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Growth, Maturity and Form Factor of Mola Carplet (*Amblypharyngodon mola*) from the Ganges River, Northwestern Bangladesh

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Abstract

The current study presents the first complete and comprehensive description of population structure, growth pattern (length-weight relationships, LWRs; length-length relationships, LLRs), maturity (size at first sexual maturity; L_m), form factor ($a_{3.0}$) and natural mortality (M_W) of *Amblypharyngodon mola* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh. Additionally, asymptotic weight (W_α), $a_{3.0}$, L_m and M_W of this fish species from different water bodies worldwide were calculated. Seasonal samples of *A. mola* were collected from the Ganges River, northwestern Bangladesh during November 2015 to October 2016 from the fishers' catch using cast net (mesh size ranges: 1.5 - 2.0 cm). The total length (TL) was measured to the nearest 0.1 cm using digital slide calipers, and the total body weight (BW) was measured using an electronic balance with 0.1 g accuracy for each individual. The growth pattern was estimated through LWR as $BW= a*TL^b$, where *a* and *b* are regression parameters. Also, $a_{3.0}$ was calculated using the equation: $a_{3.0} = 10^{\log a\text{-}s(b\text{-}3)}$, where *a* and *b* are regression parameters of LWRs and s = -1.358, is the regression slope of log *a vs. b*. Furthermore, L_m of *A. mola* was calculated using the empirical equation, log (L_m) = -0.1189 + 0.9157 * log (L_{max}), where L_{max} = maximum observed TL. A total of 308 individuals of *A. mola* were analyzed, where minimum and maximum TL was 3.9 cm and 8.1 cm, respectively, and BW was 0.5g and 5.8 g, correspondingly. The highest number (49.00 %) of its population stands at 6.00 cm size group. The *b* value of LWR indicated positive allometric growth, the $a_{3.0}$ was 0.0129, the L_m was 5.16 cm in TL and M_w was 1.75 year^{-1} of *A. mola* in the Ganges River, northwestern Bangladesh. These findings can be very effective for the sustainable management of this fish species in the Ganges River and its ecosystems.

Keywords: *Amblypharyngodon mola*, Growth pattern, form factor, Size at sexual maturity, Ganges River, Bangladesh.

1. Introduction

Amblypharyngodon mola (Cyprinidae), commonly known as Mola Carplet, is widely distributed in Asian countries including Bangladesh, India, Myanmar and Pakistan (Talwar and Jhingran, 1991). This species is a popular food fish mainly in Indian sub-continent due to its high nutritional values (Saha *et al*., 2009) of a high protein, vitamin and mineral content (Mazumder *et al*., 2008). According to Rahman (1989), *A. mola* is extensively found in rivers, canals, *beel*s, ponds, and inundated fields of Bangladesh. Even though this fish species is categorized as a least concern in Bangladesh and globally (IUCN Bangladesh, 2015; IUCN, 2017), unfortunately the natural populations are declining due to the reckless fishing, habitat destruction (Hossain *et al*., 2017a), pollution and other ecological changes to their territory (Hossain *et al*., 2015; Hossen *et al*., 2016).

Information on the population structure of *A. mola* is needed for the appropriate management and the initiation of conservation measures of this important species in the Ganges River. Growth of fishes i.e. length–weight relationships (LWRs), length–length relationships (LLRs) are the most important biological parameters for the management and conservation of the natural populations (Sarkar *et al*., 2009; Muchlisin *et al*., 2010; Hossen *et al*., 2017). Additionally, form factor ($a_{3.0}$) is used to verify whether the body shape of a given species is notably different from others **(**Froese, 2006). Moreover, the size at first sexual maturity is very significant to find out the factors that affect the spawning size of a population (Hossain *et al*., 2013, 2017b; Elahi *et al*., 2017). Entropy on length-frequency distributions (LFDs) (Hossain *et al*.,

