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Original Article

Life-history traits of Indian river shad *Gudusia chapra* (Hamilton, 1822) in the Mahananda River (tributary of the Ganges River) of northwestern Bangladesh

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Abstract

For the first time, we describe the life-history traits including growth pattern, condition factors including (relative weight, W_R), form factor ($a_{3.0}$), size at sexual maturity (L_m), and natural mortality (M_w) of *Gudusia chapra* in the Mahananda River, Bangladesh. Fishing gears, including gill (*fash jal*) and push nets (*thela jal*), were used for sampling during August 2016 to July 2017. Body lengths and weight (BW) of each individual were measured. A total of 226 individuals ranging from 6.20-15.10 cm total length (TL) and 2.44-26.10 g BW were collected. On the basis of *b* value, the growth pattern of *G. chapra* was negative allometric (b<3.0). K_F was the best for assessing the overall health of this species. W_R was not significantly different from 100 indicating balance population. Also, $a_{3.0}$ was 0.0062, which indicates that the fish was fusiform in shape. Moreover, L_m and M_w were 9.13 cm TL and 1.14 year^{-1}, respectively. These results should benefit shad management.

Keywords: *Gudusia chapra*, condition factor, size at first sexual maturity, natural mortality, Mahananda River

1. Introduction

The Indian river shad, *Gudusia chapra* (Hamilton, 1822) is a well-known, small indigenous fish species of Bangladesh (family Clupeidae in the order Clupeiformes). It is a freshwater, brackish, pelagic, and potamodromous species (Riede, 2004), commonly known as Khoira and Chapila in Bangladesh (Froese & Pauly, 2019). It is also known as Gudua and Khira in India and Suia and river shad in Nepal (Froese & Pauly, 2019). This fish is found in both Bangladesh and Indian waters flowing to the Bay of Bengal (Talwar & Jhingran, 1991), being most abundant in large river systems but also in ponds, ditches and wetlands *beel* (formed by inundation of low-lying lands during flooding), *haors* a (bowl shaped depression that is flooded automatically during monsoon) and inundated fields (Rahman, 1989). This species is a great popular food fish due to its excellent taste and highly nutritious value (Gupta, 2015). The conservational status of this species is least concern in the world (Froese & Pauly, 2019), but vulnerable in Bangladesh (IUCN Bangladesh, 2015).

Life-history traits of *G. chapra* are very important to understand for sustainable management, because it gives full description about this fish, including length-frequency distribution (LFD), length-weight relationships (LWRs), length-length relationship (LLRs), condition factors, form factor, size at sexual maturity, and natural mortality (M_w). According to Ricker (1968), LWR and LLR are generally used to assess fish stocks and populations. These are also very important for comparative growth studies in fisheries management (Moutopoulos & Stergiou, 2002). Additionally, the condition factors help to assess the physiological status, health, and overall productivity of a fish population (Blackwell, Brown, & Wills, 2000; Richter, 2007). Moreover, the relative weight (W_R) is the most important index to assess the habitat condition for fishes (Rypel & Richter, 2008), whereas form factor ($a_{3.0}$) quantifies the body shape of a species (Froese, 2006).

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Some works have been done on *G. chapra* for diverse aspects, including LFD, LWRs, LLRs, and spawning season (Table 1). However, to our knowledge, there is no complete study on life-history traits of *G. chapra* from the Mahananda River. So, this study is the first comprehensive study on life-history traits, including LFD, L-W and L-L relationships, C_F, W_R, $a_{3.0}$, L_m, and M_w the Indian river shad in NW Bangladesh, using a large of sample size across body sizes.

2. Materials and Methods

The present study was conducted in the Mahananda River of Chapai Nawabgonj a tributary of the Ganges River that originates in the Gangotri Glacier and enters Bangladesh at Shibganj in the district of Chapai Nawabgonj (24º29′ N, 88º 18′ E), in India (Himalayas). A total of 226 specimens (Chapai Nawabgonj Sadar fish landing center: 09 August 2016, n= 80; 12 November 2016, n= 90; 05 July 2017, n= 56) were sampled from the commercial fishers. Specimens were collected by traditional fishing gears, including gill (*fash jal*) and push nets (*thela jal*). The samples were preserved with ice on-site and transfer to the laboratory where samples were preserved with 10% formalin.

Different lengths (*i.e.*, total, TL; fork, FL; and standard, SL) of each individual were taken with digital slide calipers (to the nearest 0.01cm) and whole body weight (BW) was weighed on electronic balance (with 0.01 g accuracy).

The length-frequency distributions for *G. chapra* were constructed using 1.0 cm intervals of TL.

The LWRs were estimated by the expression: $W= a*L^b$, where W is the whole body weight (g), L is the total, fork and standard length (cm), and a and b are the regression parameters of LWR. Parameters a and b of the LWR were assessed by linear regression analyses using natural logarithms: ln (W) = ln(a) + b ln(L). Moreover, 95% confidence limits (CLs) of a and b and the coefficient of determination (r^2) were also estimated. To assess growth similarities to the isometric value of b=3, t- tests were used to verify b values obtained by the linear regressions (Sokal & Rohlf, 1987). Length-length relationships (LLRs) were estimated through untransformed linear regression analysis (Hossain *et al*., 2006).

