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Growth, maturity, condition, size at sexual maturity and mortality of the Banded gourami *Trichogaster fasciata* from the Ganges River, Northwestern Bangladesh

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ABSTRACT

The present study depicts the first comprehensive description on population structure, growth pattern (length-weight relationships, LWRs and length-length relationships, LLRs), condition factor (allometric, K_A; Fulton′s, K_F; relative, K_R and relative weight, W_R), maturity (size at first sexual maturity; L_m), form factor ($a_{3.0}$) and natural mortality (M_w) of *Trichogaster fasciata* (Bloch and Schneider, 1801) in the Ganges River, Northwestern Bangladesh. In addition, asymptotic weight (W_a), $a_{3.0}$, L_m and M_w of this fish from world-wide different water bodies were calculated based on maximum total length. Samples of *T. fasciata* were collected from the fisher's catch during August 2015 to July 2016 using cast net (mesh size ranges: 1.5 - 2.0 cm). For each individual, total length (TL) and body weight (BW) were measured using digital slide calipers and electronic balance with 0.01 cm and 0.01 g accuracy, respectively. A total of 278 individuals were analyzed, where minimum and maximum TL was 3.3 cm and 9.9 cm, respectively and BW was 1.1 g and 22.04 g, correspondingly. Highest number (32.4%) of its population stands at 6.0 cm to 7.0 cm TL size group. The *b* value of LWR indicated negative allometric growth. Fulton′s condition factor (K_F) is the best condition and W_R showed significant dissimilarity from 100, signifying the balanced habitat for *T. fasciata* in the Ganges River. The $a_{3.0}$ was 0.0214, the L_m was 5.91 cm TL and M_w was 1.35 year^{-1} of *T. fasciata* in the Ganges River. These findings will be very effective for its sustainable management in the Ganges River and connecting ecosystems.

INTRODUCTION

Perciformes is the largest orders of teleosts consist of maximum marine shore fishes, while about 2,000 species normally occur only in freshwater **(Froese and Pauly, 2018)**. *Trichogaster fasciata* **(Bloch and Schneider, 1801)**, commonly known as Banded

gourami is a fresh-and-brackish-water inhabitant belonging to the family Osphronemidae. This fish is also known as Kholisha in Bangladesh **(Ahmed, 1991)**, Kholiana in India **(Nath and Dey, 1989)** and Katara in Nepal **(Shrestha, 1994)**. It is an indigenous species in Asian countries including Bangladesh, India, Nepal, Bhutan, and Pakistan **(Rahman, 1989; Talwar and Jhingran, 1991; Menon, 1999; Petr, 1999; Gupta, 2015)**. This fish dominantly inhabited rivers, streams, ponds, *beels*, floodplains, *baors*, *haors*, in plains and sub-montane regions, generally preferring weedy environment **(Menon, 1999; Craig *et al.*, 2004)**. It is very hardy and air-breathing species **(Huang *et al.*, 2011)**. The fish is omnivorous in nature, so they can feed on live, frozen and sliver feeds **(Goodwin, 2003)**. This fish is a popular ornamental fish due to its brilliant colour pattern, small size and peaceful nature (Gupta, 2015). It is a major target species for small scale fishers **(Shafi and Quddus, 1982; Rahman, 2005)**. The species suffers from overexploitation since it has both ornamental and food value but, at present it is a very wide spread species **(IUCN, 2012)**, therefore, it is assessed as least concern both in Bangladesh **(IUCN Bangladesh, 2015)** and worldwide **(IUCN, 2017)**.