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2006, 2012), length-weight relationships (LWRs) (Hossain *et al*., 2016a, b, c, 2017c, d), form factor ($a_{3.0}$) (Hossain *et al*., 2013), and the size at first sexual maturity (L_m) (Hossain *et al*., 2016d) for different fish species in the Indian sub-continent are well documented. To the best of the authors' knowledge, there are no earlier studies on the population structure, growth, maturity, and form factor of *A. mola* from the Ganges River, NW Bangladesh. However, some studies on other aspects of this species from different water bodies have been done including Azadi and Mamun (2004), Mondal and Kaviraj (2013), Ahamed et al. (2017a, 2017b) etc. Therefore, this study presents the first reference on the population structure (length-frequency distributions; LFDs), growth (LWRs, LLRs), size at the first sexual maturity (L_m), form factor ($a_{3.0}$) and natural mortality (M_w) of *A. mola* from the Ganges River, NW Bangladesh.

2. Materials and Methods

In the current study, a total of 308 individuals of *A. mola* were collected seasonally from the Ganges, River of northwestern Bangladesh during November, 2015 to October, 2016 from the fishers' catch. The samples were caught using various types of traditional fishing gears i.e., cast net (mesh size ranges: 1.5 - 2.5 cm), gill net (mesh size ranges: 1.5–2.0 cm), and square lift net (mesh size: ~2.0 cm). The fresh samples (dead fish) were instantly chilled in ice on site and preserved with 10 % buffered formalin after arrival in the laboratory.

The fish were identified up-to species level through morphometric and meristic characteristics according to Rahman (1989) and Fishbase (Froese and Pauly, 2016). The total body weight (BW) of each individual was weighed using an electronic balance with a 0.01 g accuracy. Different linear dimensions i.e. lengths (Total length, TL; Fork length, FL; Standard length, SL) were taken to the nearest 0.01 cm using digital slide calipers.

The growth pattern was estimated through LWR with the equation: $BW = a*L^b$, where W is the body weight (BW, g) and L is the different lengths in cm. The regression parameters a and b were calculated by linear regression analyses based on natural logarithms: ln (W) = ln (a) + b ln(L). Moreover, 95 % confidence limit (CL) of a and b and the co-efficient of determination (r^2) were estimated. Extreme outliers were removed from the regression analyses according to Froese (2006). A t-test was used to confirm whether the b values obtained in the linear regressions were significantly different from the isometric value (b = 3), (Sokal and Rohlf 1987). The LLRs were estimated by linear regression analysis (Hossain *et al*., 2006).

The form factor ($a_{3.0}$) 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 LWR (TL *vs.* BW) and s = -1.358, is the regression slope of log a *vs.* b.

The size at first sexual maturity (L_m) of *A. mola* in the Ganges River was calculated using the empirical equation, log (L_m) = -0.1189 + 0.9157 * log (L_{max}) (Binohlan and Froese, 2009) based on the maximum observed length. Additionally, the asymptotic weight (W_α) was determined through LWR using the asymptotic length (L_α) = 10.47 cm (Azadi and Mamun, 2009) for each population. Also to estimate the $a_{3.0}$ in worldwide water bodies, the regression parameter a and b for LWRs of A. mola from different water bodies were obtained from the available literature through the Fish Base and / or the Google search. Furthermore, the maximum lengths of this species were obtained from the available literature to estimate the L_m in different water bodies worldwide.

The M_W of *A. mola* was calculated using the model, M_W =1.92 year^{-1} *(W)$^{-0.25}$ (Peterson and Wroblewski, 1984), where M_W = Natural mortality at mass W, and W = $a*L^b$, a and b are the regression parameters of LWR.

Statistical analyses were performed using Microsoft® Excel-add-in-DDXL and Graph Pad Prism 6.5 software. All statistical analyses were considered significant at 5 % ($p < 0.05$).