Multiple condition factors were used in our study. (i) Fulton's condition factor (K_F) was estimated by the equation: $K_F=100\times (W/L^3)$ (Fulton, 1904). To bring the K_F close to unit, a scaling factor of 100 was used. (ii) The allometric condition factor (K_A) was estimated by using the formula of Tesch (1968): $K_A = W/L^b$; and (iii) the relative condition factor (K_R) for each individual was estimated via the equation of Le Cren (1951): $K_R = W/ (a\times L^b)$, where W is the body weight in g, L is the total, fork and standard length in cm, and a and b are the LWRs parameter. The W_R was estimated by the formula: $W_R = (W/W_S) \times 100$ (Froese, 2006), where W is body weight of a specific individual and W_S is the predicted standard weight to individual as estimated by $W_S = a\times L^b$.

The form factor ($a_{3.0}$) was estimated by the formula: $a_{3.0} = 10^{\log a - s(b-3)}$ (Froese, 2006), where a and b are regression parameters of LWRs and s is the regression slope of ln a *vs*. b. During our study, the mean slope s = -1.358 given by Froese (2006) was used to calculate the form factor given insufficient information on LWRs for this species, for calculation of the regression (S) of *ln a vs*. *b*.

The L_m of *G. chapra* in the Mahananda River was estimated using the formula: log (L_m) = -0.1189 + 0.9157* log (L_{max}), (Binohlan and Froese, 2009).

The M_w of *G. chapra* in the Mahananda River was estimated by the model of Peterson and Wroblewski (1984) as $M_w = 1.92$ year^{-1} *(W)$^{-0.25}$.

All statistical analyses were performed using Microsoft® Excel-add-in-DDXL and GraphPad Prism 6.5 software. If the normality assumption was met, the 1-sample t-test was used to compare the mean relative weight (W_R) with 100 (Anderson & Neumann, 1996). Spearman rank-correlation test were used to analyze the relationship between the morphometric indices (TL and BW) with condition factors (K_F, K_A, K_R, and W_R). The values of all statistical analyses were considered significant at 5% (p<0.05).

3. Results

A total of 226 individuals were collected from Mahananda River, NW Bangladesh. TL of *G. chapra* ranged from 6.20 cm to 15.10 cm (mean: 10.20 ± 2.10 cm, 95% CL of mean: 9.90 to 10.50 cm) in the Mahananda River. Descriptive statistics on the three body measurements and body weight (BW) given in Table 2.

Table 1. Available studies on the Indian river shad, *Gudusia chapra* in native (South Asian) waters

Aspects	Waterbody / Country	Reference
Length-weight relationships	Lake, Mymensingh (23° 58' N, 89° 38' E), 2003-2004 Bangladesh	Ahmed *et al*. (2007)
	Lower Brahmaputra River, India	Basumatary *et al*. (2016)
	Old Brahmaputra River, Bangladesh	Ahmed *et al*. (2014)
	Betwa River	Sani *et al*. (2016)
Length-length relationships	Lower Ganges River	Hossain *et al*. (2009)
Reproduction	Lake Mymensingh	Ahmed *et al*. (2007)
	Lower Ganges River	Hossain *et al*. (2010)
	Old Brahmaputra River, Bangladesh	Ahmed *et al*. (2014)
	Old Brahmaputra River, Bangladesh	Ahmed *et al*. (2014)
	Chilya Hatchery, Sindh, Pakistan	Narejo, *et al*. (2006)
	Floodplain lake, India	Mondol & Kaviraj (2010)
	Lower Brahmaputra River, India	Basumatary *et al*. (2016)
Food and Feeding habits	Silinga *beel*,Subansiri River, Assam	Phukan *et al*. (2012)
	Floodplain lake, India	Mondol & Kaviraj (2010)

Table 2. Descriptive statistics on body measurements with 95% confidence limits for the Indian river shad, *Gudusia chapra* (Hamilton, 1822) in the Mahananda River, northwestern Bangladesh.

Measurements (C)	*n*	Min	Max	Mean ± SD	95% CL
Total length (cm)	226	6.20	15.10	10.20± 2.10	9.90–10.50
Fork length (cm)		5.40	12.10	8.60 ± 1.50	8.40 – 8.80
Standard length (cm)		4.80	11.40	7.90 ±1.50	7.70 – 8.10
Body weight (g)		2.40	26.10	10.40 ± 5.60	9.60 – 11.10

The LFD of *G. chapra* showed the range of specimens as 6.20 cm to 15.10 cm TL (Figure 1). In our study, maximum population (20.80%) was for the length class of 8.00 to 8.99 cm.

