive allometric growth, A-, Negative allometric growth [based on (Sokal & Rohlf 1981): ts = (*b*-3)/sb, where ts is the t-test value, *b* the slope and sb the standard error of the slope *b*].

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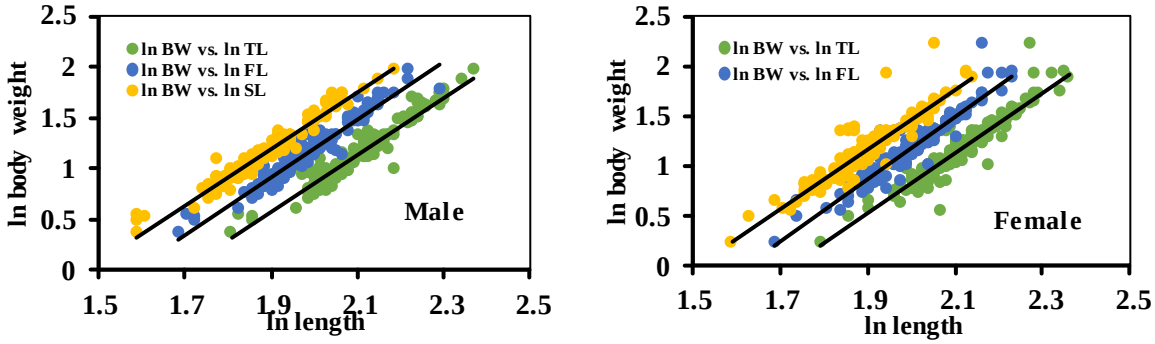

Figure 3: Length-weight relationships (ln W = ln a + b ln L) of *Salmostoma phulo* based on various body dimensions from the Payra River, Southern Bangladesh.

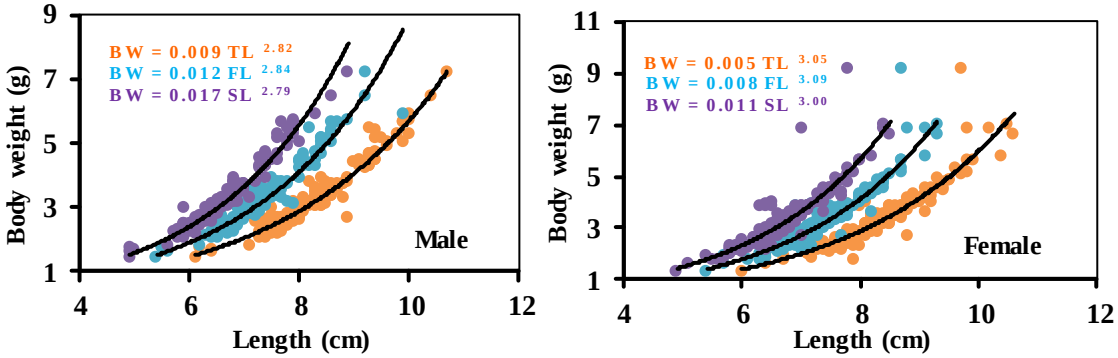

Figure 4: Length-weight relationships (W = a × L^b) of *Salmostoma phulo* based on various body dimensions from the Payra River, Southern Bangladesh.

Condition factors

Descriptive statistics of condition factors (K_F, K_A, K_R and W_R) of *S. phulo* are presented in. The K_F values ranged from 0.38 to 0.77 (mean ± SD = 0.57±0.04) in males and from 0.35 to 1.01 (mean ± SD = 00.57±0.07) in females. The estimated K_R for male and female *S. phulo* varied between 0.273 and 1.168 (mean ± SD = 0.960±0.23) and 0.818 and 1.124 (mean ± SD=1.035±.09), respectively. The K_A ranged from 0.0035 to 0.0173 (mean ± SD =0.0074±0.004) for males and from 0.0016 to 0.0189 (mean±SD= 0.0076±0.006) for females. In addition, the calculated minimum and maximum relative weight (W_R) varied between 95.61 and 116.76 (mean±SD = 102.60±5.46) and between 81.81 and 112.35 (mean±SD = 102.24±8.45) in males and females, respectively which were not significantly different from 100 (Wilcoxon rank test, p=0.074). Furthermore, Spearman rank test revealed that K was extremely correlated with various body dimensions including TL, FL, SL and BW (p<0.001) (Table 5).

