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Life-History Traits of the Climbing perch *Anabas testudineus* (Bloch, 1792) in a Wetland Ecosystem

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Abstract

The freshwater climbing perch, *Anabas testudineus* (Bloch, 1792), is an economically important, and nutritionally valuable food fish in south Asia. The present study provides the first complete description of life-history traits, i.e., length-frequency distributions (LFDs), length-weight relationships (LWRs), length-length relationship (LLR), condition factors (allometric, K_A; Fulton's, K_F; relative, K_R; relative weight, W_R), form factor ($a_{3.0}$), size at sexual maturity (L_m), and natural mortality (M_w) of *A. testudineus* in a wetland known as Gajner *Beel*, Pabna, in northwestern Bangladesh. Sampling was done using different traditional fishing gears during July to December, 2017. Total length (TL) and whole body weight (BW) were measured by the digital slide calipers and an electronic balance with 0.01cm and 0.01 g accuracy, respectively. A total of 239 specimens were measured ranging from 7.40-14.50 cm TL and 7.89- 63.78 g BW during this study. The estimated *b* values indicated an isometric growth pattern (b=3.00) in *A. testudineus*. The LWRs were highly significant (p<0.001) with r^2 values >0.956. K_F best indicated the well-being of *A. testudineus* among the four types of condition factors in the Gajner *Beel.* A Wilcoxon sign-ranked test for W_R showed no significant dissimilarity from 100, signifying the balanced habitat for *A. testudineus*. The estimated $a_{3.0}$ was 0.021, and L_m was calculated as 8.41 (~8.40) cm TL in the Gajner *Beel*. The M_w of *A. testudineus* was 1.05 year^{-1}. The results should benefit the sustainable management of *A. testudineus* species in Bangladesh and its neighboring countries.

Keywords: *Anabas testudineus*, Growth pattern, Conditions, Size at sexual maturity, Natural mortality

1. Introduction

Perciformes is the largest and most diverse order of teleosts in the world, containing about 41 % of all bony fish comprising more than 10,000 species and about 160 families (Nelson, 2006). Anabantidae is a Perciformes family with thirty-four species in it. The climbing perch, *A. testudineus* (Bloch, 1792) is a member of this family, being abundant in different parts of Asia: Bangladesh, China, India, Malaysia, Myanmar, Pakistan, Philippines, Sri Lanka, and Thailand (Talwar and Jhingran, 1991; Rahman, 2005). It is a fresh- and brackish water potamodromous species that mostly dwells in canals, lakes, ponds, swamps, and estuaries (Menon, 1999; Vidthayanon, 2002), even though adults usually inhabit rivers, flooded fields, and stagnant water bodies (slow moving canals) (Pethiyagoda, 1991). This species is known as Koi in Bangladesh, Kawai in India, Kabai in Nepal, and Kavaiya in Sri Lanka (Froese and Pauly, 2018). It is a hardy fish that can endure extremely unfavorable water conditions including low oxygen, polluted water, etc. (Pethiyagoda, 1991) through an accessory air-breathing organ called the labyrinth organ (Rahman, 1989). This species is considered commercially important, as it has a high market value for being a delicious food fish in Southeast Asia (Herre, 1935; Vidthayanon, 2002). Furthermore, it is an indigenous commercial target fish and a vital source of subsistence for small- and large-scale fishers, who employ a variety of traditional fishing gears (Craig *et al*., 2004; Hossain, 2010a; Hossain *et al.*, 2016a). Although this species is facing some potential threats such as habitat destruction and dry-out, it is a very hardy, habitat-generalist fish that is categorized as 'least concern' in Bangladesh (IUCN Bangladesh, 2015).

Knowledge of the life-history traits of fish species is very important for the implementation of proper management strategies for conserving the commercially important fish such as *A. testudineus* (Hossain *et al*., 2013a). Studies of length-frequency distributions (LFDs) usually express the life-history traits and ecology of fishes (Ranjan *et al*., 2005). Length-weight relationships (LWRs) are considered a useful tool in fisheries studies for the estimation of weight, biomass, and condition indices (Anderson and Gutreuter, 1983; Froese, 2006; Froese *et al*., 2011). Moreover, condition factors help evaluate the

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status of fish from which the present and future population success can be predetermined (Richter, 2007; Rypel and Richter, 2008). Additionally, relative weight (W_R) is one of the most accepted indices for fish condition in the USA for the last two decades (Rypel and Richter, 2008), and now it is being used in Bangladesh for assessing freshwater fishes (Rahman *et al*., 2012; Hossain *et al*., 2012a, 2015a, 2016b).

