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Sex Ratio, Length-Frequency Distributions and Morphometric Relationships of Length-Length and Length-Weight for Spiny Eel, *Macrognathus aculeatus* in the Ganges River, NW Bangladesh

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Abstract: The present study describes the sex ratio, length-frequency distribution (LFD), length-weight relationship (LWR) and length-length relationship (LLR) of *Macrognathus aculeatus* wild population from the Ganges River, northwestern Bangladesh. Sampling was done using traditional fishing gears including cast net, square lift net, conical trap, monofilament fixed gill net and fish barrier during February 2011 to January 2012. For each individual, the total length (TL) and standard length (SL) were measured by digital slide calipers. Individual body weight (BW) was also taken by a digital balance. A total of 254 specimens ranging from 9.20-19.71 cm TL and 5.10-28.60 g BW were investigated in this study. The LFD showed that the 16-16.99 cm TL size group was numerically dominant. The sex ratio (male: female) was found to be 1:1.35. The overall sex ratio was significantly differed from the expected value of 1:1 (df = 1, χ^2 = 5.69, P<0.05). The coefficient *b* of the LWRs indicated negative allometric growth (b□3.00) for males, females and combined gender of *M. aculeatus* in the Ganges River. Further, LLRs were highly correlated (r^2=0.992). These results will be convenient for fishery biologists and ecologists to recommend suitable guidelines for sustainable fishery management and conservation of its numerous stocks in the Padma River and neighboring countries.

Key words: Sex Ratio · Length Frequency Distribution · Length-Weight Relationship · Length-Length Relationship · Ganges River · *Macrognathus aculeatus*

INTRODUCTION

The spiny eel, *Macrognathus aculeatus* is one of the common species among Mastacembeliformes. It is widely distributed in Bangladesh, China, India, Indonesia, Korea Rep., Laos, Malaysia, Nepal, Singapore, Taiwan, Thailand and Viet Nam [1-11]. *M. aculeatus* is known as spiny eel in Australia, *tara baim* in Bangladesh, *timanttipuikkokala* in Finland, *augenfleck-Stachelaal*, *asiatischer tachelaal* in Germany, *gachi* in India, *nga-mwendo* in Myanmar, *gerit*, *silih*, *silih cina*, *berod* in Indonesia, *trey Chhlaunh* in Cambodia, *pa lot* in Laos, *gainchi* in Nepal, *Pla lod jud*, *Pla lod* in Thailand, *Dlugonos ciernisty* in Poland [12]. The spiny eel inhabits mainly in medium to large-sized rivers but also abundantly found in lowland wetlands, peats, canals, *beels*, ponds and available in brackish water within tidal influence as well [13, 14]. *M. aculeatus* is an economically important species and preferred by the consumers of the Asian countries as a table fish [15] and also seen in aquarium trades [16]. The demand of the species always exceeds the supply and the supply mostly depends on the capture resources [15].

The length-weight relationship is extensively used in the analysis of fishery data, mostly due to the difficulty and time required to record weight in the field [17]. The relationship is frequently used to convert growth-in-length equations for prediction of weight-at-age and use in stock assessment models [18], to compute condition indices [19] and for life history and morphological comparison of populations from different regions [20]. As length and weight of fish are among the important morphometric characters, they can also be used for the purpose of taxonomy and ultimately in fish stock assessment [21]. Moreover, length-length relationships (LLRs) are also vital for comparative growth studies [22].

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Although length-weight relationships have been extensively studied throughout the world [23-33], studies on *M. aculeatus* is still scarce. However, a few studies have been conducted on different aspects of *M. aculeatus* including length-weight relationship [34], reproductive biology [35], captive breeding [36], length-weight and length-length relationship in the Mathabhanga River, Bangladesh [37], larval rearing under different condition [15]. Nevertheless, detailed studies on biology including sex ratio, length-frequency distribution (LFD), length-weight relationship (LWR) and length-length relationship (LLR) are evidently lacking from the Ganges River. Subsequently, the aim of the present paper was to carry out the first complete and comprehensive description of the sex ratio, LFD, LWR and LLR of *M. aculeatus* from the Ganges River, NW Bangladesh.

