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Life-history traits of Pool barb *Puntius sophore* (Cyprinidae) in different ecosystems of Bangladesh

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This study describes the life history traits of *Puntius sophore* (Hamilton, 1822) including, length frequency distributions (LFDs), length-weight relationships (LWRs), length-length relationships (LLRs), condition factors (allometric, K_A; Fulton′s, K_F; relative, K_R and relative weight, W_R), form factor ($a_{3.0}$), first sexual maturity (L_m) and natural mortality (M_W) from different ecosystems of Bangladesh. The LFDs were significantly different between the ecosystems ($P < 0.001$). Allometric coefficient (b) of LWRs (TL *vs.* BW) indicated positive allometric growth in the Padma River and in the earthen pond ($b > 3.0$), but isometric growth was found in the Khoilla *beel* ($b \approx 3$). All LWRs were highly significant ($P < 0.001$) with all r^2 values are ≥ 0.931. The ANCOVA stated that, the LWRs were significantly difference between the ecosystems ($P < 0.001$). In the present study K_F was best for assessing the wellbeing of this species in the surrounding ecosystems. The W_R was not significantly different from 100 indicating the habitats were still in good condition for *P. sophore.* Calculated $a_{3.0}$ were 0.0162, 0.0225 and 0.0125 in the River, pond and *beel,* correspondingly. The estimated L_m was 5.60 cm TL in River, 6.30 cm TL in pond and 4.90 cm TL in *beel* and M_W was 1.45, 1.48 and 1.81 year^{-1} in the River, pond, *beel* respectively. The findings i.e. growth pattern, relative weight, size at sexual maturity, mortality etc. of this study will be effective for the implications of sustainable management policies and to initiate stock assessment practices in the worldwide different ecosystem.

[**Keywords:** Pool barb, *Puntius sophore*, Life history traits, Padma River, Bangladesh]

Introduction

Pool barb, *Puntius sophore* (Hamilton, 1822), is extensively distributed throughout the Indian sub-continent including Afghanistan, Bangladesh, Bhutan, India, Myanmar, Nepal and Pakistan[1, 2]. The *P. sophore* inhabits both fresh- and brackish- water including, rivers, streams, ponds, *beels*, floodplains, *baors*, *haors* and in sub-montane regions[3, 4].This fish is a vital source of animal protein and micronutrients, also important in preventing malnutrition, vitamin and mineral deficiencies especially in rural communities of Bangladesh[5,6]. It is an important target species for small scale fishers[7], and also used as an aquarium fish [8]. In present, the *P. sophore* is diminishing rapidly due to reckless fishing and other ecological changes to their surroundings [9,10,11,12,13].

Information on life-history traits of *P. sophore* is essential for the sustainable management and conservation of this species in their natural habitat, whose spawning aggregations are heavily exploited by local fishers[14,15].

Life-history traits including length-frequency distribution [16,17,18], length-weight relationship [19,20,21], length-length relationship [22,23], condition factors [24], form factor [25], size at sexual maturity [26] and natural mortality [27] of many fish species from Bangladesh are well documented. However, to the best of author's knowledge, the complete description on life-history traits of *P. sophore* from different ecosystem is still rare. Therefore, this study reported the first complete and instructive description of life-history traits including length frequency distribution (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) of *P. sophore* from three different ecosystem (River, pond, *beel*) of Bangladesh using individuals with small to large body sizes. In addition, this study presents form factor and size at first sexual maturity of *P. sophore* from worldwide different water bodies.

Materials and Methods

This study was conducted in the (i) Ganges River, known as Padma River (Latitude 24°22′ N; Longitude 88°35′ E) in Bangladesh, (ii) L-shaped earthen pond in Campus of the University of Rajshahi (Latitude 24°22′ N; 88°38′), and Khoilla *beel* (24°60′ N; 88°59′) in Bangladesh.

The samples were collected from the fishermen catch at different parts (Godagari: 24°26′ N, 88°19′ E and Saheb bazaar: 24°20′ N, 88°34′ E) of the Padma River and from Khoilla *beel*, but the samples were harvested by ourselves from the L-shaped earthen pond of the University of Rajshahi. Fishes were collected from fishermen's catch that were caught using different types of traditional fishing gears, including cast net, square lift net, gill net from May 2014 to April 2015. Fresh samples (dead fish) were immediately chilled in ice on site and fixed with 10% alcohol upon arrival in the laboratory. Total length (TL), fork length (FL), and standard length (SL) were measured to the nearest 0.1 cm using digital slide calipers and total body weight (BW) was measured using an electronic balance with 0.1 g accuracy for each individual.