Although, several authors have reported on LWRs and the condition factors (Kumar *et al*., 2013; Hossain *et al*., 2015b; Kumary and Raj, 2016), morphometric and meristic variations (Hossen *et al*., 2017), morphometric and gonadal studies (Ziauddin *et al*., 2016), captive breeding (Sarkar *et al*., 2005), reproduction and spawning behavior (Zworykin, 2012; Uddin *et al*., 2017), fecundity (Marimuthu *et al*., 2009), induced breeding (Mandal *et al*., 2016), and growth performance of *A. testudineus* (Alam *et al*., 2007; Bhaskar *et al*., 2015), this economically important species has not been studied for life-history traits from Bangladesh or elsewhere. Therefore, the current study provides a complete and informative depiction of the life-history traits of *A. testudineus* - including LFDs, LWRs, LLR, condition factors (allometric, K_A; Fulton′s, K_F; relative, K_R), relative weight (W_R), form factor ($a_{3.0}$), size at fist sexual maturity (L_m), and natural mortality (M_w) from the Gajner *Beel* wetland, Pabna in northwestern Bangladesh using many specimens of small to large sizes over a study period of six months.

2. Material and Methods

2.1. Study area and Sampling

The present study was carried out in the Gajner *Beel* (Lat. 23°55′ N; Long. 89° 33′ E), NW Bangladesh. It is one of the largest wetlands (floodplain) in the area, which is considered an important breeding and feeding ground for many freshwater fishes (Hossain *et al.*, 2017a) and is located in Sujanagar Upazilla, Pabna, Bangladesh. A total of 239 individuals of *A. testudineus* were collected monthly from that region over the period from July to December, 2017, using different types of fishing gears; gill net (mesh size: 1.5–2.5 cm), cast net (mesh size: 1.0–2.0 cm), and square lift net (mesh size ~1.0 cm). Samples were rapidly chilled in ice on site and preserved with 10% buffered formalin back in the laboratory. For each individual, lengths (total length, TL and standard length, SL) were measured by digital slide calipers, and the whole body weight (BW) was measured using an electronic balance, to the nearest 0.01cm and 0.01 g precision, respectively.

2.2. Length-frequency Distributions (LFDs)

LFDs for *A. testudineus* was constructed using 1.0 cm intervals of TL. The normal-frequency distribution was fitted to the TL frequency distribution of *A. testudineus* using a computer program Microsoft Excel-add-in-solver, based on Hasselblad′s maximum-likelihood method (Hasselblad, 1966).

2.3. Length-weight Relationships and Length-length Relationship (LWRs and LLR)

The growth pattern was estimated through LWRs with the equation: $W = a*L^b$, where W is the total body weight (g), and L is the total length (cm). The parameters a and b were estimated by linear regression analyses based on natural logarithms: ln (W) = ln (a) + b ln (L). Extremes outliers were removed from the regression analyses according to Froese (2006). A t-test was used to verify whether b values acquired in the linear regressions were significantly different from the isometric value (b = 3), according to the equation of Sokal and Rohlf (1987) as: $t_s = (b\text{-}3) / s_b$, where t_s is the t-test value, b is the slope, and s_b is the standard error of the slope (b). Additionally, on the basis of the b values of LWRs (TL *vs*. BW and SL *vs.* BW), the growth pattern of *A. testudineus* was determined. In addition, the LLR for TL *vs.* SL was estimated by linear regression analysis (Hossain *et al.*, 2006). Additionally linear regression analysis was conducted using untransformed TL-SL data to recognize the growth type for LLR. Significant divergence of the b value from the theoretical isometric value (b = 1) specifies the growth type as either positively (b>1) or negatively (b<1) allometric for LLR (Hartnoll, 1982), which was confirmed with Student's t-tests according to the equation of Sokal and Rohlf (1987) as $t_s = (b\text{-}1) / s_b$.