The sample size (*n*), LWRs, regression parameters (*a* and *b*) and their 95% CLs, coefficient of determination (r^2), and type of growth (GT) of *G. chapra* are given in Table 3 and in Figure 2. In this study, the calculated allometric coefficient (*b*) of L *vs.* BW indicates a negative allometric (b<3) growth pattern for all body lengths (Figure 2), in the Mahananda River. All LWRs were highly significant (p<0.001) with r^2 values > 0.967.

The LLRs, regression parameters (*a* and *b*) and their 95% CLs, & (r^2) of *G. chapra* are given in Table 3. All LLRs were highly significant (p<0.001), with r^2 values > 0.988, for *G. chapra* in the Mahananda River.

The value of K_F ranged from 0.74 to 1.22 (Mean ± SD = 0.91 ± 0.12) (Table 4). According to Spearman rank-correlation tests, there were highly significant relationships between (a) TL *vs*. K_F (r_s= -0.727 and p <0.0001) and (b) BW *vs*. K_F (r_s= -0.626 and p< 0.0001) (Table 5).

The value of K_A was 0.0220 to 0.0320 (mean ± SD = 0.0270 ± 0.0020) (Table 4). Spearman rank-correlation tests revealed no significant correlation between TL *vs*. K_A (r_s= 0.004 and p = 0.9538), where BW *vs*. K_A (r_s = 0.138 and p = 0.0382) (Table 5).

The minimum and maximum value of K_R were 0.80 and 1.20 (Mean ± SD = 1.01 ± 0.08) (Table 4). Spearman rank-correlation tests showed no significant relationships between TL *vs*. K_R (r_s = 0.007, p = 0.9200) where BW *vs*. K_R (r_s = 0.141 and p = 0.0339) (Table 5).

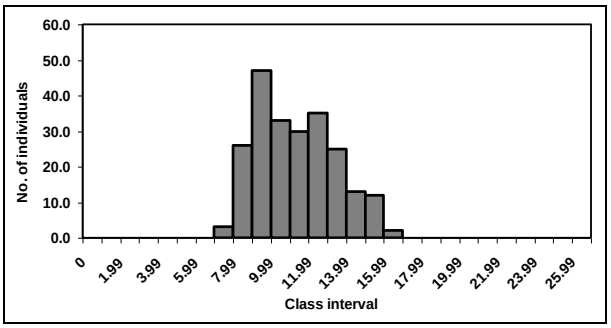

Figure 1. Length-frequency distribution of the Indian river shad, *Gudusia chapra* in the Mahananda River, northwestern Bangladesh

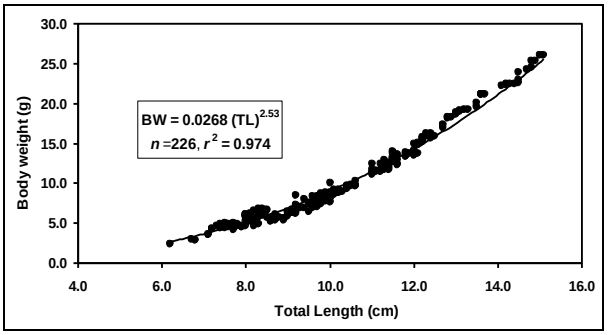

Figure 2. Relationship between total length (TL) and body weight (BW) of the Indian river shad, *Gudusia chapra* in the Mahananda River, northwestern Bangladesh

W_R ranges from 80.02 to 120.16 (mean ± SD = 100.50 ± 8.38) (Table 4). Spearman rank-correlation tests found no significant relationships between TL *vs*. W_R, where BW *vs*. W_R (Table 5). There was no significant difference of W_R from 100 (p=0.4509), indicating an ecologically balanced population for *G. chapra* in the Mahananda River (Figure 3 see the discussion).

The calculated $a_{3.0}$ was 0.0062, indicating that the fish was fusiform in shape, whereas L_m for combined sex was 9.13 cm, TL with 95% CL= 7.30 to 11.46 and L_m/ L_{max} ratio was 0.60. The estimated $a_{3.0}$, L_m and L_m/L_{max} ratio of *G. chapra* among south Asian water bodies are given in Table 6. In the present study, M_w of *G. chapra* was 1.14 year^{-1} in the Mahananda River (Figure 4) which was in the midrange of M_W for G. *chapra* among South Asian water (Table 6).