MATERIALS AND METHODS

Study Site: The present study was conducted in the lower part of the Ganges River, NW Bangladesh also known as the Padma River. The Ganges originates in the Gangotri glacier of the Himalayan and enters into Bangladesh from India at Shibganj Upazila of Chapai Nawabganj district (Latitude 24° 65' N; Longitude 88° 06' E) where becomes known as the Padma River.

Sampling: Samples of *M. aculeatus* 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 centers, from Binodpur to Godagari, Rajshahi (Latitude 24° 46' N; Longitude 88° 32' E), NW Bangladesh during February 2011 to January 2012. Fish were usually caught using the traditional fishing gears for example cast net (*jhaki jal*), square lift net (*tar jal*), conical trap (*dughair*), monofilament fixed gill net (*Current jal*) and fish barrier (*Thaga*). Samples were instantly preserved with ice in the fish landing area and fixed with 5% formalin on arrival in the laboratory. Identification of samples was made depending on the morphometric and meristic characteristics according to [12, 38]. For each individual, total length (TL) 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 weight (g) and L is the total 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 a, b and the coefficient of determination r^2 were estimated. In order to confirm whether b values obtained in the linear regressions were different from the isometric value ($b = 3$), a t-test was applied, expressed by the equation according to [39]: $t_s = (b\text{-}3) / s_b$, 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). In this study, prior to the regression analysis of ln BW on ln TL or ln SL, ln-ln plots of length and weight values were performed for visual inspection of outliers, with extremes being excluded from the regression analyses. Additionally, TL vs. SL relationship was estimated by linear regression [40].

Statistics Analyses: Statistical analyses were performed using Microsoft® Excel-add-in-DDXL and GraphPad Prism 5. 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 Shapiro-Wilk normality test. Where the normality assumption was not met, the non-parametric Mann-Whitney U test was used to compare two variables between the sexes. A Chi-square test was used to identify the sex-ratio divergence from the expected value of 1:1 (male: female). 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

Sex Ratio: Out of the 254 specimens (male=108; female=146; male: female = 1: 1.35) of *M. aculeatus* sampled in the Ganges River, northwestern Bangladesh during this study, 42.5% were males and 57.5% were females. The overall sex ratio was significantly differed from the expected value of 1:1 ($df = 1$, $\chi^2 = 5.69$, $P<0.05$). The TL dependent sex ratio is shown in Table 1. The chi-square test indicated that females outnumbered males from 16.00 to 20.00 cm TL, but that males were predominant from 9.00 to 11.00 cm TL.

Table 1: The total length dependent sex ratio (male: female = 1:1) of *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh

	Number of specimens					
Length class (TL, cm)	Male	Female	Total	Sex ratio (Male/ Female)	χ^2 (df=1)	Significance
9.00 – 9.99	3	1	4	1: 0.33	1.00	ns
10.00 – 10.99	6	2	8	1: 0.33	2.00	ns
11.00 – 11.99	10	7	17	1: 0.70	0.53	ns
12.00 – 12.99	11	23	34	1: 2.09	4.24	*
13.00 – 13.99	15	9	24	1: 0.60	1.50	ns
14.00 – 14.99	6	4	10	1: 0.67	0.40	ns
15.00 – 15.99	17	25	42	1: 1.47	1.52	ns
16.00 – 16.99	28	45	73	1: 1.61	3.96	*
17.00 – 17.99	12	25	37	1: 2.08	4.57	*
18.00 – 18.99	0	3	3	-	3.00	*
19.00 – 20.99	0	2	2	-	2.00	ns
Overall	108	146	254	1: 1.35	5.69	*

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

Table 2: Descriptive statistics on the length (cm) and weight (g) measurements of the *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh

Measurements	Sex	n	Min	Max	Median	Q_1	Q_3	IQR
Total length (cm)	Male	108	9.35	17.87	15.35	12.81	16.31	3.50
	Female	146	9.20	19.71	16.22	13.38	16.87	3.49
	Common gender	254	9.20	19.71	15.72	13.07	16.77	3.69
Standard length (cm)	Male	108	8.47	16.35	14.03	11.82	15.05	3.22
	Female	146	8.40	17.94	14.90	12.33	15.41	3.07
	Common gender	254	8.40	17.94	14.33	12.03	15.33	3.30
Body weight (g)	Male	108	5.55	23.85	16.28	9.93	18.10	8.18
	Female	146	5.10	28.60	17.60	12.10	20.17	8.07
	Common gender	254	5.10	28.60	16.95	11.45	19.55	8.10

n, sample size; Min, minimum; Max, maximum; Q_1, first quartile (25% Percentile); Q_3, third quartile (75% Percentile); IQR, inter-quartile range (Q_3- Q_1).

Length Frequency Distribution: A total of 254 specimens of *M. aculeatus* were analyzed from the Padma River in this study. Sample size, minimum and maximum lengths, minimum and maximum body weight, first quartile (Q_1), third quartile (Q_3), inter-quartile range (IQR) for male, female and combined gender are presented in Table 2 and Figs. 1 to 4. The TL ranged from 9.35 cm to 17.87 cm for males and 9.20 cm to 19.71 cm for females of *M. aculeatus*. On the other hand, SL ranged from 8.87 cm to 16.35 cm for males and 8.40 cm to 17.94 cm for females. The TL frequency distribution showed that the males and females of *M. aculeatus* were not normality distributed (Shapiro-Wilk normality test; P<0.01) in the Ganges River during this study. Thus, the Mann-Whitney U-test showed that the TL-frequency distribution was significantly different (Two tailed, Mann Whitney U = 6087, P = 0.002) between males (median = 15.35 cm, 25% percentile = 12.81 cm, 75% percentile = 16.31 cm) and females (median = 16.22 cm, 25% percentile = 13.38 cm, 75% percentile = 16.87 cm). The LFD also revealed that 16-16.99 cm TL class constituted highest number of individuals for both male and female in the Ganges River.

Furthermore, BW of *M. aculeatus* varied from 5.55 g to 23.85 g for males and 5.10 g to 28.60 g for females. The results of BW frequency distribution also showed that the males and females of *M. aculeatus* were not normality distributed (Shapiro-Wilk normality test; P<0.01) in the Padma River during this study. Thus, the Mann-Whitney U-test showed that BW of females (median = 16.28 g, 25% percentile = 9.93 g, 75% percentile = 18.10 g) was significantly higher (Two tailed, Mann-Whitney U = 5909, P<0.001) than that for males (median = 17.60 g, 25% percentile = 12.10 g, 75% percentile = 20.17 g).

Length-Weight Relationship: Sample sizes (*n*), regression parameters and 95% confidence intervals for *a* and *b* of the LWR, coefficients of determination (r^2) and growth type of *M. aculeatus* are given in Table 3 and Figs. 5 and 6. The calculated *b* values for the LWRs were found as 2.27, 2.22 and 2.26 for males, females and combined gender respectively incase of total length and 2.22, 2.21 and 2.23 for males, females and combined gender respectively while considering standard length. The calculated *b* for

Table 3: Descriptive statistics and estimated parameters of the length-weight relationships of the *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh

			Regression parameters						
Equation	Sex	n	*a*	*b*	95% CL of a	95% CL of b	r^2	t_s	*GT
$BW = a \times TL^b$	M	108	0.0324	2.27	0.0250 – 0.0418	2.17 – 2.36	0.954	- 5.66	A-
	F	146	0.0374	2.22	0.0302 – 0.0464	2.14 – 2.30	0.955	- 7.12	A-
	C	254	0.0336	2.26	0.0286 – 0.0395	2.20 – 2.32	0.956	- 8.94	A-
$BW = a \times SL^b$	M	108	0.0448	2.22	0.0343 – 0.0587	2.12 – 2.33	0.944	- 5.75	A-
	F	146	0.0479	2.21	0.0381 – 0.0602	2.12 – 2.29	0.945	- 6.78	A-
	C	254	0.0447	2.23	0.0376 – 0.0530	2.16 – 2.29	0.946	- 8.79	A-

n, sample size; M, male; F, female; C, common gender; BW, body weight; TL, total length; SL, standard length; *a*, intercept; *b*, slope; CL, confidence limit; r^2, coefficient of determination; GT, growth type; A-, negative allometric growth; [* based on Sokal and 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*)]