For management and conservation of wild populations, length weight relationships (LWRs) and length length relationships (LLRs) are the most significant biological parameters **(Sarkar *et al.*, 2009; Muchlisin *et al.*, 2010; Hossen *et al.*, 2017)**. Condition factor is a quantitative parameter of the condition of well-being of the fish that will decide present and future population success by its influence on growth, reproduction and survival **(Richter, 2007)**. Moreover, in the USA since last two decades, relative weight (W_R) is one of the most popular indexes for assessing condition of fishes **(Rypel and Richter, 2008)**. Additionally, to verify whether the body shape of a given species is remarkably different from others, form factor ($a_{3.0}$) is used **(Froese, 2006)**. Moreover, the size at first sexual maturity is very important to find out the factors that have an effect on the spawning size of a population **(Hossain *et al.*, 2013, 2017a; Elahi *et al.*, 2017)**. Entropy on length-frequency distributions (LFDs) **(Hossain *et al.*, 2006, 2012)**, length-weight relationships (LWRs) **(Hossain *et al.*, 2016a, b, c, 2017a, b)**, form factor ($a_{3.0}$) **(Hossain *et al.*, 2014)** and size at first sexual maturity (L_m) **(Hossain *et al.*, 2016d)** for different fish species of Indian sub-continent are well documented. Nevertheless, several studies have been conducted on different aspects including biology and length-weight relationship of *T. fasciata* from different waterbodies of its distribution area, which are outlined in Table 1. To the best of the authors' knowledge, there are no earlier studies on population structure, growth, maturity, condition and form factor of *T. fasciata* from the Ganges River, Northwestern Bangladesh.

Table 1. List of published works in different aspects of *Trichogaster fasciata* along with their locations and references.

Aspects	Location (water body/country)	Reference
Length-Weight Relationship	Gajner *Beel* , Bangladesh	Hossain *et. al*. (2017b)
	Jessor	Akter *et al*. (2016)
	Jhinaidah	Akter *et al*. (2016)
	Nageshwari river	Ferdaushy and Alam (2015)
	Nitai *Beel*,India	Kalita *et al*. (2016)
	Ganga, Gomti and Rapti River, India	Sarkar *et al*. (2013)
	Brahmaputra basin of Assam	Paswan *et al*. (2012)
	Deepor *beel* , Assam, India	Borah *et al*. (2016)
Biology	Floodplain Wetland of Ganga River Basin, India	Mitra *et al*. (2007)
	Assam, India	Phukon and Biswas (2013)
	Patiasola and Borsola wetlands, Assam, Inidia	Abujam *et al*. (2015)
	Feeding and reproductive biology	Gupta (2015)

MATERIALS AND METHODS

In our study, total 278 individuals were collected occasionally from the Ganges River of northwestern Bangladesh during August 2015 to July 2016 from the fishers' catch. The samples were caught using different 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 immediately chilled in ice on site and preserved with 10% formalin after arrival in the laboratory.

Fish was identified up-to species level through morphometric and meristic characteristics according to **Rahman (1989)** and FishBase **(Froese and Pauly, 2018)**. Total body weight (BW) of each individual was weighed using an electronic balance with 0.01 g accuracy and different linear dimensions i.e., lengths (Total length, TL and 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) in 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. Extremes outliers were removed from the regression analyses according to **Froese (2006)**. A t-test was used to confirm whether 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 Fulton's condition factor K_F was calculated using the equation given by **Fulton (1904)** as $K_F = 100\times (W/L^3)$, relative condition factor (K_R) for each individual was calculated via the equation of **Le Cren (1951)**: $K_R = W/(a\times L^b)$ where W is the body weight (BW), and L is the total length (TL), a and b are the LWRs parameter in addition, relative weight (W_R) was calculated by the equation given by **Froese (2006)** as $W_R = (W / Ws) \times 100$, where W is the weight of a particular individual and Ws is the predicted standard weight for the same individual as calculated by $Ws = a\times L^b$. The form factor ($a_{3.0}$) was calculated using the equation given by **Froese (2006)** as: $a_{3.0} = 10^{\log\ a\text{-}s(b\text{-}3)}$, where a and b are regression parameters of LWRs and s = -1.358, is the regression slope of log *a vs. b*.

The size at first sexual maturity (L_m) of *T. fasciata* 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 maximum observed length**.** Additionally, asymptotic weight (W_α) was determined through LWR using the asymptotic length (L_α) = 10.4 cm **(Mitra *et al.*, 2007)** for each population. Also to estimate the $a_{3.0}$ in world-wide water-bodies, the regression parameter a and b for LWRs of *T. fasciata* from different water-bodies were obtained from available literature in the FishBase and/or Google search. Furthermore, the maximum lengths of this species were obtained from available literature to estimate the L_m in different worldwide water-bodies.