The length frequency distributions (LFDs) for *P. sophore* were constructed using 1 cm intervals of TL.

The LWR was calculated using the equation: $W = a \times L^b$, where W is the body weight (BW in g) and L is the length (TL, FL and SL in cm). Parameters a and b were estimated by linear regression analyses based on natural logarithms: $\ln(W) = \ln(a) + b \ln(L)$. Additionally, 95% confidence limits of a and b and the co-efficient of determination r^2 were estimated. According to [28], 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 regressions were significantly different from the isometric value ($b = 3$) [29]. Furthermore, LLRs including TL *vs*. FL; TL *vs*. SL and SL *vs*. FL relationships were estimated by linear regression [17].

The allometric condition factor (K_A) was calculated using the equation of [30]: $K_A = W/TL^b$, where W is the body weight (BW, g), TL is the total length (TL, cm) and b is the LWRs parameter. The Fulton's condition factor (K_F) was calculated using the equation: $K_F = 100 \times (W/TL^3)$, where W is the body weight (BW, g), and TL is the total length (TL, cm). The scaling factor, 100 was used to bring the K_F close to unit. And the relative condition factor (K_R) for each individual was calculated via the equation of [31]: $K_R = W/(a \times TL^b)$ where W is the body weight (BW in g) TL is the total length (TL in cm), a and b are the LWRs parameter.

The relative weight was calculated by the equation given by [28], as: $W_R = (W/W_S) \times 100$, where W is the weight of a particular individual and W_S is the predicted standard weight for the same individual as calculated by $W_S = a*TL^b$, where a and b values were obtained from the relationships between TL and BW.

The form factor of this species was calculated using the equation given by [28] as: $a_{3.0} = 10^{log\ a-s(b-3)}$, where a and b are regression parameter of LWR and s is the regression slope of *ln a vs. b*.

The size at first sexual maturity of *P. sophore* was calculated using the equation, log (L_m) = -0.1189 + 0.9157* log (L_{max}) [32] in the different ecosystems separately. The natural mortality of *P. sophore* was calculated using the model, $M_W = 1.92\ year^{-1} *(W)^{-0.25}$ [33]; where, M_W = Natural mortality at mass W, and W = $a*TL^b$, a and b are regression parameters of LWR.

Statistical analyses were done using GraphPad Prism 6.5 software. Tests for normality of each group were conducted by visual assessment of histograms and box plots and confirmed with the Saprio-Wilk normality-test. The one sample test was used to compare the mean relative weight (W_R) with 100 [34]. The Spearman rank correlation test was used to analyze the relationship between the morphometric indices (Condition factors) with TL and BW. In addition, the non-parametric Mann-Whitney *U*-test was used to TL and BW between sexes. Furthermore, the LWRs were compared by the analysis of covariance (ANCOVA). All statistical analyses were considered significant at 5% ($P < 0.05$).

Results

In our study, Table 1 illustrates the descriptive statistics on the length and weight measurements of *P. sophore* with their 95% confidence limit (CL). LFDs of *P. sophore* showed that, the smallest and largest specimens were 5.20 cm to 8.80 cm total length (TL) in the River, 5.50 cm to 10.0 cm TL in the pond and 3.70 to 7.60 cm TL in the *beel*. TL frequency distribution showed that, 7.00−7.99 cm TL size group was numerically dominant and constituted about 53.0% of the total population in the River and 49.0% of the total population in the pond. In addition 6.00−6.99 cm TL size group was dominant in the *beel* and constituted 36.0% of the total population (Figure 1). Kruskal wallis test indicated that the

Table 1 — Descriptive statistics on the length (cm) and weight (g) measurements of *Puntius sophore* from three different ecosystems in northwestern Bangladesh