2.4. Condition Factors

The allometric condition factor (K_A) was estimated by the equation of Tesch (1968): W/L^b, where W is the body weight (g), L is the TL (cm), and b is the LWR parameter. Fulton′s condition factor (K_F) was calculated using the equation of Fulton (1904): $K_F = 100 \times (W/L^3)$, where W is the body weight (g), and L is the TL in cm. The scaling factor of 100 was used to bring the K_F close to unit (Froese, 2006). Furthermore, the relative condition factor (K_R) was analyzed following the equation of Le Cren (1951): $K_R = W/(a \times L^b)$, where W is the body weight (g), L is the total length (cm), and a and b are LWR parameters. For estimating the relative weight (W_R), the equation of Froese (2006) was used: $W_R = (W / W_s) \times 100$, where W is the weight of a particular individual and W_s is the predicted standard weight as calculated by $W_s = a \times L^b$, where the a and b values are obtained from the relationships between TL *vs.* BW.

2.5. Form Factor ($a_{3.0}$)

The $a_{3.0}$ of *A. testudineus* was estimated using the equation of Froese (2006) as: $a_{3.0} = 10^{\log a - s(b\text{-}3)}$, where a and b are the regression parameters of LWR, and s is the regression slope of *ln a vs. b*. The researchers used a mean slope S = -1.358 for calculating the form factor because there was no available information on LWR for this species to estimate the regression (S) of *ln a vs. b*.

2.6. Size at First Sexual Maturity (L_m)

Size at first sexual maturity (L_m) for *A. testudineus* was estimated by the empirical equation, log (L_m) = -0.1189 + 0.9157 * log (L_{max}), where L_{max} is the maximum TL (Binohlan and Froese, 2009). Moreover, the maximum length of *A. testudineus* obtained from available literature in the FishBase was used to estimate L_m for water bodies throughout the world.

2.7. Natural Mortality (M_W)

M_W of *A. testudineus* was estimated 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, where a and b are the regression parameters of LWR.

2.8. Statistical Analysis

For statistical analysis, Microsoft® Excel-add-in DDXL and GraphPad Prism 6.5 software were used. The Spearman rank-correlation test was applied to analyze the relationship of condition factors with TL and BW. Wilcoxon sign-ranked test was used in this study to compare the mean relative weight (W_R) with 100 (Anderson and Neumann, 1996). All statistical analyses were considered significant at 5 % (p<0.05).

3. Results

3.1. Length-frequency Distributions (LFDs)

A total of 239 *A. testudineus* were collected from fishermen throughout the Gajner *Beel*, Pabna, Bangladesh during the study period (July to December 2017). Table 1 shows the descriptive statistics of maximum and minimum length and weight measurement, and 95% confidence limits (CLs) of *A. testudineus*. LFDs showed that the range of TLs was 7.40 to 14.50 cm (Figure 1), and that body weight ranged from 7.89 to 63.78 g there. The 10.00-10.99 and 11.00-11.99 cm TL size groups were numerically dominant and constituted together 57.70 % of the total population (Figure 1).

Table 1. Length (cm) and weight (g) measurements with 95% confidence limit of combined sexes of *Anabas testudineus* (Bloch, 1792) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

Measurement	*n*	Min	Max	Mean±SD	95% CL
Total length(TL)		7.40	14.50	10.85 ± 1.33	10.68 – 11.02
Standard length(cm)	239	6.10	11.70	8.64 ± 1.07	8.50 – 8.77
Body weight(BW)		7.89	63.78	26.46 ± 10.24	25.15 – 27.76

n, sample size; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values

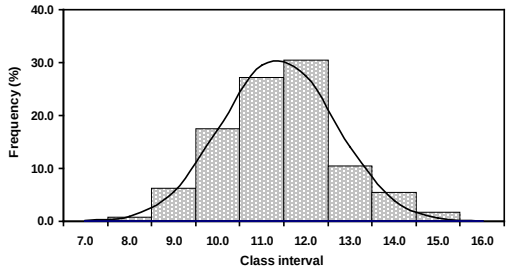

Figure 1. Total length frequency distribution of *Anabas testudineus* (Bloch, 1792) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

3.2. Length-weight Relationships (LWRs)

The sample size (n), regression parameter, 95% confidence interval of a and b, coefficient determination (r^2), and growth type (GT), of *A. testudineus* are shown in Table 2. In this study, the calculated allometric coefficient (b) of TL *vs.* BW indicates an isometric growth pattern (Figure 2), as did the SL-BW relationship (Table 2 and Figure 3) in the Gajner *Beel*. The LWRs were highly significant (p<0.001) with r^2 values >0.956.