The M_w of *T. fasciata* was calculated using the model, $M_w = 1.92\ \text{year}^{-1} * (W)^{-0.25}$ **(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% ($p < 0.05$).

RESULTS

Table 2 illustrates the descriptive statistics on length and weight measurements with mean values and its 95% confidence level. The LFDs of *T. fasciata* showed that TL varied between 3.3 cm and 9.9 cm. Maximum population stands at 6.0 cm to 7.0 cm TL size group constituting 32.4% of the total population (Figure 1). The regression parameters a and b of the LWR, and their 95% confidence limits and coefficients of determination (r^2) are given in Table 3 and Figure 2.

Table 2. Descriptive statistics on the length (cm) and weight (g) measurements of *Trichogaster fasciata* from the Ganges River, Northwestern Bangladesh.

Measurements	N	Min	Max	Mean ± SD	95% CL
TL (Total length)	278	3.3	9.9	6.42 ± 1.138	6.29 to 6.55
SL (Standard length)	278	2.5	7.5	4.90 ±0.83	4.80 to 5.00
BW (Body weight	278	1.1	22.04	6.43 ±3.36	6.03 to 6.82

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

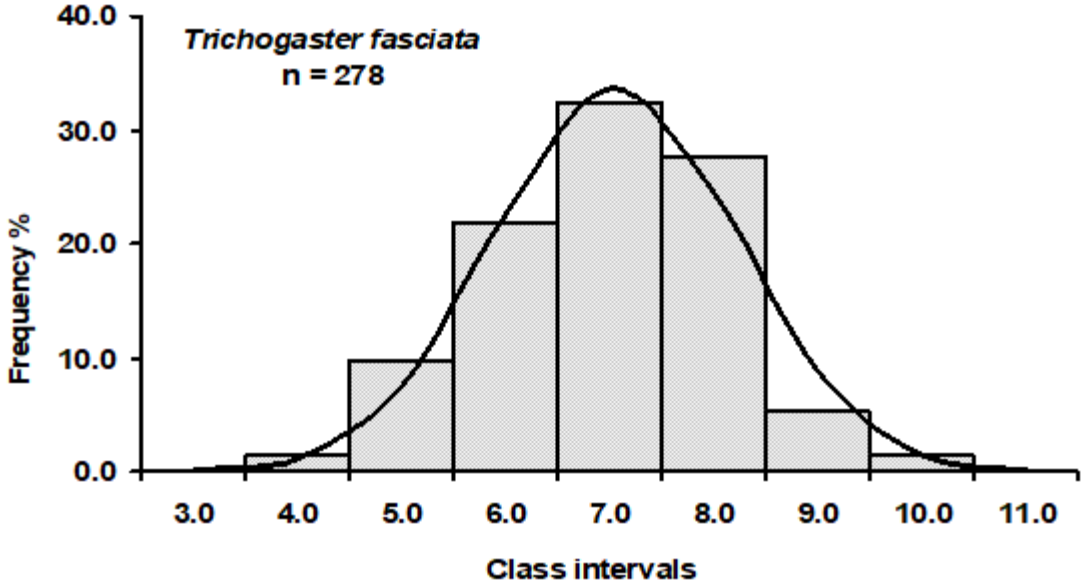

Figure 1. Total length frequency distribution of *Trichogaster fasciata* from the Ganges River, Northwestern Bangladesh.

Table 3. Descriptive statistics and estimated parameters of the length-weight relationships of *Trichogaster fasciata*.

Equation	*n*	*a*	*b*	95% CL of a	95% CL of b	r^2	GT
$BW=a\times TL^b$	278	0.0235	2.97	0.0211 -0.0261	2.91 to 3.03	0.987	A^-
$BW=a\times SL^b$		0.0433	3.09	0.0395-0.0473	3.03 to 3.14	0.976	A^+