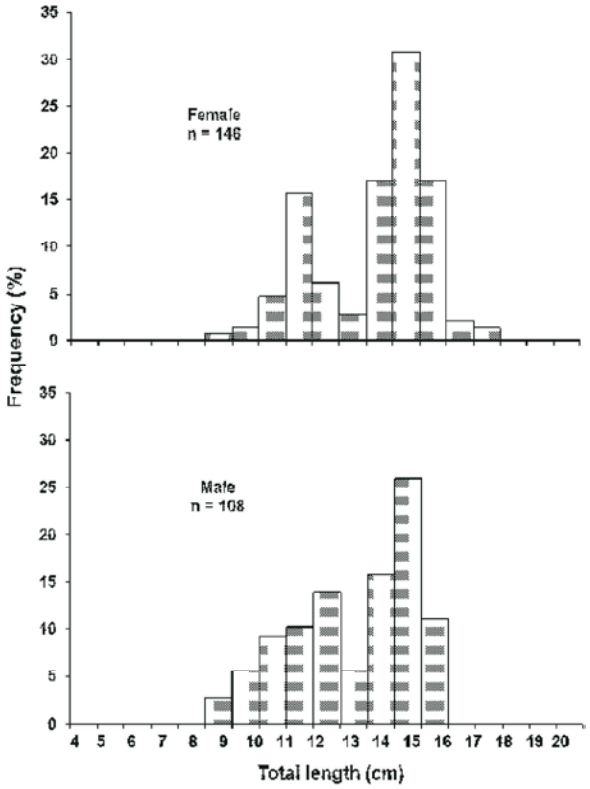

Fig. 1: Total length frequency distributions of male and female *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh

Length-Length Relationship: Relationship between TL and SL is shown in Table 4 and Fig. 7. The length-length relationship of *M. aculeatus* was found highly correlated and the coefficients of determination being = 0.992 for male, female and combined gender. There were no significant differences in the intercepts and in the slopes (ANCOVA, P>0.05) between the sexes of *M. aculeatus* in the Ganges River for TL vs. SL relationships.

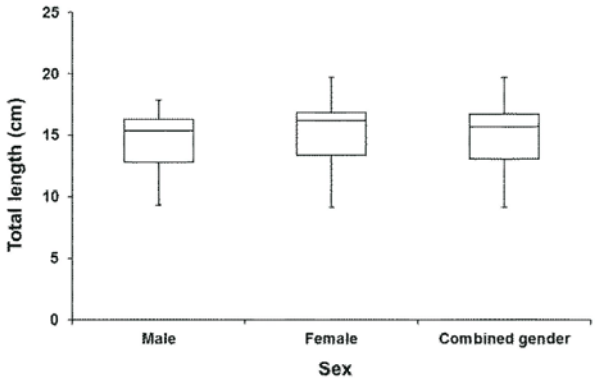

Fig. 2: Box-whiskers plot of total length (cm) for *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh. The horizontal line indicates the medium; box (?) shows the 25–75% of inter-quartiles; and the vertical line represents the range of the values