Table 2. Descriptive statistics and estimated parameters of the length-weight and length-length relationships of *Anabas testudineus* (Bloch, 1792) (n= 239) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

Equation	Regression parameter		95% CL of a	95% CL of b	r^2	t_s	GT
	a	b					
$BW = a*TL^b$	0.0160	3.09	0.0132 – 0.0194	3.01 – 3.17	0.959	1.11	I^{ns}
$BW = a*SL^b$	0.0341	3.06	0.0285 – 0.0409	2.98 – 3.15	0.956	0.77	I^{ns}
$TL = a + b*SL$	0.3048	1.22	0.0615 – 0.5481	1.19 – 1.25	0.969	0.94	I^{ns}

a, intercept; b, slope; CL, confidence limit for mean values; r^2, coefficient of determination; GT, growth type; I, isometric; *ns*, not significant

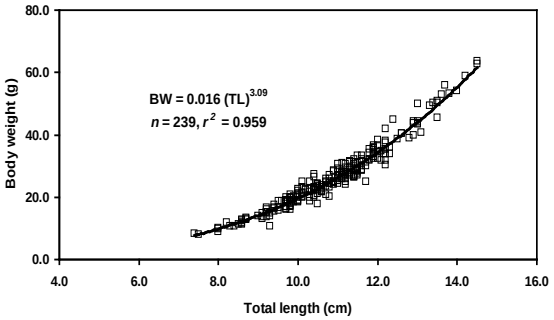

Figure 2. Total length-body weight relationship of *Anabas testudineus* (Bloch, 1792) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

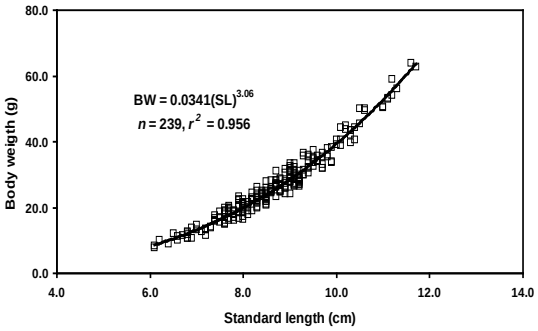

Figure 3. Standard length-body weight relationship of *Anabas testudineus* (Bloch, 1792) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

3.3. Length-length Relationship (LLR)

The relationship between TL and SL of *A. testudineus* along with the estimated parameters of the LLR and the coefficient of determination (r^2), are shown in Table 2 and Figure 4. During this study, the calculated b value of the LLR indicates an isometric growth pattern. The LLR was highly significant (p<0.001) with a coefficient of determination values of 0.969.

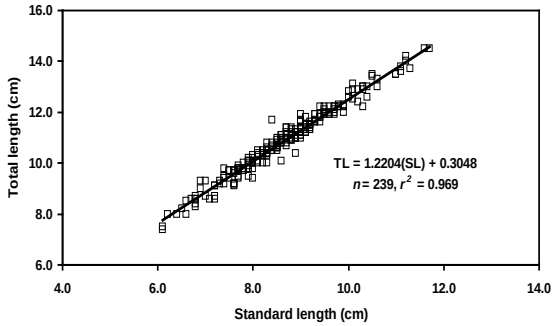

Figure 4. Total length-standard length relationship of *Anabas testudineus* (Bloch, 1792) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

3.4. Condition Factors

3.4.1. Allometric Condition Factor (K_A)

The estimated K_A of *A. testudineus* ranged from 0.0109-0.0198 (Mean ±SD, 0.0161±0.0012) (Table 3). According to Spearman rank-correlation tests, there was a significant relationship between BW *vs.* K_A (r_s= 0.1780, p = 0.0058), but not between TL *vs.* K_A (r_s= -0.0194, p = 0.7660) (Table 4).