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

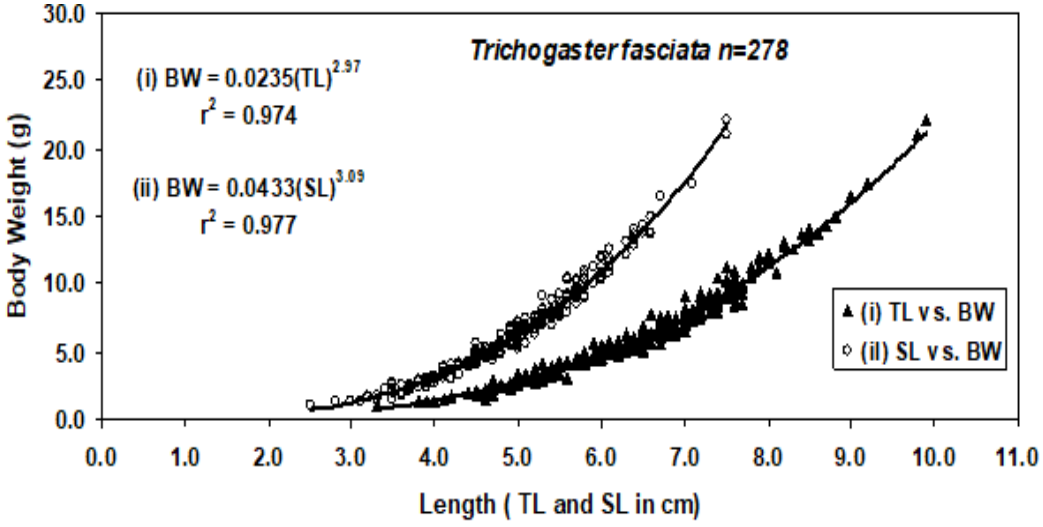

Figure 2. Length-weight relationships of *Trichogaster fasciata* from the Ganges River, Northwestern Bangladesh.

The calculated *b* values of the LWRs indicated negative allometric growth. All LWRs were highly significant ($P < 0.001$), with r^2 values greater than 0.976. In addition, the LLRs along with regression parameters *a* and *b*, and the coefficient of determination (r^2) are presented in Table 4 and Figure 3. LLR was highly significant ($P < 0.001$), with most coefficients of determination values being 0.989.

Table 4. Descriptive statistics and estimated parameters of the length-length relationships of *Trichogaster fasciata*.

Equation	*a*	*b*	95% CL of *a*	95% CL of *b*	r^2
TL=*a*+*b*(SL)	-0.1638	1.34	-0.2782 to 0.0493	1.24 to 1.29	0.989

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

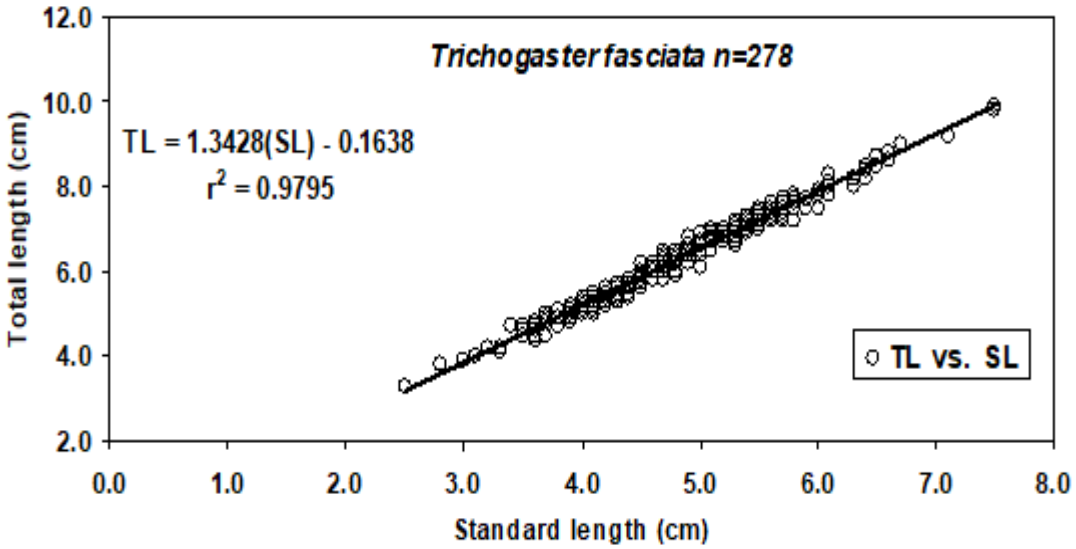

Figure 3. Length-weight relationships of *Trichogaster fasciata* from the Ganges River, Northwestern Bangladesh.