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Table 4: The estimated parameters of the length-length relationships (Y = a +b × X) of male and female of *Salmostoma phulo* from the Payra river, Southern Bangladesh.

Sex	Equation	a (LCL – UCL)	b (LCL – UCL)	r^2
Male (n:158)	TL = a+b×SL	0.029 (-0.235 to 0.294)	0.800 (0.768 to 0.832)	0.940
	FL = a+b×TL	0.327 (-0.035 to 0.689)	1.086 (1.036 to 1.135)	0.923
	SL = a+b×FL	0.356 (0.110 to 0.602)	1.047 (1.010 to 1.084)	0.953
Female (n:148)	TL = a+b×SL	0.120 (-0.148 to 0.389)	0.795 (0.763 to 0.827)	0.943
	FL = a+b×TL	0.117 (-0.137 to 0.371)	1.106 (1.072 to 1.140)	0.966
	SL = a+b×FL	0.248 (0.015 to 0.481)	1.064 (1.030 to 1.098)	0.962
Combined (n:306)	TL = a+b×SL	0.057 (-0.132 to 0.246)	0.800 (0.777 to 0.822)	0.940
	FL = a+b×TL	0.257 (0.032 to 0.483)	1.091 (1.061 to 1.122)	0.942
	SL = a+b×FL	0.302 (0.134 to 0.471)	1.055 (1.030 to 1.080)	0.958

Note: n, sample size; TL, total length; FL, fork length; SL, standard length; a, intercept; b, slope ; LCL; lower confidence limit, UCL; upper confidence limit, r^2, coefficient of determination.

Table 5: Condition factors (K_F, K_A, K_R and W_R) of the *Salmostoma phulo* in the Payra River, Southern Bangladesh.

Statistics	Male (n:158)				Female (n:148)				Combined (n:306)			
	K_F	K_A	K_R	W_R	K_F	K_A	K_R	W_R	K_F	K_A	K_R	W_R
Min	0.38	0.0035	0.273	95.61	0.35	0.0016	0.818	81.81	0.35	0.0016	0.2730	81.81
Max	0.77	0.0173	1.168	116.76	1.01	0.0189	1.124	112.35	1.01	0.0189	1.1680	116.76
Mean ± SD	0.57±0.04	0.007±0.004	0.960±0.23	102.60±5.46	0.57±0.07	0.0076±0.006	1.035±.09	102.24±8.45	0.57±0.06	0.0075±0.005	0.960±0.17	102.43±6.86
LCL-UCL	0.56-0.58	0.0048-0.0099	0.802-1.117	98.93-106.27	0.56-0.58	0.0032-0.0120	0.974-1.098	96.20-108.28	0.56-0.58	0.0053-0.0097	0.914-1.077	99.30-105.55

Note: n, sample size; Min, minimum; Max, maximum; SD, standard deviation; LCL; lower confidence limit, UCL; K_F, Fulton's condition factor; K_R, relative condition factor; K_A, allometric condition factor; W_R, relative weight

Form factor

The calculated form factor ($a_{3.0}$) was 0.0046, 0.0066, 0.0081 for TL,FL,SL, respectively in males and 0.0059, 0.0093, 0.0110 for TL,FL,SL, respectively in females of *S. phulo* in the Payra River, Southern Bangladesh (Table 2).

