Population Structure, Length-weight and Length-length Relationships, and Condition- and Form-Factors of the Pool barb *Puntius sophore* (Hamilton, 1822) (Cyprinidae) from the Chalan *Beel*, North-Central Bangladesh

(Struktur Populasi, Hubungan Berat-panjang dan Panjang-panjang, serta Faktor Keadaan dan Bentuk Pool barb *Puntius sophore* (Hamilton, 1822) (Cyprinidae) dari Chalan *Beel*, Utara-Tengah Bangladesh)

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ABSTRACT

The present study describes the length-frequency distribution, length-weight (LWR) and length-length relationships (LLR), and condition- and form-factors of Puntius sophore *wild population from the Chalan* beel, *north-central Bangladesh. Sampling was done using traditional fishing gears including* jhaki jal *(cast net),* tar jal *(square lift net), and* dughair *(conical trap) during March 2010 to February 2011. For each individual, the total length (TL), fork length (FL) and standard length (SL) were measured by digital slide calipers. Individual body weight (BW) was also taken by a digital balance. A total of 185 specimens ranging from 3.62-9.02 cm TL and 0.70-13.20 g BW were analyzed in this study. The length-frequency distribution showed that the 6-7 cm TL size group was numerically dominant and constituted 43% of the total population. The coefficient b of the LWRs indicated positive allometric growth (b>3.00) for* P. sophore *in the Chalan* beel. *The results also indicated that the LWRs were highly correlated ($r^2 > 0.945$). The calculated Fulton's condition factor (K) values ranged from 0.69-2.35, with a mean value 1.64±0.30. The relative weight (W_r) was not significantly different from 100 for (p=0.074), indicating the balance habitat with food availability relative to the presence of predators for* P. sophore. *The estimated values of form factor ($a_{3.0}$) were as 0.0138, 0.0345 and 0.0435 for TL, FL and SL of* P. sophore, *respectively. These results will be useful for fishery biologists and conservationists to suggest adequate regulations for sustainable fishery management and conservation its numerous stocks in the region.*

Keywords: Chalan beel; condition factor; form factor; length-weight relationships; Puntius sophore

ABSTRAK

Kajian ini menunjukkan pengagihan kekerapan-panjang, hubungan berat-panjang (LWR) dan panjang-panjang (LLR), bentuk keadaan dan faktor populasi liar Puntius sophore *dari Chalan* beel, *utara-tengah Bangladesh. Pensampelan dibuat menggunakan peralatan memancing tradisi termasuk* jhaki jal *(jala),* tar jal *(jaring angkut segi empat sama) dan* dughair *(perangkap kon) dari Mac 2010 hingga Februari 2011. Untuk setiap individu, jumlah panjang (TL), panjang cabang (FL) dan panjang piawai (SL) diukur menggunakan angkup slaid digital. Berat badan (BW) individu turut ditentukan menggunakan penimbang digital. Sejumlah 185 spesimen meliputi 3.62-9.02 cm TL dan 0.70-13.20 g BW telah dianalisis dalam kajian ini. Pengagihan kekerapan-panjang menunjukkan bahawa kumpulan saiz 6-7 cm TL adalah dominan dari segi bilangan dan meliputi 43% dari jumlah populasi. Pekali b LWR menunjukkan pertumbuhan alometri positif (b>3.00) untuk* P. sophore *dalam Chalan* beel. *Hasil juga menunjukkan bahawa LWR amat berhubung kait ($r^2>0.945$). Faktor keadaan Fulton (K) yang dikira merangkumi 0.69-2.35, dengan nilai min 1.64±0.30. Berat relatif (W_r) tidak berbeza secara bermakna dengan 100 untuk (p=0.074), menunjukkan habitat seimbang dengan kesediaadaan makanan relatif berbanding dengan kehadiran pemangsa untuk* P. sophore. *Nilai yang dianggarkan untuk faktor bentuk ($a_{3.0}$) adalah 0.0138, 0.0345 dan 0.0435 masing-masing untuk TL, FL dan SL* P. sophore. *Hasil ini berguna kepada ahli biologi dan pemuliharaan perikanan untuk mencadangkan peraturan yang mencukupi bagi pengurusan perikanan mampan dan pemuliharaan stok yang banyak di rantau ini.*