3. Results

A total of 308 specimens of *A. mola* were collected from the Ganges River, NW Bangladesh during this study. Table 1 illustrates the descriptive statistics on length and weight measurements with mean values and their 95 % confidence level. The LFDs of *A. mola* showed that TL varied between 3.9 cm and 8.1 cm. The maximum population stands at 6.0 cm to 7.0 cm TL size group (Figure 1). The regression parameters a and b of the LWR, and their 95 % confidence limits, and the coefficients of determination (r^2) and growth type are given in Table 2 and Figure 2. The calculated b values of the LWRs indicated positive allometric growth. All LWRs were highly significant ($P < 0.001$), with r^2 values being greater than 0.953. In addition, the LLRs along with regression parameters p and q, and the coefficient of determination (r^2) are presented in Table 3 and Figure. 3. All LLRs were highly significant ($P < 0.001$), with most coefficients of determination values being >0.971. Furthermore, the calculated W_α, $a_{3.0}$, L_m and M_W of this fish species from different water bodies worldwide are presented in Table 4. The present study reveals that M_W for the population of *A. mola* was 1.75 year^{-1} in the Ganges River, NW Bangladesh (Figure 4).

Table 1. Descriptive statistics on the length (cm) and weight (g) measurements of the *Amblypharyngodon mola* (Hamilton, 1822) (n = 308) in the Ganges River, northwestern Bangladesh.

Measurements	Min	Max	Mean ± SD	95% CL
TL (Total length)	3.9	8.1	5.41 ± 0.77	5.33-5.50
SL (Standard length)	3.0	6.3	4.20 ±0.60	4.13-4.26
FL (Fork length)	3.4	7.1	4.67 ± 0.67	4.60- 4.75
BW (body weight)	0.5	5.8	1.65 ±0.87	1.56- 1.75

Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values.

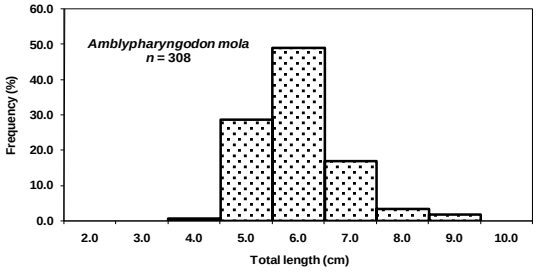

Figure 1. Total length frequency distribution of *A. mola* from the Ganges River, northwestern Bangladesh

Table 2. Descriptive statistics and estimated parameters of the length-weight relationships of the *Amblypharyngodon mola* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh.

Equation	*N*	*a*	*B*	95% CL of *a*	95% CL of *b*	r^2	GT
$BW=a*TL^b$		0.0067	3.21	0.0059 -0.0077	3.14- 3.29	0.957	A^+
$BW=a*SL^b$	308	0.0159	3.18	0.0143-0.0177	3.11 to 3.26	0.960	A^+
$BW=a*FL^b$		0.0114	3.18	0.0101-0.0129	3.10 -3.26	0.953	A^+

n, sample number; C, combined sex; BW, body weight; TL, total length; SL, Standard length; FL, Fork length; *a* and *b* are regression parameters and GT, growth type; A^+=positive allometric