Habitat	*n*	Sex	Measurements	Min	Max	Mean ± SD	95% CL
River	138	C	TL	5.20	8.80	7.01±0.69	6.90-7.13
			FL	4.70	8.00	6.30±0.61	6.20-6.40
			SL	4.10	6.80	5.48±0.52	5.39-5.57
			BW	1.90	10.70	4.98±1.54	4.73-5.24
Pond	106	C	TL	5.50	10.00	7.64±0.94	7.46-7.82
			FL	5.00	9.10	6.88±0.84	6.72-7.04
			SL	4.30	7.70	5.96±0.71	5.82-6.10
			BW	1.90	15.90	6.62±2.94	6.05-7.18
Beel	127	C	TL	3.70	7.60	5.58±0.97	5.41-5.76
			FL	3.40	6.60	4.94±0.84	4.80-5.09
			SL	2.90	5.70	4.24±0.73	4.11-4.37
			BW	0.60	5.70	2.43±1.22	2.21-2.64

n, sample size; C, combined sex; TL, total length; FL, fork length; SL, standard length; BW, body weight; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit

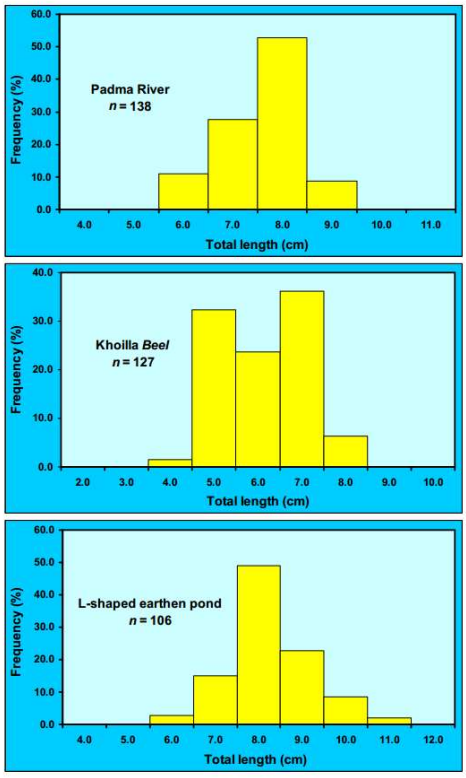

Figure 1. — Length frequency distribution of *Puntius sophore* from three (River, pond, *beel*) different ecosystems in northwestern Bangladesh.

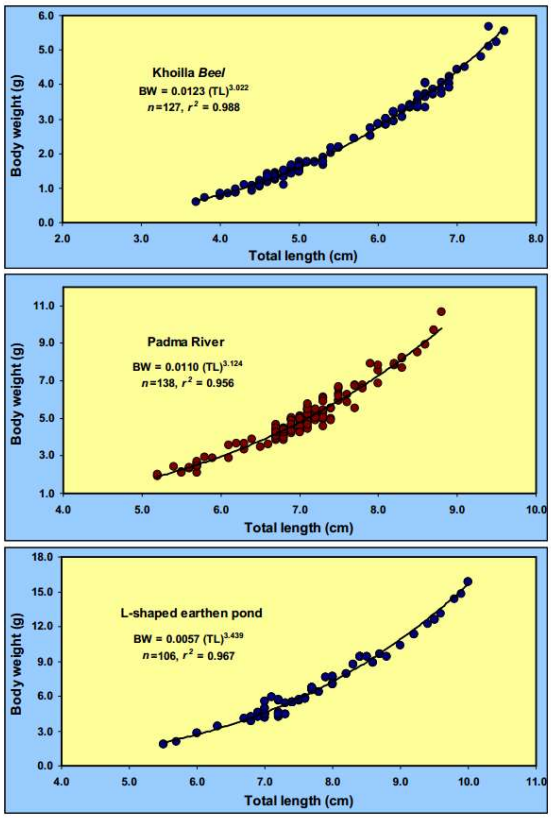

Figure 2 — Length weight relationships of *Puntius sophore* from three different ecosystems (River, pond, *beel*) in northwestern Bangladesh.

differences in the medians were highly significant ($P < 0.001$). The BW ranged from 1.90−16.70 g in the River, 1.90−15.90 g in the pond and 0.60-5.70 g in the *beel*. The Kruskal wallis test specified that, the medians were significantly different ($P < 0.001$) between waters.

