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Sex ratio, length-weight and length-length relationships of *Amblypharyngodon mola* (Cyprinidae) in the Payra River, southern Bangladesh

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Abstract
Sex ratio, length-weight and length-length relationships of *Amblypharyngodon mola* were studied in the Payra River during February 2016-January 2017. Monthly samples were collected from the small-scale fishers of set bagnet fishery in the Payra River. All specimens were sexed out and standard length (SL), total length (TL), fork length (FL) and body weight (BW) were measured. The overall sex ratio showed no significant difference between sexes. However, the monthly sex ratio was 1:1 for almost all the year, except in June when females were significantly more abundant than males. With regard to the size class, the sex ratio was found to be non-significant up to 4.0 cm TL, however; at 5.0 cm TL the number of male was significantly higher than female and after that the number of female increased significantly than male till the maximum size class. The allometric coefficient 'b' of the LWRs between SL vs. BW and FL vs. BW indicated negative allometric growth and isometric growth respectively for both sexes. While TL vs. BW indicated positive allometric growth in males and isometric growth in females. On the other hand, the LWRs for pooled data indicated negative allometric growth, positive allometric growth and isometric growth for SL vs. BW, TL vs. BW and FL vs. BW respectively. The allometric coefficient 'b' of the LLRs between SL vs. TL, SL vs. FL and TL vs. FL indicated positive allometric growth, isometric growth and negative allometric growth respectively for both sexes. However, the pooled data shows positive allometric growth between SL vs. TL, negative allometric growth between SL vs. FL and between TL vs. FL. It was concluded that the data generated from the study will form a baseline tool for effective fisheries management and sustainable exploitation of *A. mola* in the Payra River as well as surrounding waters of Bangladesh.

Keywords: *Amblypharyngodon mola*, sex ratio, length–weight relationships, length–length relationships, Payra River

1. Introduction
Amblypharyngodon mola, commonly known as 'Mola carplet' or 'Pale carplet' is a small indigenous freshwater fish species that inhabits ponds, rivers, floodplain lakes, canals, paddy fields and many other small water bodies in the Indian subcontinent. The species is widely distributed in South Asian countries including Bangladesh, Pakistan, India, Myanmar and Afghanistan [1, 2]. The conservation status of the species is categorized as 'lower risk least concern' (LR L_c) by the Conservation Assessment and Management Plan (CAMP) [3]. This is an important species for the artisanal fisheries of the Indian sub-continent and is an important source of livelihood for many of the subsistence and artisanal fisher folks [2, 4, 5]. It is found to contain higher amount of vitamin-A than any other edible fish [6]. In Bangladesh, this species has been reported as a vital source of micronutrients essential to prevent malnutrition for the rural people, particularly women and children [7]. This species also has a good demand as an ornamental fish in the international market [8].
Length-weight relationships (LWRs) and length-length relationships (LLRs) are still scarce for most tropical and sub-tropical fish species [9, 10, 11, 12, 13, 14, 15]. Sex ratio, the proportion of males and females in a population, is a key demographic parameter and an indicator of the population's behavior and fecundity, and is a fundamental concept in evolutionary biology [16]. To the best of our knowledge, very few information is available on the length-weight relationships [8, 17, 18, 19] of *A. mola* in the literature from different water bodies of the world.

However, there is no information on the sex ratio, LWRs and LLRs of from the Payra River, hampering the formulation of sound management strategies for this important fishery. Hence, the aim of the present study was to carry out the comprehensive description of the sex ratio, LWRs and LLRs of *A. mola* from the Payra River, southern Bangladesh which will be useful for the fishery and stock enhancement of this species.

2. Materials and methods

The present study was conducted in the Payra River, a southern coastal river of Bangladesh situated in the Patuakhali district (straddling 22º 35´ N and 90º 26´ E). Samples were collected monthly from the small-scale set bag net fishers of the Payra River during February 2016-January 2017. After collection the samples were preserved in 10% formalin and transferred to the laboratory for further analysis. Standard length (SL), total length (TL) and fork length (FL) for all individuals was measured to the nearest 0.01 cm using a measuring scale, while the body weight (BW) was recorded using a digital balance (AND, FSH, Korea) to 0.01 g accuracy. Sex was determined by incision of the abdomen of each individual and visual inspection of the gonad by naked eye.