Table 3. Descriptive statistics and estimated parameters of different length-weight relationships (BW = a*L^b) and length-length relationships ($L_2 = a + b \times L_1$) of the Indian river shad, *Gudusia chapra* (Hamilton, 1822) in the Mahananda River, northwestern Bangladesh

Equation (C)	*n*	Regression parameters		95% CL of *a*	95% CL of *b*	r^2
		a	*b*			
BW = *a**TL^b	226	0.0268	2.53	0.0240 to 0.0300	2.47 to 2.58	0.974
BW = *a**FL^b		0.0191	2.88	0.0170 to 0.0220	2.82 to 2.95	0.972
BW = *a**SL^b		0.0413	2.63	0.0360 to 0.0470	2.57 to 2.70	0.967
TL = *a*+*b* (FL)	226	-1.5024	1.36	-1.6713 to 1.3335	1.34 to 1.38	0.988
TL = *a*+*b* (SL)		-0.4939	1.36	-0.6229 to -0.3628	1.34 to 1.37	0.992
SL = *a*+*b* (FL)		-0.7156	0.99	-0.8300 to -0.6020	0.99 to 1.01	0.990

n, Sample number; C, combined sexes; *a*, intercept; *b*, slope; TL, total length; FL, fork length; SL, standard length; r^2, coefficient of determination

Table 4. Descriptive statistics on condition factors (C_F) including relative weight (W_R) measurements with 95% confidence limits for the Indian river shad, *Gudusia chapra* (Hamilton, 1822) in the Mahananda River, northwestern Bangladesh.

Measurement	Min	Max	Mean ± SD	95% of CL
Allometric C_F (K_A)	0.0220	0.0320	0.0270 ± 0.0020	0.0270 - 0.0280
Fulton C_F (K_F)	0.74	1.22	0.91 ± 0.12	0.89 - 0.93
Relative C_F (K_R)	0.80	1.202	1.06 ± 0.08	0.99 - 1.02
W_R	80.02	120.16	100.50 ± 8.38	99.41 - 101.60

n, sample size; min, minimum; max, maximum; SD, standard deviation; CL, confidence limit

Table 5. Relationship of condition factor with total length (TL) and body weight (BW) for the Indian river shad, *Gudusia chapra* (Hamilton, 1822) in the Mahananda River, northwestern Bangladesh

Relationships	r_s values	95% CL of r_s	*p* value	Significance
TL *vs*. K_F	-0.726	-0.784 to 0.656	0.0001	***
TL *vs*. K_A	0.0039	-0.1310 to 0.1380	0.9538	*ns*
TL *vs*. K_R	0.007	-0.128 to 0.141	0.9200	*ns*
TL *vs*. W_R	0.007	-0.128 to 0.141	0.9191	*ns*
BW vs. K_F	-0.626	-0.701 to 0.537	< 0.0001	***
BW *vs*. K_A	0.1380	0.0040 to 0.2680	0.0382	*
BW *vs*. K_R	0.141	0.007 to 0.270	0.0339	*
BW *vs*. W_R	0.141	0.007 to 0.270	0.0339	*

r_s, coefficient of Spearman rank correlation test; *r*, coefficient of Pearson correlation test; *ns*, not significant; *, significant (p<0.05); ****, very much significant (p<0.001) (Sokal & Rohlf, 1981)

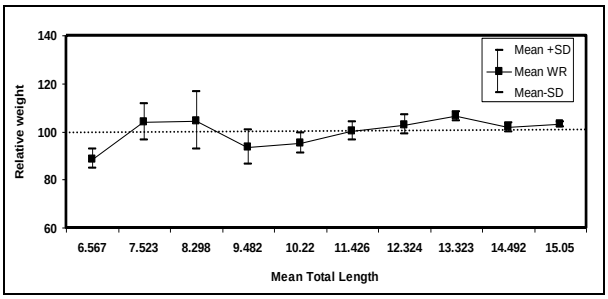

Figure 3. Relationship between total length (TL) and relative weight (W_R) of the Indian river Shad, *Gudusia chapra* (Hamilton, 1822) in the Mahananda River, northwestern Bangladesh

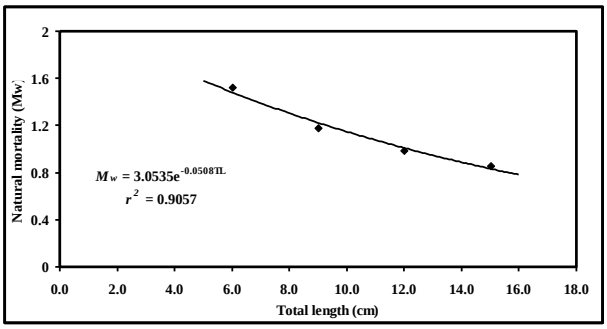

Figure 4. Natural mortality (M_W) of *Gudusia chapra* from the Mahananda River, northwestern Bangladesh

4. Discussion

Information on the life-history traits of *G. chapra* from Bangladesh is limited, although several works have been done on other species from this region (Hossain *et al*., 2013 a, b; 2016 a, b). Our study describes several life-history traits including LFD, LWRs, LLRs, condition and form ($a_{3.0}$) factors, size at sexual maturity (L_m), and natural mortality (M_w) of *G. chapra*, Mahananda River. In our study, many specimens of small to large body size were collected, but it was impossible to catch *G. chapra* smaller than 6.20 cm TL, which can be attributed to either the absence of small fishes (<6.20 cm TL) in the sample sites or selectivity of the fishing gears (Hossain *et al*., 2012, 2015; 2017a, b).