Sample size (n), regression parameters (a and b) and 95 % confidence limit of a and b of the LWRs, co-efficient of determination (r^2) and growth type (GT) of *P. sophore* from different ecosystems are given in Table 2 and Figure 2. All LWRs were highly

Table 2 — Descriptive statistics and estimated parameters of the length-weight relationships of *Puntius sophore* from three different ecosystems in northwestern Bangladesh

Habitat	*n*	Sex	Equation	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
				a	*b*				
River	138	C	$BW = a \times TL^b$	0.0110	3.124	0.0088-0.0137	3.010-3.238	0.956	+A
			$BW = a \times FL^b$	0.0136	3.190	0.0107-0.0173	3.061-3.319	0.946	+A
			$BW = a \times SL^b$	0.0209	3.198	0.0163-0.0269	3.050-3.346	0.931	+A
Pond	106	C	$BW = a \times TL^b$	0.0057	3.439	0.0044-0.0073	3.315-3.356	0.967	+A
			$BW = a \times FL^b$	0.0078	3.465	0.0058-0.0134	3.311-3.619	0.950	+A
			$BW = a \times SL^b$	0.0132	3.447	0.0097-0.0180	3.273-3.620	0.937	+A
Beel	127	C	$BW = a \times TL^b$	0.0123	3.022	0.0111-0.0136	2.964-3.079	0.989	I
			$BW = a \times FL^b$	0.0160	3.087	0.0145-0.0177	3.024-3.150	0.987	I
			$BW = a \times SL^b$	0.0275	3.040	0.0246-0.0307	2.963-3.118	0.980	I

Table 3 — The estimated parameters of the length-length relationships of *Puntius sophore* from three different ecosystems in northwestern Bangladesh

Habitat	*n*	Sex	Equation	Regression parameters		95% CL of *a*	95% CL of *b*	r^2
				a	*b*			
River	138	C	TL = *a*+*b* (SL)	-0.0395	1.287	-0.3034 to 0.2244	1.240 – 1.336	0.954
			TL = *a*+*b* (FL)	-0.0637	1.124	-0.2663 to 0.1389	1.092 - 1.156	0.973
			SL = *a*+*b* (FL)	0.1561	0.846	-0.0392 to 0.3514	0.814 – 0.877	0.956
Pond	106	C	TL = *a*+*b* (SL)	-0.1032	1.230	-0.3490 to 0.1424	1.259 – 1.340	0.974
			TL = *a*+*b* (FL)	-0.0226	1.113	-0.2374 to 0.1920	1.082 – 1.144	0.980
			SL = *a*+*b* (FL)	0.1633	0.842	-0.0314 to 0.3581	0.814 – 0.870	0.971
Beel	127	C	TL = *a*+*b* (SL)	-0.0267	1.323	-0.1521 to 0.0986	1.294 – 1.352	0.984
			TL = *a*+*b* (FL)	-0.1180	1.154	-0.2141 to -0.0219	1.135 – 1.173	0.991
			SL = *a*+*b* (FL)	-0.0304	0.864	-0.1124 to 0.0514	0.848 – 0.880	0.988

significant ($P < 0.001$) with all r^2 values is ≥ 0.931. The calculated *b* value of the LWRs (TL *vs.* BW, FL *vs.* BW and SL *vs.* BW) indicated positive allometric growth in the River and pond ($b > 3.0$), but isometric growth found in the *beel* ($b \approx 3.0$) for *P. sophore.* The ANCOVA stated that, the intercepts and slopes were extremely different for *P. sophore* in River and pond ($P < 0.001$), and in pond and *beel* ($P < 0.001$). But for River and *beel* the slopes were not different (P = 0.097), although the intercepts were extremely different (P < 0.001).

The LLRs including TL *vs.* SL, TL *vs.* FL and SL *vs.* FL of *P. sophore* along with estimated parameters and the coefficient of determination (r^2) are presented in Table 3. All LLRs were highly significant ($P < 0.001$) and most of the coefficients of determination values were ≥ 0.954.