Table 3. Condition factors of *Anabas testudineus* (Bloch, 1792) (n= 239) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

Condition factors	Min	Max	Mean ± SD	95% CL
Allometric condition factor (K_A)	0.0109	0.0198	0.0161 ± 0.0012	0.0159 – 0.0162
Fulton's condition factor (K_F)	1.33	2.43	1.98 ± 0.15	1.96 – 1.20
Relative condition factor (K_R)	0.68	1.24	1.00 ± 0.08	0.99 – 1.01
Relative weight (W_R)	68.35	123.82	100.44 ± 7.76	99.46 – 101.43

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

Table 4. Relationships of condition factor with total length (TL) and body weight (BW) of *Anabas testudineus* (Bloch, 1792) (n= 239) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

Relationship	r_s value	95% CL of r_s	p values	Significance
TL *vs.* K_A	-0.019	-0.150 to 0.112	0.766	*Ns*
TL *vs.* K_F	0.345	0.485 to 0.188	< 0.001	***
TL *vs.* K_R	-0.031	-0.161 to 0.100	0.634	*Ns*
TL *vs.* W_R	-0.031	-0.161 to 0.099	0.632	*Ns*
BW *vs.* K_A	0.178	0.048 to 0.302	0.006	**
BW *vs.* K_F	0.310	0.187 to 0.424	< 0.001	***
BW *vs.* K_R	0.171	0.041 to 0.295	0.008	**
BW *vs.* W_R	0.171	0.041 to 0.295	0.008	**

TL, total length; BW, body weight; K_A, allometric condition factor; K_F; Fulton′s condition factor; K_R, relative condition factor; W_R, relative weight; r_S, Spearman rank-correlation values; CL, confidence limit; p, shows the level of significance; *Ns*, not significant; * significant; ** highly significant; ***very highly significant.

3.4.2. Fulton's Condition Factor (K_F)

The calculated K_F ranged from 1.33-2.43 (Mean ± SD, 1.98±0.15) (Table 3). Spearman rank-correlation tests showed that K_F had highly significant relationships with both TL (r_s= 0.345, p < 0.001) and BW (r_s= 0.310, p < 0.001) (Table 4).

3.4.3. Relative Condition Factor (K_R)

The K_R of *A. testudineus* ranged from 0.68-1.24 (Mean ± SD, 1.00±0.08) during this study (Table 3). From Spearman rank-correlation tests, K_R showed a significant relationship with BW (r_s=0.171, p =0.008), but not with TL (r_s= -0.031, p =0.634) (Table 4).

3.4.4. Relative Weight (W_R)

W_R of *A. testudineus* ranged from 68.35-123.82 (Mean ± SD, 100.44±7.76) during this study (Table 3). According to Spearman rank-correlation tests, there was a significant relationship between BW *vs.* W_R (r_s=0.171, p =0.008), but not between TL *vs.* W_R (r_s=-0.031, p =0.632) (Table 4). According to a Wilcoxon sign-ranked test, W_R showed no significant variation from 100 for *A. testudineus* (p = 0.452).The relationship between TL *vs.* W_R is shown in Figure 5.

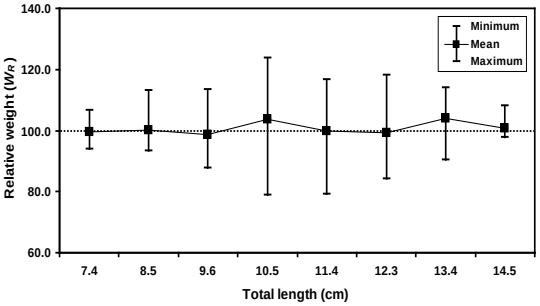

Figure 5. The relationship between total length and relative weight of *Anabas testudineus* (Bloch, 1792) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

3.5. Form Factor ($a_{3.0}$)

The $a_{3.0}$ was calculated as 0.021 for combined sex of *A. testudineus* in the Gajner *Beel*, Pabna, Bangladesh, and this value indicates that this fish is short and deep in body shape. The researchers also calculated the $a_{3.0}$ of *A. testudineus* from various water bodies worldwide using available data to compare the findings with the current study's (Table 5).

3.6. Size at First Sexual Maturity (L_m)

L_m for *A. testudineus* was estimated as 8.41 (~ 8.4) (95% CL= 6.08-11.62) cm TL in the Gajner *Beel* (Figure 6). Moreover, the researchers calculated the L_m of *A. testudineus* from different water bodies worldwide using the available literature (Table 5).

3.7. Natural Mortality (M_W)

M_W for the population of *A. testudineus* in the current study was estimated as 1.05 year^{-1} in the Gajner *Beel* (Figure 7). In addition, M_w of *A. testudineus* acquired from various water bodies worldwide were calculated using the available data (Table 5).