In our study, the maximum size of *G. chapra* was 15.10 cm TL from the Mahananda River, which were (a) higher than the previously observed values of 12.95 cm TL from the Dalani *Beel*, Assam, India and 11.30 cm from the lower Brahmaputra River, India but (b) lower than the maximum record value of 20.00 cm TL in Bangladesh and 19.00 cm from Sindh, Pakistan and 17.6 cm TL from the Ganga River, India (Table 6).

Information of LFD of *G. chapra* in Bangladesh is limited except for Ahamed *et al*. (2014). In our study, maximum abundance was found for the length class of 8.00 to 8.99 cm (20.80%). Ahamed *et al*. (2014) found a polymodal and asymmetrical pooled length-frequency distribution for larger *G. chapra*, the main mode peak at ~7.00 cm for both sexes being lower than the found.

The length-weight relationship is helpful for differentiating populations among localities (Chonder, 1972; Le Cren, 1951). LWR parameters are also important to assess fish-stock condition. Parameter *b* can vary between 2.00 to 4.00 (Carlander, 1969). In general, *b* values close to three indicate that fish growth isometric, but values significantly different from 3 indicate allometric growth (b> 3, positive; b< 3, negative) (Tesch, 1971). In our study, the values of *b* for combined sexes of *G. chapra* were 2.50-2.58 for TL *vs*. BW, indicating negatively allometric growth of *G. chapra* in the Mahananda River that means the growth rate was relatively

Table 6. Calculated form factor ($a_{3.0}$), size at sexual maturity (L_m) in TL, and natural mortality (M_W) of *Gudusia chapra* across south Asian water bodies.

Water-bodies	Sex	Regression parameters		Max TL (cm)	Reference	Calculated				
		a	*b*			$a_{3.0}$	L_m	95% CL of L_m	L_m/L max	M_W (year^{-1})
Lower Brahmaputra, India	U	0.0120	2.88	13.8	Basumatary *et al*. (2017)	0.0082	8.41	6.74 to 10.52	0.61	1.17
Old Brahmaputra, Bangladesh	M	0.0236	2.92	12.5 (SL)	Ahmed *et al*. (2014)	0.0184	7.68	6.18 to 9.58	0.61	1.18
	F	0.0289	2.83	13.7 (SL)		0.0170	8.36	6.70 to 10.45	0.61	1.23
	U	0.0260	2.87	13.7 (SL)		0.0173	8.36	6.70 to 10.45	0.61	1.24
Betwa River, India	U	0.0079	2.98	15.0	Sani *et a*l. (2016)	0.0074	9.08	7.25 to 11.39	0.61	1.32
Ganges River, Bangladesh	F			13.7 (SL)	Hossain *et al*. (2010)		8.36	6.70 to 10.45	0.61	
Chilya Hatchery, Pakistan	U			19.0 (TL)	Narejo *et al*. (2006)		11.27	8.92 to 14.24	0.60	
Dalani *Beel*, Assam, India	U	0.1572	2.81	12.95	Sheikh *et al*. (2017)	0.0868	7.94	6.38 to 9.91	0.61	0.62
Floodplain lake, India	U			12.20	Mondol & Kaviraj (2010)		7.51	6.05 to 9.36	0.61	
Ganga main channel, India	C	2.32	2.06	17.60	Sarkar *et al*. (2013)	0.1227	10.51	8.34 to 13.25	0.60	0.51
Gomti River, India	C	2.44	2.16	14.70		0.1765	8.91	7.13 to 11.17	0.61	0.50
Rapti River, India	C	3.64	1.98	11.50		0.1499	7.12	5.75 to 8.85	0.62	0.53
Mahananda River, Bangladesh	C	0.0268	2.53	15.10	Present study	0.0062	9.13	7.30 to 11.46	0.60	1.14

a and *b* are regression parameters of length-weight relationships; TL, total length; $a_{3.0}$, form factor; M_W, natural mortality

slow and trend to be thinner. Sarkar *et al*. (2013) found a TL-BW *b* value of 2.16 for this species & Ahamed *et al*. (2014) reported a SL-BW *b* value for of 2.87, also indicating negatively allometric growth. In contrast Hossain *et al*. (2009) found growth pattern was to be positively allometric (b = 3.11). For this species this difference might be due to feeding, seasonal, and/or environmental limitations to proper growth and development of fish for most South Asian studies. According to Ricker (1973), the functional regression *b* value represents the body form, and it is directly related to the weight which is influenced by environmental factors like temperature, food supply, spawning conditions, gender, fishing time/area and fishing vessel. More for example, (i) excessive supply of food may decrease the aggressive behavior of fish may result the faster growth and uniformity in size similarly if food supply is low than the growth of fishes may reduce. Moreover, patterns of growth survival, body composition are strongly correlated to the available food supply and feeding (Zhou *et al*., 2003, Shackleton, 2012). (ii) As temperature affects consumption rates of fishes that ultimately affect the growth rates of fish. For most fish species increases in growth rates with increasing temperatures will be seen, up to a certain point, only to decline abruptly once the critical limit (Shackleton, 2012; Salih *et al*., 2016).