Discussion

The present study recorded the maximum size of *S. phulo* as 10.70 cm TL, which was lower than the maximum recorded value of 12.00 cm TL in Fishbase (Froese *et al*., 2012). The reduction in the recorded maximum sizes of individuals of *S. phulo*in the Payra River in this study might be attributed either to the absence of larger-sized individuals in the fishing ground or the selectivity of target species which may greatly influence the size distribution of the individuals (Hossain *et al.*, 2014). Size differentiation between males and females might be influenced by several factors including temperature change, feeding regime and reproductive cycle (Newman *et al.*, 2000).

In a normal distribution, the sex ratio of males and females may vary between 1:1 and 1:1.3 for most aquatic fish and shellfish, although some finfish and prawn populations have shown a strong bias in this ratio (Hossain *et al.*, 2014). In the present study, the male and female sex ratio was 1:1.05 indicating that the overall sex ratio did not differ

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significantly from the expected value of 1:1. Sex ratio may be influenced by various causes, including thermal influences on sex determination, selective mortality by sex through differential predation, divergent sexual behavior, variant climate and regional conditions, reproduction, growth and longevity of a species (Stergiou and Moutopoulos, 2001; Oh *et al*., 2002; Chilari *et al.*, 2005).

In context of length-weight and length-length relationships, *b* values in this study were within the limits (Froese, 2006) of freshwater fishes from the region reported by Hossain *et al.* (2014). The allometric coefficient *b* obtained from length weight relationship (Table 3) indicated negative allometric growth ($b<3$) for males and positive allometric growth ($b>3$) for females, as well as negative allometric growth for combined values of both sexes based on various body dimensions. The results of b for both male and female indicate differences in their growth type (FigS. 3 and 4). The calculated *b* value of *S. phulo* based on various body dimensions were within the limits of 2.5 to 3.5 indicating that the growth was positively allometric, i.e. weight faster than length (Froese, 2006). Variations in the *b* values may be attributed to differences in ecological conditions of the habitats or variations in the physiology of animals, or both (Le Cren, 1951), due to sex and season (Hossain *et al.*, 2014), feeding rate, gonadal development and growth phase, behavior (active or passive swimmer), and water flow (Muchlisin *et al.*, 2010) all of which were not accounted for in the present study. There was a highly significant correlation of coefficient (r^2) found in the length-length relationship of fishes indicating intimate relationship of lengths to each other in a proportionality which provides a strength between the length-length relationship. Due to the lack of literature dealing with LWR and LLR for this species, we are unable to compare these results with previous studies.

Earlier reports on condition factors of *Xenentodon cancila* in southern Bangladesh were 0.96-1.10 (mean ± SD = 1.02 ± 0.20), 0.99-1.07 (mean ± SD = 1.03 ± 0.18) and 0.96-1.05 (mean ± SD = 1.01 ±0.20) for males, females and combined gender, respectively (Hossain *et al*., 201٤), which are in accordance with that in the present study. Furthermore, the Fulton's condition factor (K_F) was found significantly different between sexes, likely indicating the presence of mature females. Additionally, relative weight (W_R) showed no significant differences from 100 for males and females in this study, indicating the habitat was still in good condition for *S. phulo*. However, there is no available data in literature comparing the relative weight of this species to the previous results.

The form factor ($a_{3.0)}$ of the species was within the limits reported by Froese (2006) and (Hossain *et al*., 2014). There are no references dealing with the $a_{3.0}$

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for this species in the Fish Base and therefore, the present results may contribute to this invaluable electric database.

In conclusion, the present study provided the basic information on some biological aspects including length-frequency distributions, sex ratio, length-weight and length-length relationships based on various body dimensions, condition factor, and relative weight for *S. phulo* from Payra River, southern Bangladesh, which would be effective for fishery biologists, managers and conservationists to implement adequate regulations for sustainable fishery management and conservation of the species. Furthermore, no length-weight and length-length data and condition factors currently exist in the Fish Base for this species, so our results may contribute to this invaluable electric database.

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