The length-weight relationship (LWR) was estimated by the log-transformed linear regression: ln (W) = ln (a) + b ln (L), where the W is the body weight (BW g) and L the standard length (SL cm), total length (TL cm), fork length (FL cm). In addition, 95% confidence limits of a and b, and the coefficient of determination r^2 were estimated. All extreme outliers were excluded from the analyses according to Froese [20]. Furthermore, SL vs. TL, SL vs. FL and TL vs. FL relationships were estimated by linear regression separately for both sexes. T-test was used to determine the significant differences of b value from the isometric value (b = 3.0 for length-weight relationship and b = 1.0 for length-length relationship) [21]. Deviation of the b value from the theoretical isometric value indicates either positive (b > isometric value) or negative (b < isometric value) allometric growth. Analysis of covariance (ANCOVA) [21] was used to test for significant differences in slopes and intercepts among the relationships. Sex ratio (female/ male+female) was calculated in terms of monthly basis and size (TL in cm) class and the results were analyzed by using χ^2 test (1:1; $p<0.05$).

3. Results

A total of 1203 specimens of *A. mola* were collected during this study, with 574 (47.71%) males and 629 (52.29%) females. The SL ranged from 2.0 to 5.5 cm in males and from 0.5 to 5.8 cm in females, whereas BW ranged from 0.11 to 3.53 g and from 0.12 to 4.4 g for male and female respectively. The overall sex ratio showed no significant difference from the expected value of 1:1 (male:female = 1:1.10, $\chi^2 = 2.51$, $p>0.05$). However, the monthly sex ratio was 1:1 for almost all the year (Fig. 1), except in June when females were significantly more abundant than males (χ^2 test; $p<0.05$). With regard to the size (TL) class, the sex ratio was found to be non-significant from the expected value of 1:1 (χ^2 test; $p>0.05$) up to 4.0 cm TL, however; at 5.0 cm TL the number males were significantly higher than females and after that the number of females increased significantly than males till the rest of the size class (χ^2 test; $p<0.05$) (Fig. 2).

The LWRs are summarized in Table 1. The relationships between SL vs. BW indicated negative allometric growth for both sexes as the allometric coefficient b values were significantly different (<3.0) from the expected isometric value of 3 (t test; $p<0.05$). On the other hand, the relationships between TL vs. BW indicated positive allometric growth for males and isometric growth for females. The relationship between FL vs. BW indicated isometric growth for both sexes. However, the pooled data shows negative allometric growth between SL vs. BW, positive allometric growth between TL vs. BW and isometric growth between FL vs. BW. All LWRs were significant ($P<0.05$), with most of the coefficient of determination values being >0.910.

Conversion among length measurements, i.e. relationships between SL, TL and FL of 1203 *A. mola* fish specimens along with the estimated parameters of the length-length relationship and the coefficient of determination r^2 are presented in Table 2. The relationships between SL vs. TL, SL vs. FL and TL vs. FL indicated positive allometric growth, isometric growth and negative allometric growth respectively for both sexes as the allometric coefficient b values were significantly different from the expected isometric value of 1 (t test; $p<0.05$). However, the pooled data shows positive allometric growth between SL vs. TL, negative allometric growth between SL vs. FL and between TL vs. FL. All LLRs were highly significant ($P<0.001$), with most of the coefficient of determination values being >0.950.

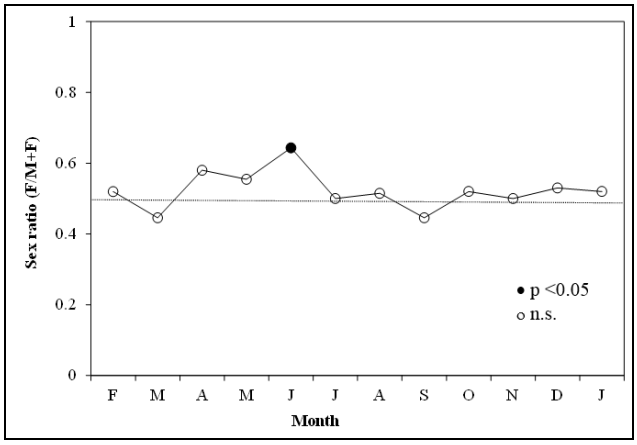

Fig 1: Temporal variation in sex ratio of *Amblypharyngodon mola* in the Payra River, southern Bangladesh. (• statistically significant difference from 1:1 ratio, o non-significant).