In our study, the relationship between total length (TL) and other body lengths were also estimated. The estimated values were: TL=1.36(SL)-0.4939, (r^2=0.992) and TL=1.36(FL)-1.5024, (r^2=0.989) for combined sexes of *G. chapra*, which were significant relationships (p<0.001). Likewise, all the LLRs were highly correlated with all r^2 values being ≥0.980. However, lack of LLRs for this species from the Mahananda River prevented comparison of our results to previous literature there.

Several condition factors (K_F, K_A, K_R, and W_R) were calculated during this study to assess the wellbeing and productivity of *G. chapra* in the Mahananda River, NW Bangladesh. Condition factors based on the LWRs is a good indicator general fish condition and food reserves (Offem *et al*., 2007). Among these four condition factors, K_F was most highly correlated with TL and BW (Table 5), so K_F was the best condition index for assessing the wellbeing of *G. chapra*. Other studies will be needed to test the robustness of this finding.

Relative weight (W_R) helps to infer the prey-predator status and/or ecosystem disturbances at the population level (Rypel & Richter, 2008). According to the one- sample t-test, there was no significant difference from 100 for *G. chapra* in the Mahananda River. This suggests that there was an ecologically balanced condition, with few predators relative to the presence of prey (food) availability. However, there were no other references dealing with W_R on *G. chapra* for comparison.

Form factor ($a_{3.0}$) can be used to assess differences of body shape among populations of a given species (Froese, 2006). In our study, $a_{3.0}$ was 0.0062, suggesting that *G. chapra* is relatively fusiform, which is characteristic of many riverine fishes *i.e.* good swimming abilities. Studies on $a_{3.0}$ for Bangladeshi freshwater fishes are scant (except Hossain *et al*., 2013 a, b; 2016b). There are no other references dealing with the $a_{3.0}$ of *G. chapra* for comparison.

Length at first maturity (L_m) is the most important parameter, not only to study reproductive biology and captive breeding, but also for conservation of any fish species. Not much L_m information is available for *G. chapra* from Bangladesh and elsewhere. In the our study, L_m obtained for *G. chapra* was 9.13 cm TL, whereas Hossain *et al*. (2010) reported 8.30 cm SL as L_m for this fish species in the lower Ganges River. More detailed studies could provide further insight into the specific combination of factors affecting L_m and spawner body across populations of *G. chapra* in the Ganges River basin. M_w for the population of *G. chapra* was found to be 1.14 year^{-1} in the Mahananda River. Our study is the first work on M_w of this species.

5. Conclusions

Our findings have provided new and updated information on length-frequency distributions, length-length relationships, length-weight relationships, condition and form factors, size at first maturity, and natural mortality of *G. chapra* in the Mahananda River of Bangladesh. This should be very helpful for the stock assessment and management of *G. chapra* in the Mahananda River and its surrounding ecosystems.

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References

Ahamed, F., Ahmed, Z. F., Hossain, M. Y., & Ohtomi, J. (2014). Population biology of the Indian river shad, *Gudusia chapra* (Clupeidae) in the Old Brahmaputra River, north-eastern Bangladesh. *Sains Malaysiana, 43,* 1645-1655.

Ahmed, Z. F., Smith, C., Ahamed, F., & Hossain, M. Y. (2007). Growth and reproduction of the Indian river shad, *Gudusia chapra* (Clupeidae). *Folia Zoologica, 56*(4), 429-439.

Anderson, R. O., & Neumann, R. M. (1996). Length, weight and associated structure indices. In B. R. Murphy & W. D Willis, (Eds.), *Fisheries techniques, 2nd ed.* (pp. 447-482). *Bethesda, MD: American Fisheries Society Bethesda*.

Basumatary, S., Talukdar, B., Choudhury, H., Kalita, H. K., Saikia, D. J., Mazumder, A., & Sarma, D. (2016). Female gonadal histology of Indian river shad, *Gudusia chapra* (Hamilton, 1822) – a tactic of reproductive biology. *Poultry, Fisheries and Wildlife Science, 4,* 173.

Binohlan, C., & Froese, R. (2009). Empirical equations for estimating maximum length from length at first maturity. *Journal of Applied Ichthyology, 25,* 611-613.

Blackwell, B. G., Brown, M. L., & Wills, D. W. (2000). Relative weight (W_R) status and current use in fisheries assessment and management. *Reviews in Fisheries Science and Aquaculture, 8,* 1-44.

Carlander, K. D. (1969). *Handbook of freshwater fishery biology, Volume 1*. Ames, IA*:* The Iowa State University Press.

Chonder, S. L. (1972). Length–weight relationship of mature female *Labeo gonius* (Hamilton) from the Keetham Reservoir. *Journal of Inland Fisheries Society of India, 4,* 216-217.

Froese, R. (2006). Cube law, condition factor and weight length relationship: history meta-analysis and recommendations. *Journal of Applied Ichthyology, 22,* 241-253.