Kata kunci: Chalan beel; faktor bentuk; faktor keadaan; hubungan berat-panjang; Puntius sophore

INTRODUCTION

The Pool barb, *Puntius sophore* (Hamilton 1822), belongs to the family Cyprinidae, is a small indigenous fish of Bangladesh. This species is widely distributed throughout the Indian sub-continent including Bangladesh, Bhutan, India, Nepal, and Pakistan (Menon 1999; Mirza 2002; Petr 1999; Rahman 1989; Talwar & Jhingran 1991). This fish is also reported from Afghanistan, Myanmar and

Yunnan (China) (Petr 1999; Talwar & Jhingran 1991; Oo 2002). As *P. sophore* inhabits rivers, streams, ponds, *beels*, floodplains, *baors*, *haors* in plains and sub-montane regions dominantly (Craig et al. 2004; Menon 1999), it is an important target species for small scale fishers (Rahman 2005; Shafi & Quddus 1982), who use a variety of traditional fishing gears (Ahmed & Kibria 2005). This fish is a major source of animal protein and micronutrients in the diet of rural small-scale farmers (Roos et al. 2007). In addition, it is an important small indigenous fish species of Bangladesh and very much famous food fish item (Rahman 2005) and can also be used as aquarium fish (Froese & Pauly 2011). However, *P. sophore* is declining rapidly due to heavy fishing pressure, and in recent studies from the Indian waters, it is categorized as lower risk near threatened in the Western Ghat (Balasundaram et al. 2000), in Harike wetland, a Ramsar site (Dua & Parkash 2009) and in Gomti river, a tributary of river Ganga (Sarkar et al. 2010).

The size structure of a fish population at any point in time can be considered a 'snapshot' that reflects the interactions of the dynamic rates of recruitment, growth and mortality (Gay & Brown 2007). On the other hand, the relationship between length and weight as well as the condition factors are useful parameters for assessing the well-being of the individuals and for determining possible differences among different stocks of the same species (King 2007). In addition, condition factor is a quantitative parameter of the state of well-being of the fish that will determine present and future population success by its influence on growth, reproduction and survival (Richter 2007). Moreover, relative weight (W_r) is one of the most popular indexes for assessing condition of fishes in the USA since last two decades (Rypel & Richter 2008).

Several studies on *P. sophore* population including the biology, length-weight relationship (LWR), and relative condition factor in Indian waters (Jhingran & Talwar 1991; Menon 1999; Reddy & Rao 1992), growth in Jamuna river, Bangladesh (De Graff 2003), length-weight and length-length relationships in the Mathabhanga river, northwestern Bangladesh (Hossain et al. 2006a), biodiversity in Pravana Sangam district Ahmednagar, India (Shinde et al. 2009) and breeding ground profile in Damodar River System, India (Sarkar & Banerjee 2010) have been conducted. However, detailed studies on the length-frequency distributions, length-weight, length-length relationships (except Hossain et al. 2006a), and condition- and form-factors of this species are evidently lacking in Bangladesh, nevertheless a number of studies have been conducted on these issues (Hossain et al. 2006a; 2006b; 2008; 2009a; 2009b; 2009c; Hossain 2010a; 2010b; 2012). Therefore, this study describes the length-frequency distribution, length-weight, length-length relationships as well as condition- and form-factors of *P. sophore* wild population from the Chalan *beel* using various body dimensions over a one year study period.