The different condition factors (allometric, K_A; Fulton′s K_F; relative K_R) and relative weight (W_R) of *P. sophore* in three different ecosystems are shown in Table 4. Mann Whitney U-test indicated that there was significant difference in K_A values between River and pond ($P < 0.001$), pond and *beel* ($P < 0.001$) and River and *beel* ($P < 0.001$). Unpaired t- test indicated that there was no significant difference in K_F values between River and pond ($P = 0.570$, two tailed test), but significant different was existed between pond and *beel* ($P < 0.001$, two tailed test), and River and *beel* ($P < 0.001$, two tailed test). On the other hand, the Mann Whitney *U*-test shows there was no considerable differences in K_R values between River and pond ($P = 0.754$, U = 7143), pond and *beel* ($P = 0.861$, U = 6641), and for River and *beel* ($P = 0.895$, U = 8680). Moreover, the Spearman rank correlation test specified that, there was no significant correlation between TL and W_R for River, pond and *beel* ($r_s = 0.005$, $P = 0.957$ for River; $r_s = 0.014$, $P = 0.889$ for pond; and $r_s = -0.028$, $P = 0.757$ for *beel*) and One sample t-test designated that, the mean W_R was not significantly different from 100 ($P = 0.923$ for River, $P = 0.776$ for pond, $P = 0.953$ for *beel*), indicating the habitats were in good condition for *P. sophore* in our study area. The relationships of condition factor with TL and BW of *P. sophore* shown in Table 5.

Table 4 — Condition factors (K_A, K_F, K_R,& W_R) of *Puntius sophore* from three different ecosystems in northwestern Bangladesh

Habitat	*n*	Sex	Condition factor	Min	Max	Mean ± SD	95% CL
River	138	C	K_A	0.009	0.013	0.011±0.0007	0.010-0.011
			K_F	1.140	1.615	1.401±0.097	1.384-1.417
			K_R	0.835	1.151	1.001±0.068	0.989-1.012
			W_R	83.465	115.134	100.06±6.80	98.91-101.20
Pond	106	C	K_A	0.005	0.007	0.0057±0.004	0.0056-0.0058
			K_F	1.118	1.660	1.392±0.129	1.367-1.417
			K_R	0.830	1.231	1.002±0.079	0.987-1.017
			W_R	82.986	123.150	100.218±7.88	98.70-101.74
Beel	127	C	K_A	0.009	1.0141	0.0123±0.007	0.0121-0.0124
			K_F	0.994	1.4588	1.276±0.0717	1.264-1.289
			K_R	0.781	1.1470	1.000±0.0562	0.989-1.009
			W_R	78.120	114.70	99.97±5.62	98.98-100.95

n, sample size; R, regardless of sex; K_A, allometric condition factor; K_F; Fulton's condition factor; K_R, relative condition factor; W_R, relative weight; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit

Table 5 — Relationships of condition factor with total length (TL) and body weight (BW) of *Puntius sophore* from three different ecosystems in northwestern Bangladesh

Relationships	r_s values	95% CL of r_s	*p* values	Significance
River				
TL *vs.* K_A	-0.0288	-0.1998 to 0.1439	*P*=0.737	*ns*
TL *vs.* K_F	0.1635	-0.0088 to 0.3263	*P*=0.055	*ns*
TL *vs.* K_R	0.0053	-0.1668 to 0.1771	*P*=0.951	*ns*
TL *vs.* W_R	0.0046	-0.1675 to 0.1765	*P*=0.957	*ns*
BW *vs.* K_A	0.2435	0.0746 to 0.3968	*P*=0.004	*
BW *vs.* K_F	0.4443	0.2948 to 0.5725	*P*<0.001	****
BW *vs.* K_R	0.2928	0.1272 to 0.4425	*P*=0.001	***
BW *vs.* W_R	0.2921	0.1265 to 0.4419	*P*=0.001	***
Pond				
TL *vs.* K_A	-0.0510	-0.2444 to 0.1472	*P*=0.607	*ns*
TL *vs.* K_F	0.5673	0.4175 to 0.6871	*P*<0.001	****
TL *vs.* K_R	0.0132	-0.1836 to 0.2090	*P*=0.893	*ns*
TL *vs.* W_R	0.0137	-0.1831 to 0.2094	*P*=0.889	*ns*
BW *vs.* K_A	0.1115	-0.0867 to 0.3012	*P*=0.255	*ns*
BW *vs.* K_F	0.7415	0.6381 to 0.8136	*P*<0.001	****
BW *vs.* K_R	0.2189	0.0236 to 0.3981	*P*=0.024	*
BW *vs.* W_R	0.2192	0.0239 to 0.3983	*P*=0.024	*
Beel				
TL *vs.* K_A	-0.1636	-0.3332 to 0.0161	*P*=0.066	*ns*
TL *vs.* K_F	0.0401	0.1402 to 0.2178	*P*=0.654	*ns*
TL *vs.* K_R	-0.0271	-0.2054 to 0.1530	*P*=0.762	*ns*
TL *vs.* W_R	-0.0277	-0.2060 to 0.1524	*P*=0.757	*ns*
BW *vs.* K_A	-0.0695	-0.2457 to 0.1112	*P*=0.438	*ns*
BW *vs.* K_F	0.1465	-0.0337 to 0.3174	*P*<0.001	***
BW *vs.* K_R	0.0793	-0.1014 to 0.2550	*P*=0.375	*ns*
BW *vs.* W_R	0.0788	-0.1019 to 0.2545	*P*=0.078	*