The values of all condition factors (Fulton's condition, K_F; Relative condition factor, K_R; Allometric condition factor, K_A; and relative weight, W_R) are given in Table 5. On the basis of Spearman rank correlation test, there were significant co-relationships of K_R with BW and W_R was also highly correlated ($r_s = 0.0264$, $P = 0.007$) with BW (Table 6). W_R showed significant dissimilarity from 100, signifying the balanced habitat for *T. fasciata* in the Ganges River (Figure 4).

Table 5. Condition factors (K_F, K_R, K_A,) and Relative weight (W_R) of *Trichogaster fasciata* from the Ganges River, Northwestern Bangladesh.

Condition factor	n	Min	Max	Mean ± SD	95% CL
Fulton's condition factor (K_F)	278	1.490	3.061	2.225 ± 0.200	2.202 to 2.249
Relative condition factor (K_R)	278	0.664	1.350	1.001 ± 0.089	0.990 to 1.011
Allometric condition factor (K_A)	278	0.016	0.032	0.024 ± 0.002	0.023 to 0.024
Relative weight (W_R)	278	66.360	135.001	100.078 ± 8.944	99.022 to 101.134

Table 6. Spearman rank correlation coefficient (r_s) for Relative condition factor (K_R) and Relative weight (W_R) with body weight (BW, g) of *Trichogaster fasciata*.

	Spearman rank correlation (r_s)	*P* value
BW *vs.* K_R	0.0259	$P = 0.007$
BW *vs.* W_R	0.1613	$P = 0.007$

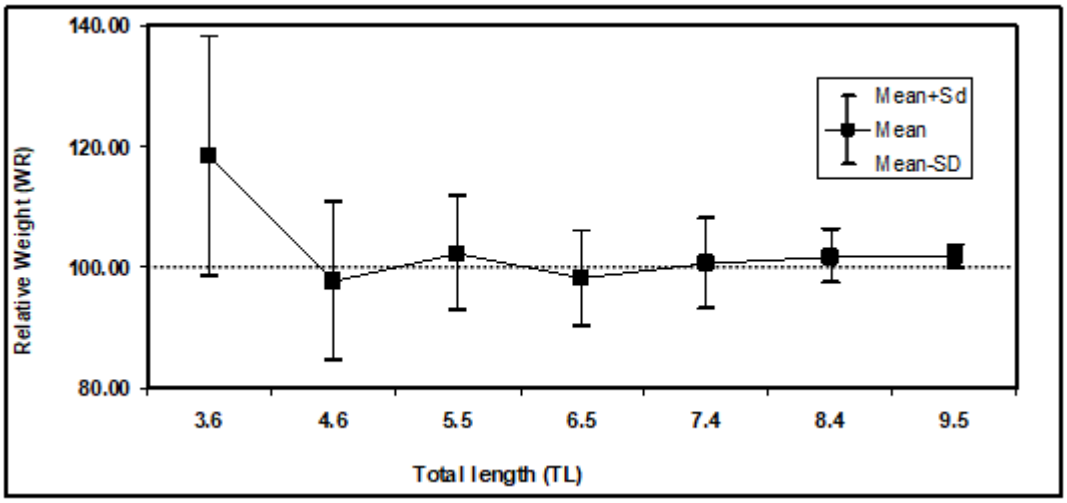

Figure 4. Relation between TL and relative condition factor (W_R) of *Trichogaster fasciata* from the Ganges River, Northwestern Bangladesh.

Furthermore, the calculated W_α, $a_{3.0}$, L_m and M_w of this fish species from world-wide different water bodies are presented in Table 7. The present study reveals that M_w for the population of *T. fasciata* was 1.35 year^{-1} in the Ganges River, Northwestern Bangladesh (Figure 5).

Table 7. The calculated form factor $a_{3.0} = 10^{\log a - s\,(b-3)}$ of *Trichogaster fasciata*.