MATERIALS AND METHODS

STUDY SITE

This study was conducted in Chalan *beel*, north-central Bangladesh. According to the Banglapedia (2004), the term *beel* is used for relatively large surface, stagnant water-body which accumulates surface run-off water through an internal drainage system. *Beel* is common in low-lying floodplain areas in Bangladesh. Chalan *beel* is one of the largest, most important watersheds in north-central Bangladesh (24.35° to 24.70°N and between 89.10° to 89.35°E). Iqbal (2006) reported that this *beel* is a confluence for numerous smaller water ways and, in turn, is drained by channels that flow south, finally discharging into the Padma and Brahmaputra Rivers.

SAMPLING

The samples of *P. sophore* were collected during daytime (8:00-17:00) on a seasonal basis (Pre-monsoon: May, Monsoon: July, and Post-monsoon: October) from fisherman catch landed at the fish landing center, Singra, Natore (24°50'N; 89°14'E) during March 2010 to February 2011. *Puntius sophore* were caught by the traditional fishing gears including *jhaki jal* (cast net), *tar jal* (square lift net), and *dughair* (conical trap) (Kibria & Ahmed 2005). Samples were immediately preserved with ice in the fish landed area and fixed with 5% formalin on arrival in the laboratory. For each individual, total length (TL), fork length (FL) and standard length (SL) were measured to the nearest 0.01 cm using digital slide calipers, and whole body weight (BW) was taken on a digital balance with 0.01 g accuracy.

LENGTH-WEIGHT AND LENGTH-LENGTH RELATIONSHIPS

The length-weight relationship was calculated using the expression: $W= aL^b$, where the W is the body weight (g) and L is the total length (cm), fork length (cm) or standard length (cm). Parameters a and b were estimated by linear regression analysis based on natural logarithms: $\ln(W) = \ln(a) + b \ln(L)$. Additionally, 95% confidence limits of b and the coefficient of determination r^2 were estimated. In order to confirm whether b values obtained in the linear regressions were significantly different from the isometric value ($b = 3$), a *t*-test was applied, expressed by the equation according to Sokal & Rohlf (1987): $t_s = (b\text{-}3)\,/\,s_b$, where t_s is the *t*-test value, b the slope and s_b the standard error of the slope (b). The comparison between obtained values of *t*-test and the respective tabled critical values allowed for the determination of the b values statistically significant, and their inclusion in the isometric range ($b = 3$) or allometric range (negative allometric; $b < 3$ or positive allometric; $b > 3$). Additionally, SL vs. TL; SL vs. FL; and TL vs. FL relationships were estimated by linear regression (Hossain et al. 2006b).

CONDITION FACTORS

The Fulton's condition factor K was calculated using the equation given by Fulton (1904) as $K = 100 \times (W/L^3)$, where W is the body weight (BW), and L is the total length (TL). In addition, relative weight (W_r) was calculated by the equation given by Froese (2006) 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 $W_s = aL^b$ (a and b values obtained from the composite of length-weight relationships throughout the range of the species).

FORM FACTOR

The form factor ($a_{3.0}$) for *P. sophore* was calculated using the equation given by Froese (2006) as: $a_{3.0} = 10^{\log a - s (b-3)}$, where a and b are regression parameters of LWRs, and S is the regression slope of log a vs. b. During this study, a mean slope $S = -1.358$ (Froese 2006) was used for estimating the form factor because information on LWRs is not available for this species for estimation of the regression (S) of *ln a* vs. *b*.

STATISTICS ANALYSES

Statistical analyses were performed using Microsoft® Excel-add-in-DDXL, GraphPad Prism 5 and VassarStats online software (http://faculty.vassar.edu/lowry/VassarStats.html). All data were checked for homogeneity of variance. Tests for normality was conducted by visual assessment of histograms and box plots, and confirmed using the Kolmogorov-Smirnov test. Where test for normality assumption was not met, then the non-parametric Wilcoxon rank test was used to compare the mean relative weight of a population with 100 (Anderson & Neumann 1996), whereas Spearman rank test was used to correlate body measurements (e.g., TL, FL, SL, and BW) with Fulton's condition factor (K) and relative weight (W_r) if the normality assumption was not met. In addition, the parameters a and b of the LWR was compared by the analysis of covariance (ANCOVA). All statistical analyses were considered significant at 5% ($p<0.05$).