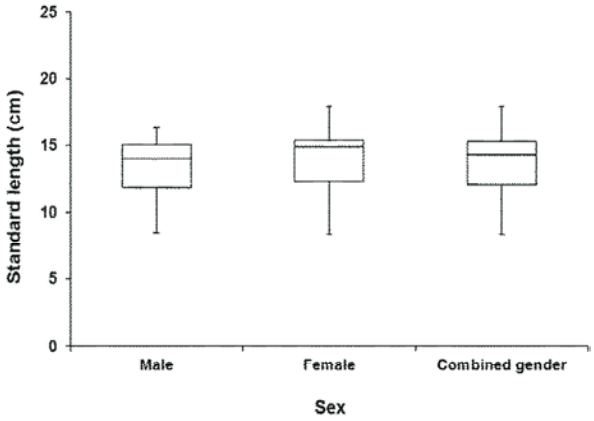

Fig. 3: Box-whiskers plot of standard length (cm) for *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh. The horizontal line indicates the medium; box (?) shows the 25–75% of inter-quartiles; and the vertical line represents the range of the values

Table 4: Descriptive statistics and estimated parameters of the length-length relationships ($TL = p + q \times SL$) of the *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh

		Regression parameters				
Sex	n	p	q	95% CL of p	95% CL of q	r^2
Male	108	0.1864	1.08	-0.0561 to 0.4289	1.06 – 1.10	0.993
Female	146	0.0477	1.09	-0.1754 to 0.2707	1.08 – 1.11	0.992
Common gender	254	0.1086	1.09	-0.0515 to 0.2688	1.08 – 1.10	0.993

n, sample size; TL, total length; SL, standard length; p, intercept; q, slope; CL, confidence limit; r^2, coefficient of determination

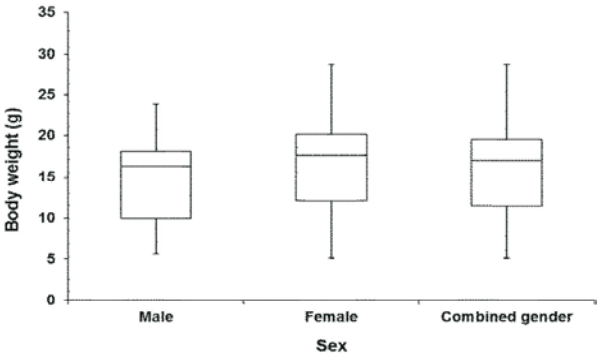

Fig. 4: Box-whiskers plot of body weight (g) for *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh. The horizontal line indicates the medium; box (□) shows the 25–75% of inter-quartiles; and the vertical line represents the range of the values

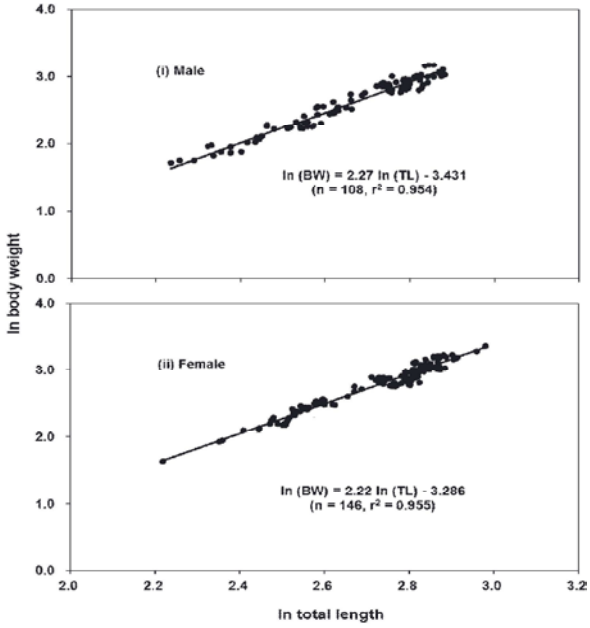

Fig. 5: Relationships (ln W = ln a + b ln L) between body weight (BW) and total length (TL) of (i) male and (ii) female *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh

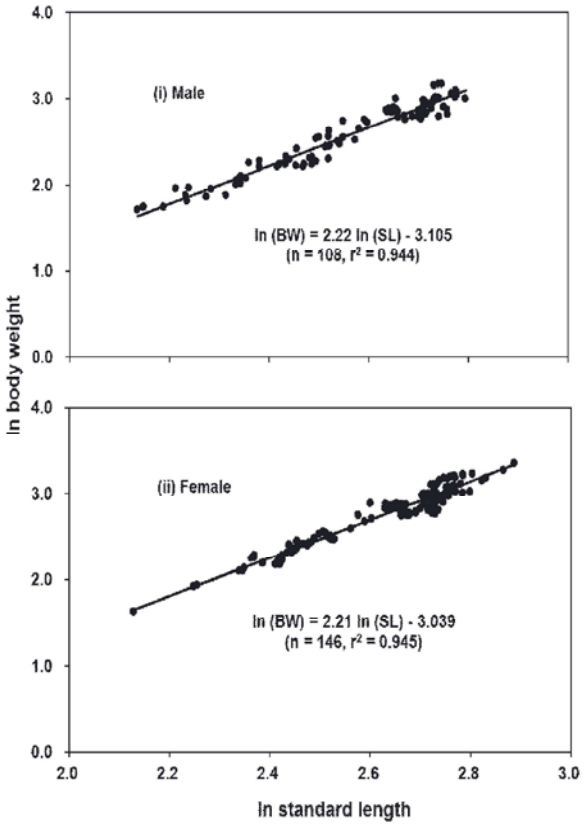

Fig. 6: Relationships (ln W = ln a + b ln L) between body weight (BW) and standard length (SL) of (i) male and (ii) female *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh

the LWR indicated negative allometric growth (t_s = -1.03, $b \approx 3.00$) in males, females and combined sexes (b<3.00). However, there were significant differences in the intercepts (ANCOVA, F=5.78, df = 251, P=0.017) but not in the slopes (ANCOVA, F = 0.535, df = 250, P = 0.465) between the sexes of *M. aculeatus* in the Ganges River. The regression models showed that there were no significant differences between observation and prediction growth patterns in males and females (ANCOVA, P>0.05).

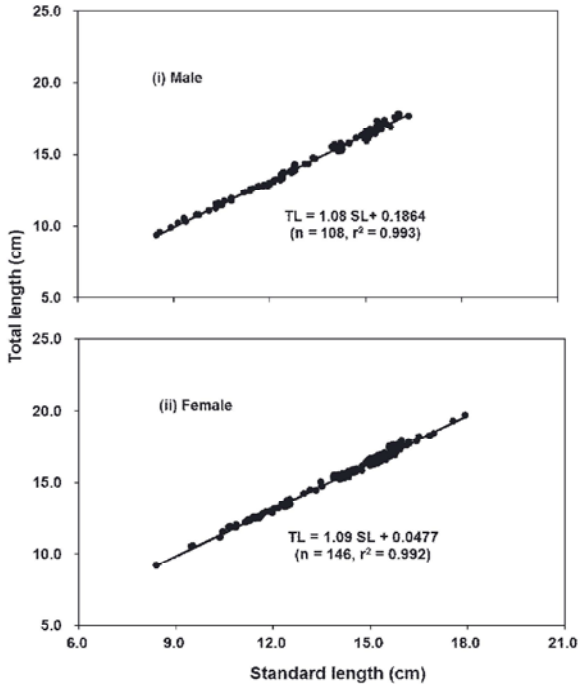

Fig. 7: Relationships (TL = a + b × SL) between standard length (SL) and total length (TL) of (i) male and (ii) female *Macrognathus aculeatus* (Hamilton, 1822) in the Ganges (Padma) River, northwestern Bangladesh

DISCUSSION

Sex Ratio: Departure from a 1:1 sex ratio is not expected for most aquatic (fin- and shellfish) species, although some finfish and prawn populations may show a strong bias in this ratio [41]. In this study, the male and female sex ratio was 1:1.35 which differed significantly from the expected value of 1:1. Lack of adequate information on sex ratio of this species restrains the comparison with other studies. However, an increase in sex ratio with body size has been documented for other species, possibly due to the high mortality of males and greater longevity of females [41]. Additionally, differences in growth between sexes, sexual dimorphism and migration may also be factors. No sexual dimorphism was found in the present study. Therefore, the increase of the sex ratio with size might be related to different growth between sexes.