Table 5. The calculated form factor ($a_{3.0}$), size at first sexual maturity (L_m) and natural mortality (M_w) of *Anabas testudineus* in different waterbodies worldwide.

Water body	Sex	Regression parameter		L_{max} (cm)	$a_{3.0}$	L_m (cm)	95% CL of L_m	M_w	Reference
		a	*b*						
Chi River, Thailand	Unsexed	0.078	2.51	16.5	0.0167	9.47	6.81–13.18	0.82	Satrawaha and Pilasamorn (2009)
Dacca city, ponds, Bangladesh	Male	0.047	2.73	-	0.0200		-	-	Shafi and Mustafa (1976)
	Female	0.034	2.80	-	0.0184		-	-	
Pampanga River, Philippines	Unsexed	0.056	2.84	11.7 (SL)	0.0340	6.90	5.05–9.43	1.14	Garcia (2010)
Agushan Marsh, Philippines	Mixed	0.086	2.86	17.0	0.0555	9.74	6.99 – 13.57	0.57	Jumawan and Seronay (2017)
	Unsexed	0.086	2.86	17.0	0.0555	9.74	6.99 – 13.57	0.57	
Tetulia River, Bangladesh	Unsexed	0.022	2.90	16.1	0.0161	9.26	6.67 – 12.87	0.89	Hossain *et al.* (2015b)
Kuttanad, Kerala	Unsexed	0.011	2.84	18.4	0.0070	10.48	7.49 – 14.65	0.96	Kumary and Raj (2016)
Kausalyaganga, India	Unsexed	0.275	2.62	17.5	0.0859	10.00	7.17 – 13.96	0.91	Kumar *et al.* (2013)
	Unsexed	0.217	2.76	17.5	0.1053	10.00	7.17 – 13.96	0.87	
	Unsexed	0.011	2.77	17.5	0.0056	10.00	7.17 – 13.96	1.07	
West Bengal, India	Mixed	0.119	2.13	17.0	0.0077	9.74	6.99 – 13.57	0.81	Ziauddin *et al.* (2016)
Gajner *Beel*, Bangladesh	**Unsexed**	**0.016**	**3.09**	**14.5**	**0.021**	**8.41**	**(6.08 – 11.62)**	**1.05**	**Present study**

a and *b* are regression parameters of length-weight relationships; L_{max}, Maximum length; $a_{3.0}$, form factor; L_m, Size at first sexual maturity; M_w, Natural mortality.

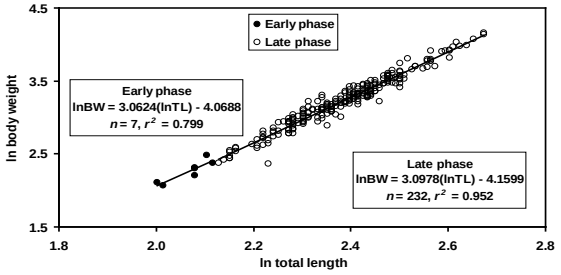

Figure 6. Size at first sexual maturity of *Anabas testudineus* (Bloch, 1792) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

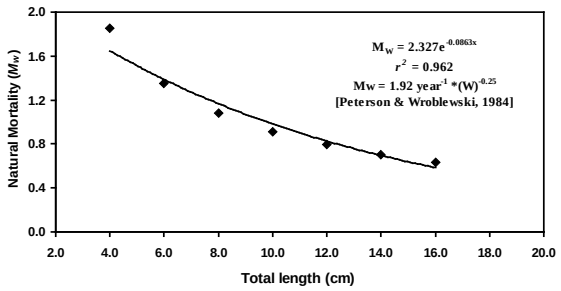

Figure 7. Natural mortality of *Anabas testudineus* (Bloch, 1792) in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem.

4. Discussion

The information on the life history of *A. testudineus* is scant in literature from Bangladesh and elsewhere. Therefore, this study focuses on the complete depiction on life-history traits - including LFDs, LWRs, LLR, condition factors (K_A, K_F, K_R), W_R, $a_{3.0}$, L_m and M_W - using a number of specimen of various body sizes from the Gajner *Beel*, NW Bangladesh.