RESULTS

A total of 185 specimens of *P. sophore* were collected from Chalan *beel*, north-central Bangladesh during the study. Table 1 illustrates the descriptive statistics for length and weight measurements of the Pool barb. The length-frequency distribution (LFD) of *P. sophore* showed that the smallest and largest specimens were 3.62 cm and 9.02 cm TL, respectively. The 6-7 cm TL size group was numerically dominant and constituted 43% of the total population (Figure 1). The LFD for this barb did not pass the normality (Kolmogorov-Smirnov test; KS distance =0.088, $p<0.05$).

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 *P. sophore* are given in Figure 2 and Table 2. All relationships were highly significant (p<0.01), with r^2 values being greater than 0.945. The calculated allometric coefficient

TABLE 1. Descriptive statistics on the length (cm) and weight (g) measurements of the pool barb *Puntius sophore* (Hamilton 1822) from the Chalan *beel*, north-central Bangladesh

Water-body (Region)	n	Measurements	Min	Max	Mean ± SD	95% CL
Chalan Beel: 24° 50' N - 89° 14' E (Singra, Natore)	185	TL	3.62	9.02	6.46 ± 1.07	6.30 – 6.62
		FL	3.24	8.37	5.87 ± 1.07	5.71 – 6.03
		SL	2.79	7.62	5.18 ± 1.00	5.04 – 5.32
		BW	0.70	13.20	5.02 ± 2.67	4.63 – 5.41

n, sample size; Min, minimum; Max, maximum; TL, total length; FL, fork length; SL, standard length; BW, body weight; SD, standard deviation; CL, confidence limit of mean value.

TABLE 2. Descriptive statistics and estimated parameters of the length-weight relationships, and form factor ($a_{3.0} = 10^{\log a - S (b-3)}$) of the pool barb *Puntius sophore* (Hamilton 1822) (n = 185) from the Chalan *beel*, north-central Bangladesh

Equation	Regression parameters		95% CL of a	95% CL of b	r^2	*Growth	$a_{3.0}$
	a	b					
$BW = a \times TL^b$	0.004	3.396	0.003 - 0.006	3.267 - 3.525	0.945	A +	0.0138
$BW = a \times FL^b$	0.011	3.366	0.009 - 0.014	3.262 - 3.472	0.956	A +	0.0345
$BW = a \times SL^b$	0.023	3.204	0.019 - 0.027	3.109 - 3.299	0.957	A+	0.0435