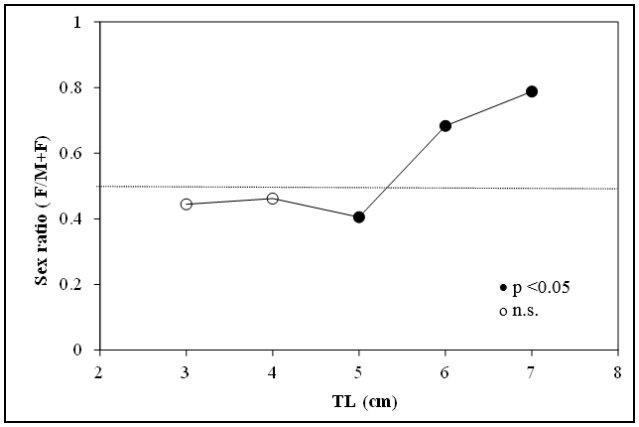

Fig 2: Sex ratios calculated for the total length (TL) classes of *Amblypharyngodon mola* from the Payra River, southern Bangladesh. (• statistically significant difference from 1:1 ratio, o non-significant).

Table 1: Descriptive statistics and estimated parameters of length–weight relationships for male, female and both sex of *A. mola* in the Payra River (southern Bangladesh) from February 2016-January 2017.

Sex	n	Equation	Regression parameters		95% confidence of a	95% confidence of b	r^2
			a	b			
Male	574	ln (BW) = ln (a) + b ln (SL)	-3.708	2.889	-3.799 to -3.615	2.815 to 2.962	0.913
		ln (BW) = ln (a) + b ln (TL)	-5.039	3.274	-5.138 to -4.940	3.209 to 3.340	0.944
		ln (BW) = ln (a) + b ln (FL)	-4.386	3.150	-4.467 to -4.304	3.090 to 3.209	0.950
Female	629	ln (BW) = ln (a) + b ln (SL)	-3.746	2.946	-3.816 to -3.675	2.893 to 2.998	0.951
		ln (BW) = ln (a) + b ln (TL)	-4.895	3.191	-4.980 to -4.809	3.137 to 3.245	0.956
		ln (BW) = ln (a) + b ln (FL)	-4.219	3.047	-4.295 to -4.141	2.993 to 3.099	0.953
Both	1203	ln (BW) = ln (a) + b ln (SL)	-3.724	2.913	-3.813 to -3.701	2.900 to 2.986	0.925
		ln (BW) = ln (a) + b ln (TL)	-4.969	3.233	-5.033 to -4.906	3.193 to 3.274	0.953
		ln (BW) = ln (a) + b ln (FL)	-4.287	3.087	-4.343 to -4.230	3.047 to 3.127	0.950

n, number of individuals; a, intercept; b, slope; Cl, confidence limits; r^2, coefficient of determination.

Table 2: Length–length relationships between standard length (SL), total length (TL), and fork length (AL) and of *A. mola* in the Payra River (southern Bangladesh) from February 2016-January 2017.

Sex	n	Equation	Regression parameters		95% confidence of a	95% confidence of b	r^2
			a	b			
Male	574	TL=a+ b×SL	0.387	1.187	0.325 to 0.449	1.170 to 1.204	0.970
		FL=a +b×SL	0.298	1.034	0.236 to 0.360	1.017 to 1.051	0.961
		FL=a +b×TL	- 0.051	0.874	-0.108 to 0.005	0.861 to 0.886	0.972
Female	629	TL=a+ b×SL	0.420	1.178	0.357 to 0.484	1.161 to 1.196	0.968
		FL=a +b×SL	0.212	1.060	0.165 to 0.258	1.047 to 1.073	0.979
		FL=a +b×TL	- 0.069	0.878	-0.791 to 0.149	0.792 to 1.116	0.976
Both	1203	TL=a+ b×SL	0.445	1.170	0.389 to 0.501	1.155 to 1.185	0.952
		FL=a +b×SL	1.044	0.263	0.215 to 0.309	1.032 to 1.057	0.957
		FL=a +b×TL	- 0.070	0.878	-0.117 to -0.024	0.868 to 0.887	0.964

n, number of individuals; a, intercept; b, slope; Cl, confidence limits; r^2, coefficient of determination.