Froese, R., & Pauly, D. (2019, 22 February). Fishbase 2019. Retrieved from http://www. fishbase.org.

Fulton, T. W. (1904). *The rate of growth of fishes*. *Twenty-second annual reports, Part III*. Edinburgh, Scotland*:* Fisheries Board of Scotland.

Gupta, S. (2015). A note on feeding and reproductive biology of banded gourami, *Trichogaster fasciata* (Bloch and Schneider, 1801). *International Journal of Fisheries and Aquaculture Resources, 5,* 147-150.

Hossain M. Y., Hossen M. A., Khatun, D., Nawer, F., Parvin, M. F., Rahman, O., & Hossain, M. A. (2017a). Growth, condition, maturity and mortality of the Gangetic leaf fish *Nandus nandus* (Hamilton, 1822) in the Ganges River (northwestern Bangladesh). *Jordan Journal of Biological Science, 10,* 57-62.

Hossain, M. Y., Ahmed, Z. F., Islam, A. B. M. S., Jasmine, S., & Ohtomi, J. (2010). Gonadosomatic index-based size at first sexual maturity and fecundity indices of the Indian river shad *Gudusia chapra* (Clupeidae) in the Ganges River (NW Bangladesh). *Journal of Applied Ichthyology, 26,* 550–553.

Hossain, M. Y., Ahmed, Z. F., Leunda, P. M., Jasmine, S., Oscoz, J., Miranda, R., & Ohtomi, J. (2006). Condition, length-weight and length-length relationships of the Asian striped catfish *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhanga River, southwestern Bangladesh. *Journal of Applied Ichthyology, 22,* 304-307.

Hossain, M. Y., Hossen, M. A., Pramanik, M. N. U., Nawer, F., Rahman, M. M., Sharmin, S., Khatun, D., Bahkali, A. H., Elgorban, A. M., & Yahya, K. (2017b**)**. Life-history traits of the endangered carp *Botia dario* (Cyprinidae**)** from the Ganges River in northwestern Bangladesh. *Pakistan Journal of Zoology, 49,* 801-803.

Hossain, M. Y., Jasmine, S., Ibrahim, A. H. M., Ahmed, Z. F., Rahman, M. M., & Ohtomi, J. (2009). Length–weight and length–length relationships of 10 small fish species from the Ganges River, Bangladesh. *Journal of Applied Ichthyology, 25,* 117–119.

Hossain, M. Y., Jewel, M. A. S., Rahman, M. M., Haque, A. B. M. M., Elbaghdady, H. M., & Ohtomi, J. (2013b). Life-history traits of the freshwater garfsh *Xenentodon cancila* (Hamilton 1822) (Belonidae) in the Ganges River, northwestern Bangladesh. *Sains Malaysiana, 42,* 1207–1218.

Hossain, M. Y., Khatun, M. M., Jasmine, S., Rahman, M. M., Jahan, S., Jewel, M. A. S., & Ohtomi, J. (2013a). Life-history traits of the threatened freshwater fish *Cirrhinus reba* (Hamilton 1822) (Cypriniformes:

Cyprinidae) in the Ganges River, northwestern Bangladesh. *Sains Malaysiana, 42,* 1219–1229.

Hossain, M. Y., Naser, S. M. A., Bahkali, A.H., Yahya, K., Hossen, M. A., Elgorban, A.M., Islam, M. M., & Rahman, M. M. (2016b). Life history traits of the flying barb *Esomus danricus* (Hamilton, 1822) (Cyprinidae) in the Ganges River, northwestern Bangladesh. *Pakistan Journal of Zoology, 48,* 399-408.

Hossain, M. Y., Rahman, M. M., Bahkali, A. H., Yahya, K., Arefn, M.S., Hossain, M. I., Elgorban, A. M., Hossen, M. A., Islam,M. M., & Masood, Z. (2016a). Temporal variations of sex ratio, length-weight relationships and condition factor of *Cabdio morar* (Cyprinidae) in the Jamuna (Brahmaputra River distributary) River, northern Bangladesh. *Pakistan Journal of Zoology, 48,* 1099-1107.

Hossain, M. Y., Rahman, M. M., Miranda, R., Leunda, P. M., Oscoz, J., Jewel, M. A. S., Naif, A., & Ohtomi, J. (2012). Size at first sexual maturity, fecundity, length-weight and length-length relationships of *Puntius sophore* (Cyprinidae) in Bangladesh waters. *Journal of Applied Ichthyology, 28,* 818-822.

Hossain, M. Y., Sayed, S. R. M., Rahman, M. M., Ali, M. M., Hossen, M. A., Elgorban, A. M., Ahmed, Z. F., & Ohtomi, J. (2015). Length-weight relationships of nine fish species from the Tetulia River, southern Bangladesh. *Journal of Applied Ichthyology, 31,* 967–969.

International Union for Conservation of Nature, Bangladesh. (2015). *Red list of Bangladesh Volume 5: Freshwater fishes*. Dhaka, Bangladesh: Author.