n, sample size; BW, body weight; TL, total length; FL, fork length; SL, standard length; a, intercept; b, slope ; CL, confidence limit; r^2, coefficient of determination; A+, positive allometric growth; [* based on Sokal and Rohlf (1987): $t_s = (b-3) / s_b$, where t_s is the t-test value, b the slope and s_b the standard error of the slope (b)].
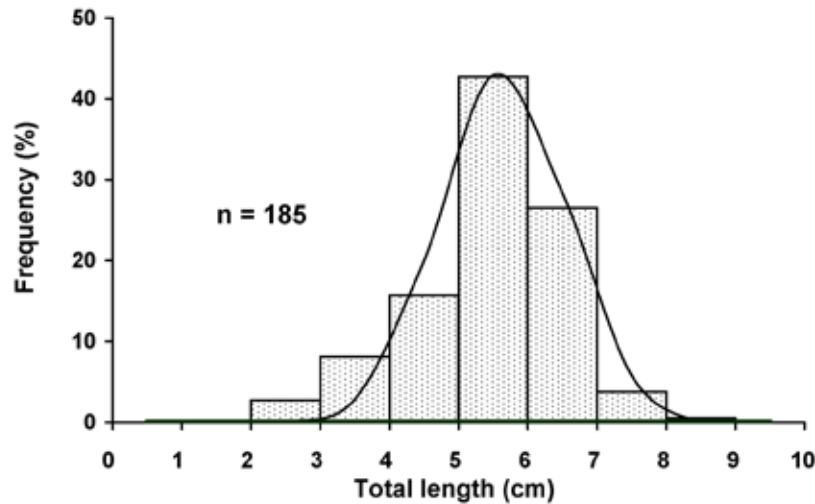
FIGURE 1. Length-frequency distribution of the pool barb *Puntius sophore* (Hamilton 1822) in the Chalan *beel*, north central Bangladesh
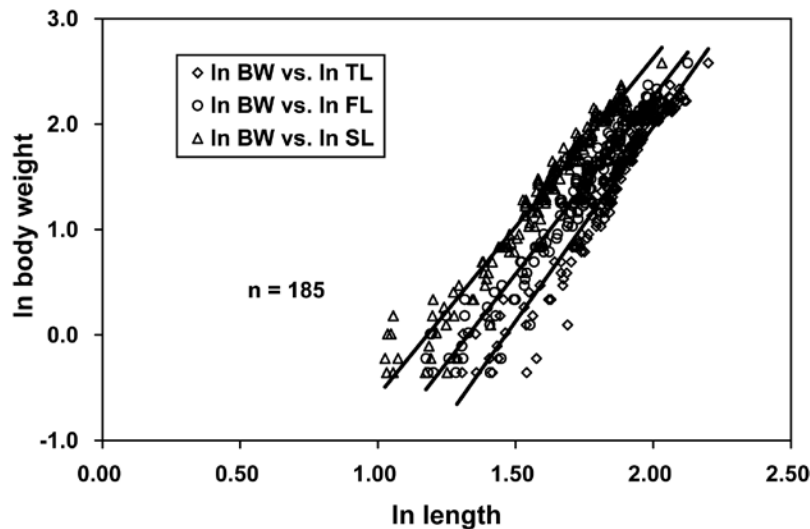

FIGURE 2. Length-weight relationships (*ln W = ln a + b ln L*) the pool barb *Puntius sophore* (Hamilton 1822) based on various body dimensions from the Chalan *beel*, north central Bangladesh

b ranged from a minimum of 3.204 for BW vs. SL, to a maximum of 3.396 for BW vs. TL in the Chalan *beel*, with an average value of 3.322. The coefficient (*b*) of the LWR indicated positive allometric growth with pool barb in the Chalan *beel* of Bangladesh, as the t-test revealed that the *b* value was significantly different from 3 (*b*<3.00, p<0.01) (Table 2). This study observed significant differences in intercepts (*a*) and slopes (*b*) of the LWR (df =549, F=19.03, *p*<0.001) in same population with different length dimensions (TL, FL / and SL).

Moreover, the relationships between TL, FL and SL of *P. sophore* including 185 specimens along with the estimated parameters of the LLR and the coefficient of determination (*r²*) are presented in Table 3. All LLRs were highly significant (*p*<0.001) and most of the coefficients of determination values being > 0.989.

The Fulton's condition (*K*) and relative weight (*W_r*) values calculated for *P. sophore* is shown in Table 4. Minimum and maximum *K* values for this small indigenous fish were 0.69 and 2.35, respectively, with a mean value 1.64±0.30. In addition, the calculated minimum and maximum relative weight (*W_r*) were 48.62 and 179.96, respectively in the Chalan *beel*, with a mean value of 102.28±16.38, which was 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). Also, *W_r* was significantly correlated with TL (r_s=0.185, *p*=0.012) and FL (r_s=0.185, p=0.011).

The calculated form factor ($a_{3.0}$) was 0.0138 for TL, 0.0345 for FL and 0.0435 for SL of *P. sophore* in the Chalan *beel*, north-central Bangladesh (Table 1).