Water body	TL_{max}	W_α	Regression Parameter		References	$a_{3.0}$	L_m	(95% CL of L_m)	M_w
			a	*b*					
Gajner *Beel*	3.8	25.10	0.0143	3.19	Hossain *et al*. (2017)	0.0259	2.58	(2.18-3.1)	1.51
Nageshwari river	7.8	5.79	0.0048	3.03	Ferdaushy and Alam (2015)	0.0053	4.99	(4.09-6.13)	2.25
Nitai *Beel*,India	8.14	104.78	0.2491	2.58	Kalita *et al*. (2016)	0.0670	5.19	(4.25-6.38)	1.51
Jessor*	9.1	59.00	0.1084	2.69	Akter *et al*. (2016)	0.0411	5.75	(4.68-7.09)	1.03
Jhinaidah*	8.6	5.14	0.1599	1.48	Akter *et al*. (2016)	0.0014	5.46	(4.46-6.73)	1.71
Ganges river	**9.9**	**24.64**	**0.0235**	**2.97**	**Present study**	**0.0214**	**5.91**	**(4.36-8.01)**	**1.35**

TL, total 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. *Sample collected from fish market.

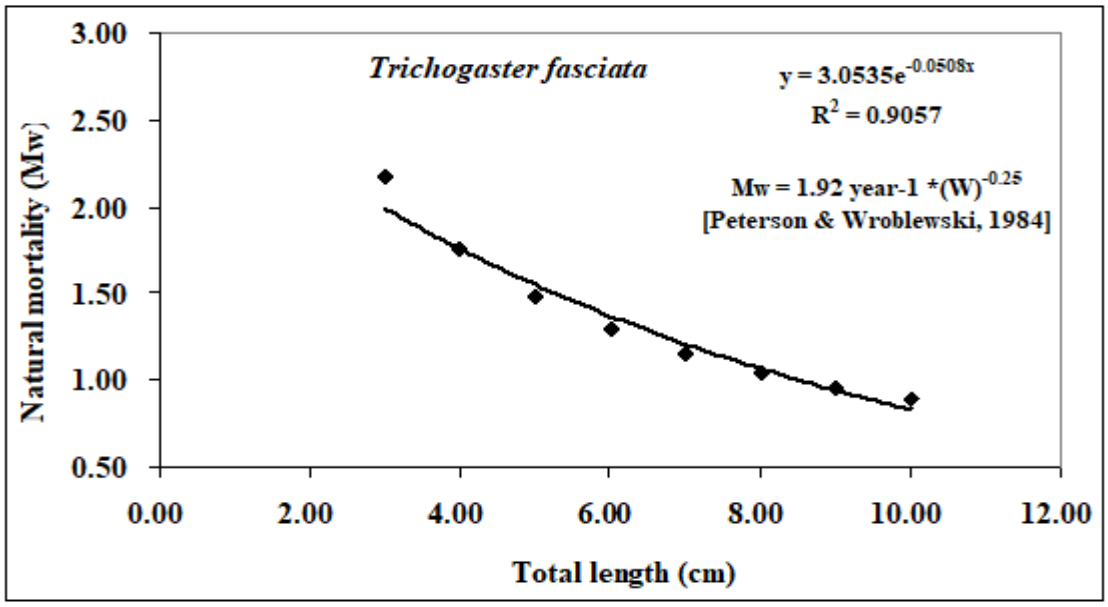

Figure 5. The natural mortality (M_w) of *Trichogaster fasciata* from the Ganges River, Northwestern Bangladesh.

DISCUSSION

Information on the population structure of *T. fasciata* is needed for appropriate management and initiate conservation measures for this important species in the Ganges River. During this study, a large number of specimens of *T. fasciata* were collected with different body sizes. However, it was not possible to collect <3.3 cm TL, which can be assigned due to the selectivity of fishing gears / mesh (Hossain et al. 2017c). In this study, the maximum length was found 9.9 cm TL in the Ganges River, which is higher than the maximum TL = 9.18 cm for Male and 9.01 cm for female **(Akter *et al.*, 2016)** in

Jessore District, TL= 7.80 cm **(Ferdaushy and Alam, 2015)** in Nageshawari, Bangladesh, TL= 8.8 cm **(Sakar *et al.*, 2013)** in Ganga River Channel, TL = 8.14 cm **(Kalita *et al.*, 2016)** in Nitai Beel, Assam, and TL = 7.5 cm **(Paswan *et al.*, 2012)** in Dubri District, India. However this value is lower than the FishBase value 12.5 cm TL **(Frose and Pauly, 2018)**. This differences might be due to the geographical location and environmental factors, predominantly water temperature and food availability **(Hossain and Ohtomi, 2010)**. Information on maximum length is essential to estimate the population parameters as well as asymptotic length and growth coefficient of fishes, which is significant for fisheries resource planning and management **(Hossain *et al.*, 2017c)**.