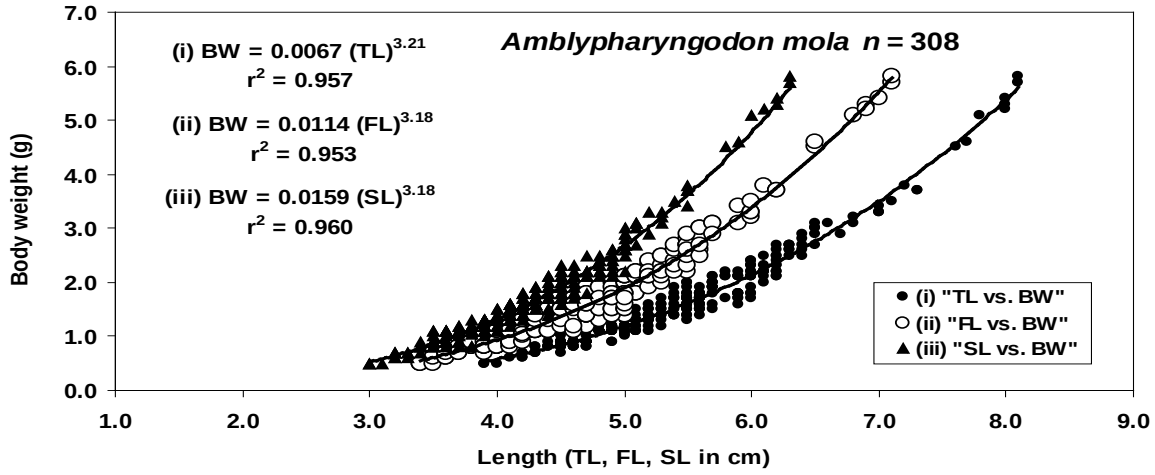

Figure 2. Length-weight relationships of *Amblypharyngodon mola* from the Ganges River, northwestern Bangladesh

Table 3. Descriptive statistics and estimated parameters of the length-length relationships of the *Amblypharyngodon mola* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh.

Equation	*p*	*Q*	95% CL of *p*	95% CL of *q*	r^2
TL=*p*+*q*(SL)	0.1009	1.27	0.0006- 0.2013	1.24-1.29	0.973
TL=*p*+*q*(FL)	0.1050	1.14	0.0134-0.1964	1.11-1.16	0.978
SL=*p*+*q*(FL)	0.0740	0.88	-0.0072 to 0.1551	0.87-0.90	0.971

n, Sample number; C, combined; *p*, Intercept; *q*, Slope ; TL, Total Length; SL, Standard Length; r^2, Coefficient of Determination

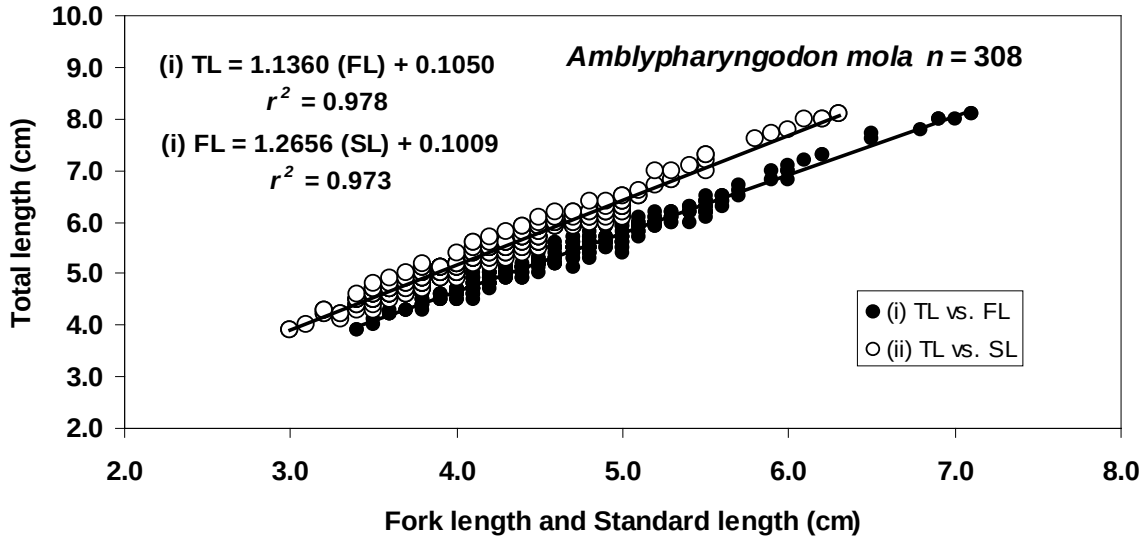

Figure 3. Length-weight relationships of *Amblypharyngodon mola* from the Ganges River, northwestern Bangladesh

Table 4. The calculated size at sexual maturity and form factor $a_{3.0}=10^{\log a - s(b-3)}$ of *Amblypharyngodon mola* (Hamilton, 1822) in different water bodies worldwide.