TABLE 3. The estimated parameters of the length-length relationships ($Y = a + b \times X$) of the pool barb *Puntius sophore* (Hamilton 1822) ($n = 185$) from the Chalan *beel*, north-central Bangladesh

Equation	Regression parameters		95% CL of a	95% CL of b	r^2
	a	b			
SL = $a + b \times$ TL	- 0.775	0.923	- 0.865 to - 0.684	0.908 to 0.936	0.989
SL = $a + b \times$ FL	- 0.256	0.926	- 0.315 to - 0.197	0.916 to 0.936	0.995
TL = $a + b \times$ FL	0.589	1.100	0.535 to 0.644	0.991 to 1.009	0.996

n, sample size; TL, total length; FL, fork length; SL, standard length; a, intercept; b, slope ; CL, confidence limit; r², coefficient of determination.

TABLE 4. Fulton's condition factor, $K = 100 \times (BW/TL^3)$ and Relative weight, (W_r) of the pool barb *Puntius sophore* (Hamilton 1822) ($n = 185$) from the Chalan *beel*, north-central Bangladesh

Condition factor	Min	Max	Mean ± SD	95% CL
Fulton's condition factor (K)	0.69	2.35	1.64 ± 0.30	1.60 – 1.68
Relative weight (W_r)	48.62	179.96	102.28 ± 16.38	99.90 – 104.66

n, sample size; TL, total length; BW, body length; Min, Minimum; Max, maximum; SD, standard deviation; CL, confidence limit of mean value.

TABLE 5. Spearman rank correlation coefficient (r_s) for Fulton's (K) and Relative weight (W_r) with total length (TL, cm), Fork length (FL, cm), standard length (SL, cm) and body weight (BW, g) of the pool barb *Puntius sophore* (Hamilton 1822) ($n = 185$) from the Chalan *beel*, north-central Bangladesh

r_s for Fulton's condition factor				r_s for Relative weight			
K - TL	K - FL	K - SL	K - BW	W_r - TL	W_r - FL	W_r - SL	W_r - BW
0.715***	0.714***	0.724***	0.784***	0.185*	0.185*	0.201**	0.286 ***
p<0.001	p<0.001	p<0.001	p<0.001	p=0.012	p=0.011	p=0.006	p<0.001

*n, samples size; p shows significance level (***, extremely significant; **, highly significant; * significant)*

DISCUSSION

Information on biological aspects of *P. sophore* from Bangladesh is quite insufficient (Hossain et al. 2006a). No previous records of length frequency distribution of this species could be traced from the related literature, inhibiting the comparison with previous result. The present study recorded the maximum size of *P. sophore* as 9.02 cm TL, which was lower than the maximum record value of 18.00 cm TL in India (Froese & Pauly 2011). However, Hossain et al (2006a) reported the maximum TL for *P. sophore* from the Mathabhanga River as 10.20 cm, northwestern Bangladesh, while Shrestha (1994) recorded the maximum length of this fish as 10.00 cm TL from Nepal, which are higher than that found in the present study. Nevertheless, Shan et al. (2000) recorded the maximum size of this fish as 6.00 cm SL (standard length) in China, which is lower than any population of Bangladesh, India and Nepal. In addition, the maximum weight of *P. sophore* observed in this study (13.20 g) was lower than the maximum recorded value of 70.0 g in Maharashtra, India (Archarya & Iftekhar 2000).