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; r_S, spearman rank correlation values; CL, confidence limit; *p*, shows the level of significance; *ns*, not significant; **** Extremely significant; *** highly significant; * significant

The calculated $a_{3.0}$ for *P. sophore* was 0.0162, 0.0225 and 0.0125 in the River, pond and *beel,* correspondingly (Table 6). The L_m was 5.60, 6.30 and 4.90 cm in TL in the River, pond and *beel,* accordingly (Table 7).

In addition our study calculated form factor and size at first sexual maturity of *P. sophore* from the world-wide different water-bodies using available data (Table 6 and 7). The natural mortality was estimated as 1.45 $year^{-1}$ in River, 1.48 $year^{-1}$ in pond and 1.81 $year^{-1}$ in *beel.*

Table 6 — The calculated form factor $a_{3.0} = 10^{\log a - s\,(b-3)}$ of *Puntius sophore* in the world-wide different waterbodies

Water body/ Country	Sex	*a*	*b*	References	$a_{3.0}$
Bankura, West Bengal, India	C	0.0300	2.440	42	0.0052
PIRDP, Talimnagar Sluicegate, Pabna, Bangladesh	C	0.0001	3.210	43	0.0002
Floodplain in West Bengal, India	F	0.0077	3.017	35	0.0081
Floodplain in West Bengal, India	M	0.0115	2.783	35	0.0058
Mathabhanga River, Bangladesh	C	0.0134	3.050	17	0.0157
Old Brahmaputra River, Bangladesh	M	0.0030	3.034	16	0.0033
Old Brahmaputra River, Bangladesh	F	0.0030	3.042	16	0.0034
Chalan *beel,* Bangladesh	C	0.0040	3.396	39	0.0138
Jamuna River, Bangladesh	C	0.0140	3.038	44	0.0158
Padma River, Bangladesh	C	0.0170	2.943	44	0.0142
Rupsha River, Bangladesh	C	0.0140	3.027	44	0.0152
Kolkata, India	C	0.1188	3.242	45	0.2532
Karnataka, India	M	0.1457	1.925	46	0.0051
Karnataka, India	F	0.1126	2.071	46	0.0062
Wetlands of Assam, India	C	0.0080	3.302	40	0.0206
Padma River, Rajshahi Bangladesh	C	0.0110	3.124	Present study	0.0162
Pond, Rajshahi, Bangladesh	C	0.0057	3.439	Present study	0.0225
Khoilla *beel*, Rajshahi, Bangladesh	C	0.0123	3.022	Present study	0.0124

C, combined sex; M, male; F, female; *a*, intercepts; *b*, slopes; $a_{3.0}$, form factor

Table 7 — The calculated size at first sexual maturity (L_m) of *Puntius sophore* in the world-wide different water-bodies