Water body	TL_{max}	W_α	Regression Parameter		References	$a_{3.0}$	L_m (95% CL of L_m)	M_w
			A	*b*				
Garjan beel, Assam	7.6	12.60	0.0053	3.31	Baishya *et al*. (2010)	0.0138	4.87 (4.00-5.98)	1.27
Ganges lower region	5.9*	28.06	0.0109	3.34	Hossain *et al*. (2009)	0.0316	3.86 (3.20-4.71)	1.33
Mathabhanga River	7.0	16.15	0.0055	3.40	Hossain *et al*. (2006)	0.0190	4.52 (3.72-5.53)	1.35
Garjan beel, Assam	8.3	17.79	0.0037	3.61	Baishya *et al*. (2010)	0.0250	5.28 (4.32-6.50)	1.07
Payra River, Bangladesh	5.8*	5.76	0.0065	2.89	Ahamed *et al*. (2017a)	0.1494	3.80 (3.16-4.63)	1.85
Wetlands of Assam	9.0	14.19	0.1678	2.87	Devi and Das (2017)	0.1118	5.69 (4.64-7.02)	0.62
Atrai & Bramhaputra River	6.2	1.14	0.009	2.06	Islam *et al*. (2017)	0.0005	4.04 (3.35-4.93)	2.29
Ganges River	-		0.1097	1.92	Sarkar *et al*. (2013)	0.0037	-	
Gomti River	-		0.0132	1.82	Sarkar *et al*. (2013)	0.0003	-	
Rapti River	-		0.1097	1.91	Sarkar *et al*. (2013)	0.0036	-	
South 24 Parganas, India	8.7		-	-	Pal *et al*. (2014)	-	5.51 (4.50-6.80)	
Wetland of Balarampur, Baruipur, West Bengal	8.9		-	-	Gupta and Banerjee (2015)	-	5.63 (4.59-6.95)	
Ganges River	**8.1**	**12.59**	**0.0067**	**3.21**	**Present study**	**0.0129**	**5.16 (4.23-6.35)**	**1.75**

TL, total length; *standard length; max, maximum; W_α = asymptotic weight; *a* and *b* are regression parameters of length-weight relationships; $a_{3.0}$, form factor; L_m, size at first sexual maturity; CL, confidence limit for mean values; M_W, natural mortality.

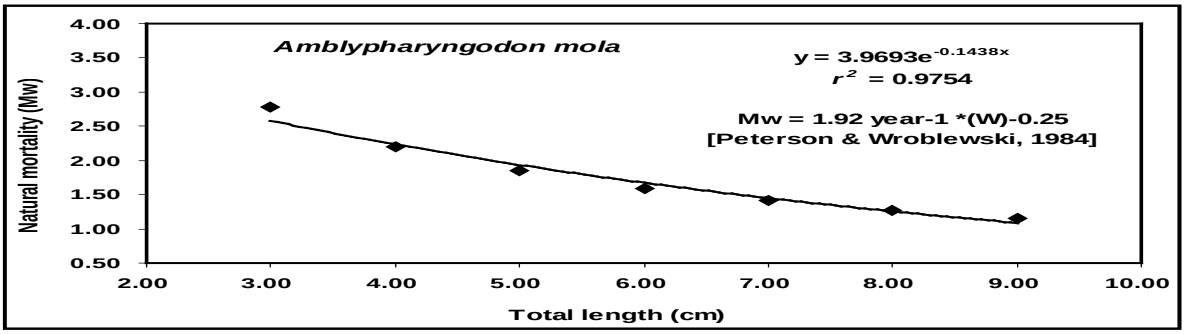

Figure 4. The natural mortality (M_W) of *Amblypharyngodon mola* from the Ganges River, northwestern Bangladesh

4. Discussion

During this study, a large number of specimens of *A. mola* were collected with various body sizes. However, it was not possible to collect < 8.1 cm TL, which can be attributed to the selectivity of fishing gears/ mesh (Hossain *et al*., 2017a). The present study observed the maximum TL of *A. mola* as 8.1 cm which is lower than the maximum recorded length of 15.0 cm (Ahmad, 1953). According to Rahman (1989) the maximum length of this fish species as 9.0 cm. Bhuiyan (1964) recorded the maximum TL as 8.0 cm which is lower than the present study. The variations in the recorded maximum TL of *A. mola* in different waters can be attributed to the nonexistence of bigger-sized individuals in the populations in fishing grounds/ areas (Hossain *et al.,* 2016d). In addition, the variations in the fishing gear used and the selectivity on the target species may greatly influence the size distribution of the caught individuals which resulted in highly biased estimations of various population parameters including the maximum size (Hossain *et al.*, 2017b, Azad *et al*., 2018).