Le Cren, E. D. (1951). The length-weight relationships and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology, 20,* 201-219.

Mondal, D. K., & Kaviraj, A. (2010). Feeding and reproductive biology of Indian shad *Gudusia chapra* in two floodplain lakes of India. *Electronic Journal of Biology, 6,* 98-102

Moutopoulos, D. K., & Stergiou, K. I. (2002). Length-weight and length-length relationship of fish species from the Aegean Sea (Greece). *Journal of Applied Ichthyology, 18,* 200-203.

Narejo, N. T., Lashari, P. K., Laghari, M. Y., Mastol, A. M., & Khoso, H. B. (2006). Fecundity of palri, *Gudusia chapra* (Hamilton) from fishponds of Chilya hatchery (Distt. Thatta), Sindh, Pakistan. *Pakistan Journal of Zoology, 38,* 269-272.

Offem, B. O., Akegbejo-Samsons, Y., & Omoniyi, I. T. (2007). Biological assessment of *Oreochromis niloticus* (Pisces: Cichlidae: Linne, 1958) in a tropical floodplain river. *African Journal of Biotechnology, 6,* 1966-1971.

Peterson, I., & Wroblewski, J. S. (1984). Mortality rate of fishes in the pelagic ecosystem. *Canadian Journal of Fisheries and Aquatic Sciences, 41,* 1117-1120.

Phukan, B., Baishya, S., Sharma, P., Rajbongshi, A., & Rahman, A. (2012). Food and feeding habits of *Gudusia chapra* (Hamilton, 1822) from Silinga *beel* of lower reaches of Subansiri River in Assam, N-E India. *Environmental Ecology, 30*(3), 578-580.

Rahman, A. K. A. (1989). Freshwater fishes of Bangladesh. *Zoological Society of Bangladesh*. *Department of Zoology, University of Dhaka* (pp. 364).

Richter, T. J. (2007). Development and evaluation of standard weight equations for Bridgelip sucker and large scale suckers. *North American Journal of Fisheries Management, 27,* 936–939.

Ricker, W. E. (1968). Methods for assessment of fish production in freshwaters. *IBP Handbook No. 3.F. A. Davis, Philadelphia, Pennsylvania* (pp. 328).

Ricker, W. E. (1973). Linear regressions in fishery research. *Journal of Fisheries Research, 30***:** 409-434.

Riede, K. (2004). Global register of migratory species - from global to regional scales. *Final Report of the R&D-Project 808 05 081. Federal Agency for Nature Conservation, Bonn, Germany* (pp. 329).

Rypel, A. L., & Richter, T. J. (2008). Empirical percentile standard weight equation for the Blacktail redhorse. *North American Journal of Fisheries Management, 28,* 1843-1846.

Salih, M. A. A., El-Noor, T. E., & Mohamed, A. H. (2016). Effects of varying stocking density and temperature on growth performance of *O. niloticus* fingerlings Cultured in semi-closed sys. *International Journal of Advance Science and Research, 1(11),* 19-23.

Sani, R., Gupta, B. K., Sarkar, U. K., Pandey, A., Dubey, V. K., & Lakra, W. S. (2016). Length-weight relationships of 14 Indian freshwater fish species from the Betwa (Yamuna River tributary) and Gomti (Ganga River tributary) Rivers. *Journal of Applied Ichthyology, 26,* 456-459.

Sarkar, U. K., Khan, G. E., Dabas, A., Pathak, A. K., Mir, J. I., Rebello, S. C., Pal, A., & Singh, S. P. (2013). Length weight relationship and condition factor of selected freshwater fish species found in River Ganga, Gomit and Rapti, India. *Journal of Environmental Biology, 34,* 951-956.

Shackleton, E. (2012). Effects of temperature and terrestrial carbon on fish growth and pelagic food web efficiency, Umeå University: 978-91-7459-412-6 Printed Print & Media.

Sheikh, J., Singha, N., Nag, R., & Deka, P. (2017). Length-weight relationship and relative condition factor of *Gudusia chapra* (Hamilton, 1822) of Dalani *Beel* (wetland) of Assam, India. *International Journal of Fisheries and Aquatic Studies, 5,* 485-489.

Sokal, R. R., & Rohlf, F. J. (1981). Introduction to Biostatistics. *2nd edition New York: Freeman Publication* (pp. 225-227).

Talwar, P. K., & Jhingran, A. G. (1991). Inland fishes of India and adjacent countries, *vol. 2. A. A. Balkema, Rotterdam* (pp. 541).

Tesch, F. W. (1968). Age and growth. In: *Methods for assessment of fish production in fresh waters*. Ricker WE (Ed.). Blackwell Scientific Publications, Oxford, pp. 93-123.

Zhou, Z., Cui, Y., Xie, S., Zhu, W., Lei, W., & Xue, M. (2003). Effect of feeding frequency on growth, feed utilization, and size variation of juvenile gibel carp (*C. auratus gibelio*). *Journal of Applied Ichthyology, 19* (*4),* 244-249.