Water body	Sex	Max TL (cm)	References	L_m	95% CL of L_m
Mathabhanga River, Bangladesh	C	10.20	17	6.40	5.20-7.90
Old Brahmaputra River, Bangladesh	M	7.60*	16	4.90*	4.00-6.00
Old Brahmaputra River, Bangladesh	F	9.10*	16	5.80*	4.70-7.10
Fisheries pond, Mymensingh, Bangladesh	F	12.00	47	7.40	6.0-9.20
Chalan *beel,* Bangladesh	C	9.02	39	5.70	4.70-7.00
Jamuna River, Bangladesh	C	7.31	44	4.70	3.90-5.80
Padma River, Bangladesh	C	8.22	44	5.20	4.30-6.40
Rupsha River, Bangladesh	C	10.20	44	6.40	5.20-7.90
Kolkata, India	C	11.10	45	6.90	6.60-8.60
wetlands of Assam, India	C	7.41	40	4.80	3.90-5.80
Padma River, Rajshahi Bangladesh	C	8.80	Present study	5.60	4.60-6.90
Pond, Rajshahi, Bangladesh	C	10.00	Present study	6.30	5.10-7.80
Khoilla *beel*, Rajshahi, Bangladesh	C	7.60	Present study	4.90	4.00-6.00

C, combined sex; M, male; F, female; TL, total length; L_m, size at first sexual maturity; CL, confidence limit; *, standard length

Discussion

Life history traits of *P. sophore* including, length frequency distribution, length-weight and length-length relationships, condition factors, form factor, size at first sexual maturity and natural mortality from different ecosystem is quite scarce from Bangladesh or any other country of the world. Only a few studies on various aspects of *P. sophore* have been conducted in Indian sub-continent[35,27]. During the study, it was unfeasible to seize *P. sophore* smaller than 5.20 cm in TL and 1.90 g in BW for River, 5.50 cm in TL and 1.90 g in BW for Pond and 3.70 cm in TL and 0.60 g in BW for *beel*, which may be due to the nonappearance of smaller size individuals or selectivity of fishing device or fishermen did not go where smaller size survive [15,21]. Larger size of *P. sophore* was found 10.00 cm TL from pond among the three ecosystems, which was smaller than the maximum recorded value of 20.00 cm in TL in the Myanmar [36]. Information on maximum length is obligatory to estimate the population parameters eg., asymptotic length and growth coefficient of fishes, which is important for the proper management of fisheries resource [37]. The differences in size structure might be ascribed to the variation of environmental factors, mostly of water temperature and food accessibility [38].

For most fish species the *b* values were within the limits of 2.5−3.5 [28]. In our study the *b* value is > 3.0 indicating positive allometric growth for *P. sophore*

in the River and Pond ecosystems, which is similar to [39,40]. But isometric growth (b ≈ 3) was estimated in the *beel*. Such differences in growth pattern for the same species may be documented due to influence of various factors including habitat differences, food and feeding habit, seasonal effect, maturity, and differences in observed length [41].

To compare the health and habitat condition of *P. sophore* from three different ecosystems, we have worked on four condition factors (allometric, K_A; Fulton's, K_F; relative, K_R and relative weight, W_R). Among these condition factors K_F is the best described. The ANCOVA stated that, for TL *vs.* K_F the differences between the slopes were extremely significant in River and pond (*df*= 240, F = 13.88, $P = 0.001$,), and in Pond and *beel* (*df*= 229, F = 42.47, $P < 0.001$). On the other hand, for TL *vs.* K_F the slopes were not significant (*df*= 261, F = 2.72, $P = 0.100$), but the intercepts were extremely significant (*df* = 262, F = 61.70, $P < 0.001$) in River and *beel*. Therefore, it can be postulated that, the Fulton's condition factor (K_F) is the best for assessing the wellbeing of this *P. sophore* in different ecosystems.

The calculated $a_{3.0}$ was 0.0162, 0.0225 and 0.0124 for *P. sophore* in the River, pond and *beel,* respectively and it can be used to confirm whether the body shape of individuals in a given population or genus is significantly different from others [28]. During our study, various L_m of *P. sophore* were observed in River, pond and *beel*, and it might be due to different environmental and biological factors. Also the M_W was estimated as 1.45, 1.48 and 1.81 year^{-1} in River, pond and *beel,* respectively and it was higher in *beel* than in other ecosystems and it may be due to the reducing of water level, increasing water temperature, reckless fishing etc. In addition our study calculates form factor and size at first sexual maturity of *P. sophore* from worldwide different waterbodies, which would be more effective for sustainable management and conservation of *P. sophore* in the worldwide different ecosystems.

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