Average *b* value of *P. sophore* from the Chalan *beel* (3.322) was within the limits 2.5-3.5 reported by Froese (2006) for most fishes. This indicates that the growth was positively allometric, i.e. faster in weight than in length (Ŝantić et al. 2006). Variations in the *b* values may be attributed to differences in ecological conditions of the habits or variation in the physiology of animals, or both (Le Cren 1951). In addition, the length-weight relationship in fishes can vary significantly due to sex and season (Hossain et al. 2006b), feeding rate, gonadal development and growth phase (Tarkan et al. 2006), behavior (active or passive swimmer), and water flow (Muchlisin et al. 2010), all of which were not accounted for the present study. Since samples included individuals collected over several seasons, the parameters *a* and *b* would be treated as mean annual values. In a recently study, Hossain et al. (2006a) recorded the length-weight regression parameters are $a = 0.0134$ and $b = 3.050$ for *P. sophore* from the Mathabhanga River, southwestern Bangladesh, which is in accordance with the present study. Nevertheless, the slope (*b*) of the LWR was quite a bit lower ($b = 2.440$) than 3.00, as reported by De (1985) from the Bankura, West Bengal,

India. According to Rypel and Richter (2008), the predicted standard weight for respective observed length was calculated using the estimated *a* and *b* parameters of the length-weight regression. However, ANCOVA showed that there was no significant difference between observation and prediction growth patterns in the studied population of Pool barb.

The condition factor (*K*) is an index reflecting interactions between biotic and abiotic factors in the physiological condition of the fishes. It shows the well-being of the population during various life cycle stages (Angelescu et al. 1958). The condition factor (*K*) for this species ranges between 0.69 and 2.35. No references dealing with the condition factors of *P. sophore* are available in the literature (Hossain et al. 2009a), preventing the comparison with previous results. However, condition factor based on the LWR is an indicator of the changes in food reserves and therefore an indicator of the general fish condition (Offem et al. 2007). In general, the seasonal cycle in fish's condition suggested a relationship to gonadal development. According to Ahmed et al. (2012), the condition factor of the silver hatchet chela, *Chela cachius* (Hamilton 1822), (Cyprinid) was constant during the pre-spawning period, decreased in the period of spawning and was lowest immediately after spawning. However, only the several seasonal data were used during this study, thus it is difficult to compare among the condition of fishes throughout the year.

In addition, the values of W_r falling below 100 for an individual, size group, or population suggest problems such as low prey availability or high predatory density; whereas values above 100 indicate a prey surplus or low predatory density (cf. Rypel & Richter 2008). Recently, a number studies have espoused the use of W_r for assisting in the management and conservation of nongame fishes, particularly those that are threatened or endangered (Bister et al. 2000; Didenko et al. 2004; Richter 2007). However, to the best our knowledge, the present paper was to carry out the first comprehensive description of W_r for this sub-tropical freshwater fish in Bangladesh. This study showed that the mean relative weight value (W_r) of *P. sophore* was close to 100 in Chalan *beel*, indicating the balance habitat with food availability relative to the presence of predators (Anderson & Neumann 1996). In addition, it might be indicated that the water quality of this water-body is still adequate to support fish communities including *P. sophore*. Nevertheless, this fish is categorized as lower risk near threatened in the Western Ghat (Balasundaram et al. 2000), in Harike wetland - a Ramsar site (Dua & Parkash 2009) and in Gomti river, a tributary of river Ganga (Sarkar et al. 2010) in India. This might be attributed to other reasons rather than water quality. Moreover, this information would allow for urgent detection of any long-term declines in condition that may have occurred, possibly as a result of environmental change as the relative condition integrates key physiological components of fish life history (lipid storage and growth), it suggests a strong, handy metric

that managers can use to evaluate the overall health and fitness as well as population-level responses to ecosystem disturbance (cf. Rypel & Richter 2008).

In conclusion, this study provided the basic information on the length-frequency distributions, length-weight, length-length relationships based on various body dimensions, condition factor, and relative weight for *P. sophore* from the Chalan *Beel*, north-central Bangladesh, which would be effective for fishery biologists and conservationists to impose adequate regulations for sustainable fishery management and conservation its numerous stocks in the region. Moreover, no condition factors currently exist in the Fish Base for this species and therefore, our results may contribute to this invaluable electric database.

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