The present study revealed that the calculated *b* value (3.21) for TL *vs.* BW lies between 2.50 and 3.50 (Froese, 2006). In earlier studies, Hossain (2010) and Hossain *et al*., (2009) recorded the regression parameter '*b*' as 3.76 and 3.34, respectively for *A. mola* from the Ganges River, NW Bangladesh. Additionally, Hossain *et al*. (2006) also recorded positive allometric growth in *A. mola* (*b* = 3.40) in the Mathabhanga River, southwestern Bangladesh, which are similar with the present findings. Gogoi and Goswami (2014) recorded the '*b*' value of LWR for combined sex of *A. mola* from the Jorhat district of India as 2.97 indicating negative allometric growth. This finding is not compatible with the result of the present study. However, the *b* values may vary in the same species due to the mixture of one or more factors including variations of growth in different body parts, sex, physiology, preservation methods, and differences in the observed length ranges of the specimens collected (Tesch, 1971; Hossen *et al*., 2016, 2018; Nawer *et al*., 2017), which were excluded during this study. All LLRs were highly correlated, and were compared with the available literatures.

The $a_{3.0}$ of this fish species was within the limits reported by Froese (2006), and Hossain *et al*. (2012). In addition, the form factor ($a_{3.0}$) using available *a* and *b* regression parameters of LWRs in ten different water bodies worldwide have been calculated. The $a_{3.0}$ can assess whether the body shape of individuals in a given population or species is considerably different from others

(Froese, 2006). No references dealing with the $a_{3.0}$ are available in the literature about these species, and therefore the present results provide an important basis for future comparisons.

Studies on size at first sexual maturity (L_m) for *A. mola* from the Ganges River, NW Bangladesh are absent in the literature. Studies dealing with L_m of this species from different regions have been conducted (Suresh *et al.*, 2007; Hoque and Rahman, 2008; Gupta and Banergee, 2013). In this study, The L_m for *A. mola* was 5.16 cm TL, regardless of sex which would be used for the permissible size of catch and for the special awareness in the fisheries management (Lucifora *et al*., 1999). Suresh et al. (2007) found L_m 5.1-5.6 cm and 3.9-4.4 cm whereas Hoque and Rahman (2008) reported 4.8 cm and 5.5 cm for males and females, respectively. Gupta and Banerjee (2013) have documented 5-5.5 cm and 5.5-6 cm for males and females, respectively. The variation on L_m might be due to geographical changes. Additionally, the L_m for *A. mola* from nine different water bodies has been calculated using the maximum length in the available literature, which would be used for conservation regulations in its own habitat.

The calculated W_α in this study was 12.59 g. Hossain et al. (2009) have used juveniles for their study, resulting in an error in the calculated W_α. Additionally, the b value from the study of Sarkar et al. (2013) might be wrong as well because the b values are not between 2.0 to 3.0 (Carlander, 1969). The M_w for the population of A. mola was estimated as 1.75 year^{-1} in the Ganges River, NW Bangladesh. Comparing this value with the calculated M_W of other water bodies, it is found that the value is almost similar with the calculated value of the Payra River, Bangladesh, but is much higher than all the calculated values of Indian waterbodies (Table 4), which may be attributed to the geographical variation.

In conclusion, our study gives valuable information on the population structure, growth pattern (length-weight relationships; length-length relationships), maturity (size at first sexual maturity), form factor and natural mortality of *A. mola*. The results of this study can be very beneficial for further studies in the Ganges River and other water bodies. Furthermore it can serve as a valuable means for stock assessment and a sustainable management of this fish species in the Ganges River and its ecosystems.

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Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of the present paper.

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