Length-Frequency Distribution: This study sampled 254 specimens with various body sizes using traditional fishing gears, though it was not possible to catch *M. aculeatus* smaller than 9.20 cm TL during the study period, which can be ascribed to either the absence of small sized fishes (< 9.20 cm TL) in the populations or selectivity of the fishing gears [41, 42]. The maximum TL of *M. aculeatus* found in this study (23.40 cm) was much lower than the maximum recorded value of 38 cm TL [43]. Shrestha [44] and Vidthayanon [16] reported the maximum TL of *M. aculeatus* in the rivers of Terai and mid hills, India and in Thailand as 25 cm SL which are higher than that found in this study. However, the value found in this study is higher than that recorded by [37] in the Mathabhanga River as 21.80 cm. Present study records maximum weight of the spiny eel as 23.80 g which is way less than the maximum recorded weight of 50 g in Maharashtra, India [3].

These regional dissimilarities in total length probably depend on the ecological conditions in the areas of research. Moreover, water temperature can be directly linked to rates of biological production and food availability, as well as to nekton and plankton species composition, both of which influence fish growth [45, 46]. The differences in the recorded maximum sizes of individuals of *M. aculeatus* in different regions might also be attributed either to the absence of larger-sized individuals in the populations in fishing grounds [41] and/or shrinkage in body size of the formalin-preserved specimens. In addition, the variations in the fishing gear used and the selectivity on the target species may greatly influence the size distribution of the individuals caught resulting in highly biased estimations of the various population parameters including the maximum size [29]. However, Hossain *et al*. [47] described that the information on maximum length is essential to estimate the population parameters including asymptotic length and growth coefficient of fishes, which is important for fisheries resource planning and management. Nevertheless, the decrease in the maximum sizes of individuals of *M. aculeatus* landed within the Padma River system signaling the need for urgent measures to conduct extensive studies on this species to provide more information for their management and conservation [42].

Length-Weight Relationship: The parameter *b* values of LWR vary between 2 and 4, however, values ranging from 2.5 to 3.5 are more common [48, 49]. In general and despite the many variations in fish forms between species, *b* is close to 3, indicating fish grow isometrically; values significantly different from 3.0 indicate allometric growth [50]. Results showed that the *b* values of LWR were within the range described by Carlander and Froese [48, 49] suggesting negative allometric growth in the

Padma River, NW Bangladesh. Hossain *et al.* [37] also reported negative allometric growth for *M. aculeatus* in the Mathabhanga River, Bangladesh though the *b* value was a bit higher (*b* = 2.86) in their study. However, Lazarus *et al*. [34] recorded the *b* values as 3.16 for males and 2.97 for females of *M. aculeatus*. But they didn't take samples from any specific waterbody rather took samples from the market, Tambaram, India. Nonetheless, the LWR in fishes can be affected by several factors including habitat, area, seasonal effect, degree of stomach fullness, gonad maturity, sex, health, preservation techniques and differences in the observed length ranges of the specimen caught [50]. In addition, growth increment, differences in age and stage of maturity [40], food, as well as environmental conditions such as temperature, salinity and seasonality can also affect the value of *b* for the same species [46], all of which were not accounted in the present study. Since sample of *M. aculeatus* were collected over an extended period of time, this data are not representative of any particular season, so should be treated only as mean-annual values for comparative purposes.

Length-Length Relationship: The present study revealed highly correlated relationship between TL and SL of *M. aculeatus*. Hossain *et al.* [37] found the relationship between TL and SL as TL = 1.021 SL + 0.771 which is in accordance with the findings of this study. However, statistical analyses revealed no significant differences in LLR between sexes during the study.

CONCLUSION

This study provided basic information on the sex ratio, length frequency distributions, length-weight and length-length relationships based on various body dimensions of *M. aculeatus* from the Padma River, northwestern Bangladesh which would be effective for fishery biologists and conservationists to impose adequate regulations for sustainable fishery management and conservation of its numerous stocks in the region. These results will help in further studies on the population assessment of the species in the Ganges River and surrounding ecosystems.

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