4. Discussion

Understanding variation in sex ratio is especially important, as it is a key parameter of population fecundity. Unbalanced sex ratios can drive sexual selection, affect mating system, and influence population persistence and conservation status, owing to the effect of sex ratio on effective population size [29, 30]. From the study of sex ratio of *A. mola* it was found that the number of females was more than that of males, which was in accordance with the recent study of Gogoi and Goswami [8] from Assam. Dominance of females over the males in case of *A. mola* was also reported by Azadi and Mamun, [31] from the Kaptai Reservoir, Bangladesh. Analysis of size frequency distribution of *A. mola* by Afroze *et al.,* [32] stated dominance of females over males all throughout the year (n=3.60). Examining sex ratios across TL classes showed that female proportion gradually increased with increasing length. Sex ratio variations may be attributed to reproduction, growth and longevity of a species [34, 35]. However, in the present study, it was not clear which factors might be responsible in the fluctuation of male-female sex ratio.

Length-weight relationship (LWR) can be derived from length and weight measurements of the same fishes throughout their lives or from a sample of fish taken at a particular time [23]. The parameters of length-weight relationship are influenced by a series of factors including season, habitat, gonad maturity, sex, diet, stomach fullness, health of the individuals in their natural habitats as well as the treatment of specimens and preservation techniques after sampling [24, 25]. The allometric coefficient (b) generally lies between 2.5 and 3.5 [26], but they can vary between 2.0 and 4.0 [24]. The values of a and b of LWRs for *A. mola* in this study were within the limits reported by Froese [26]. In the present study, negative allometric growth of *A. mola* both for male and female was observed in LWR (SL vs. BW) which was in accordance with the recent study by Devi and Das [19] from wetlands of Assam, India. On the other hand, Gogoi and Goswami [8] reported positive allometric growth for female and negative allometric growth for male. Suresh *et al.* [27] reported that the length-weight relationship of *A. mola* for combined sex was isometric in the floodplain of West Bengal. Few other studies [12, 17, 18] reported positive allometric growth of *A. mola* for combined sex. The parameters of length-weight relationship might be influenced by a series of factors including season, habitat, gonad maturity, sex, diet, stomach fullness, health of the individual in their natural habitat as well as the treatment of specimens and preservation techniques after sampling [24, 25].

All length-length relationships were highly correlated and they were compared with the available literatures. In the present study, the length-length relationships were as TL= 0.387+ 1.187 SL (r^2=0.970); FL= 0.298 + 1.034 SL (r^2 =0.961); FL= -0.051 + 0.874 TL (r^2=0.972) for male and TL=0.420 + 1.178 SL (r^2=0.968); FL=0.212 + 1.060 SL (r^2 =0.979); FL= -0.069 + 0.878 TL (r^2=0.976) for female. Earlier, Hossain *et al.* [12] reported the length-length relationships as TL= 1.168 SL + 0.187 (r^2=0.901), SL=0.079 FL + 0.822 (r^2=0.868) and FL= 1.014 TL - 0.553 (r^2=0.936) for combined sexes of *A. mola* in the Mathabhanga River, southwestern Bangladesh. Another study by Hossain [18] also reported the length-length relationships as SL=0.823 TL-0.297 (r^2=0.998); TL=1.129 FL+ 0.309 (r^2=0.995) and FL= 1.076 SL+ 0.196 (r^2=0.995) for combined sexes of *A. mola* in the Padma River, NW Bangladesh. For the variations of LLRs in the same species from different locations the ecological conditions of the habits or variation in the physiology of animals, or both are responsible [28].

5. Conclusion

This study has provided basic information on the sex ratio, LWRs and LLRs of *A. mola* that would be useful for fishery biologists/managers to impose adequate regulations for sustainable fishery management in the Payra River (southern

Bangladesh) and nearby areas of Bangladesh. However, further and more detailed research are necessary for future assessment.

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