The present study revealed that the calculated *b* value (2.97) for TL *vs.* BW that lies between 2.50 and 3.50 **(Froese, 2006)**. In earlier studies, **Kalita *et al.* (2016)** recorded the '*b*' value of LWR for combined sex of *T. fasciata* was 2.58 from the Nitai Beel, Assam, India which indicates the negative allometric growth. **Akter *et al.* (2016)** recorded *b* = 1.69 in Jessor, Bangladesh which is also, shows the negative allometric growth. **Hossain *et al.* (2009)** found *b* = 3.19 in Gajner *beel*, floodplain and **Ferdaushy and Alam (2015)** recorded *b* = 3.03 in the Nageshwari, Bangladesh; both showed the positive allometric growth for *T. fasciata*. However, the *b* values may be different in the same species due to the combination 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, Nawer *et al.*, 2017)**, which were excluded during this study.

We have worked several condition factors in this study, (K_F, K_R, K_A and W_R) to assess the physical and environmental condition of *T. fasciata* in the Ganges River. The Fulton's condition factor is being >1 indicate that growth of these species were perfect condition. Therefore, it can be assumed that, the Fulton′s condition factor (K_F) is the best for determining the wellbeing of *T. fasciata* in the Ganges River and adjacent ecosystem. The K_F ranged from 1.489 to 3.061 for T. *fasciata* in the Padma River with a mean value of 2.23±0.20. **Ferdaushy and Alam (2015)** found K_F as 1.15 in Nageshawari, Bangladesh and **Mitra *et al.* (2007)** found K_F (1.87-2.37) in a Floodplain Wetland of Ganga River Basin, India.

In the present study the Relative weight (W_R) ranged from 66.360 to 135.001 g with mean value 101.367±10.898 g. W_R showed significant dissimilarity from 100, signifying the balanced habitat for *T. fasciata*. There was no previous work on that study to compare with our findings. The $a_{3.0}$ of this fish species was within the limits reported by **Froese (2006)**. In addition, form factor ($a_{3.0}$) using available *a* and *b* regression parameters of LWRs in 5 different world-wide water-bodies 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 for these species, and therefore the present results provide an important basis for future comparisons.

Studies on size at first sexual maturity (L_m) for *T. fasciata* from the Ganges River, Bangladesh are absent in the literature. Studies dealing with L_m of this species from different regions have been conducted (**Mitra *et al.*, 2007; Hossain et al., 2010**). In this study, The L_m for *T. fasciata* as 5.91 cm TL, regardless of sex which would be used for its permissible size of catch and for special awareness in fisheries management **(Lucifora *et al.*, 1999)**. **Mitra *et al.* (2007)** found L_m 5.7 cm. The variation on L_m might be due to geographical changes. Additionally, the L_m for *T. fasciata* from 5 different water-bodies has been calculated using maximum length from available literature, which would be used for conservation regulations in its own habitat. The calculated W_α in this study was 24.64 g. As our study is the first attempt, it is not possible to compare with other findings.

The M_w for the population of *T. fasciata* was estimated 1.35 year^{-1} in the Ganges River, Northwestern 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 Gajner *beel*, Bangladesh but much lower than the calculated values of Nageshwari, Bangladesh (Table 7) which may be attributed due to the geographical variation.

CONCLUSION

In conclusion, our study gives precious information on population structure, growth pattern (length-weight relationships; length-length relationships), condition factor (Fulton's, relative, allometric), relative weight, size at first sexual maturity, form factor and natural mortality of *T. fasciata*. The results of this study would be effective for further studies in the Ganges River and other water bodies. It is also valuable means for stock assessment and sustainable management of this fish species in the Ganges River and connecting 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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