The researchers could not sample individuals of *A. testudineus* below 7.40 cm TL, for one or more of the following reasons: the biased selection of fishing gear, or because fishermen did not go where the smaller fish were (Hossain *et al.*, 2012b; 2016b, c; Azad *et al.*, 2018, Khatun *et al.*, 2018), or perhaps because of the small fish's absence on the fishing grounds (Hossain, 2010a, b; Hossain *et al.*, 2012b, c, d, 2013a, b; 2017b, c), and/or because fishermen discarded smaller fish (Rahman *et al.*, 2018). The maximum length of *A. testudineus* within the Gajner *Beel* was 14.50 cm TL which is lower than the maximum recorded value of 25.0 cm TL (Froese and Pauly, 2018). Moreover, Satrawaha and Pilasamorn (2009) reported the maximum length of *A. testudineus* as 16.50 cm TL from the Chi River in northeastern Thailand, Hossain *et al.* (2015b) reported a value of 16.10 cm TL in the Tetulia River in Bangladesh, and Jumawan and Seronay (2017) reported the maximum TL in Agushan Marsh of the Philippines as 17.0 cm TL, all of which being higher than those in the current study. Maximum length is considered as a functional tool for fisheries resource planning and management, and is crucial for the

determination of asymptotic length and growth coefficient of fishes (Ahmed *et al*., 2012; Hossain *et al.*, 2016c, 2017b, c; Nawer *et al*., 2017; Hossen *et al*., 2016, 2018).

In the current study of *A. testudineus*, the estimated *b* values ranged from 3.00 to 3.17 for LWRs from the Gajner *Beel* which were within the usual range (2.50 to 3.50) of *b* values for fishes (Carlander, 1969; Froese, 2006). Whereas the *b* values being close to 3 signify that fish grow isometrically, and values >3 indicate positive allometry, and <3 indicate negative allometry (Tesch, 1971). In this study, *b* values of the LWRs were ~3 indicating isometric growth for *A. testudineus* in the Gajner *Beel*. However, other Asian studies have found negative allometric growth for this species: Jumawan and Seronay (2017) reported *b*=2.86 in Agushan Marsh, Philippines; Hossain *et al.* (2015b) observed *b*=2.91 from the Tetulia River in Bangladesh; and Kumar *et al.* (2013) found *b*=2.77 from ponds in Kausalyaganga, India. Such differences may arise due to variation in observed length class, preservation technique, stock health, stomach fullness, gonadal maturity, gender, season, or geographic location (Hossain *et al*., 2017b, Khatun *et al*., 2019), which were not considered for this study. However, LLR in this study was highly significant (p<0.001), and the calculated *b* value suggests isometric growth, similar to the LWRs (see above). Other LLR data for *A. testudineus* are unavailable for comparison.

In the present study, four condition factors (K_A; K_F; K_R and W_R) were estimated to evaluate the health and habitat status of *A. testudineus*, though most studies deal with a single condition factor. Spearman rank-correlation test indicated that, among these condition factors, Fulton′s K_F was significantly correlated with TL and BW (Table 4), so K_F is the best condition index for assessing the well-being of *A. testudineus* in the Gajner *Beel* and nearby ecosystems. It is the first study on condition factor for *A. testudineus*, so future comparisons with other findings are needed.

According to Rypel and Richter (2008), W_R helps judge the overall health and fitness, as well as ecosystem disturbances at the population-level. In this study, the Wilcoxon sign-ranked test indicates that W_R had no remarkable distinction from 100, for combined sex *A. testudineus* in the Gajner *Beel*. This suggests that the population was of balanced condition, with few predators relative to food availability. However, the lack of available literature regarding W_R of *A. testudineus* prevents comparison with other studies.

According to Froese (2006), form factor ($a_{3.0}$) can help determine whether the body profile of individuals in a particular population or species differs from others. The $a_{3.0}$ for *A. testudineus* was 0.021, indicating that this fish is short and deep-bodied in the Gajner *Beel*. There are no references dealing with $a_{3.0}$ for this species to make comparisons across water bodies.

The size at first maturity can be used to set minimum-permissible capture size and for stock assessment (Lucifora *et al*., 1999). Size at first sexual maturity (L_m) was estimated as 8.41 cm for *A. testudineus* in the Gajner *Beel*. This is the first attempt to estimate L_m for *A. testudineus* worldwide, so it constitutes a baseline for future studies of environmental factors affecting L_m and spawning season. The natural mortality (M_w) of *A. testudineus* was calculated as 1.05 year^{-1} in the Gajner *Beel*, also the first worldwide assessment.

5. Conclusion

The present results provide the first inclusive information on the life history traits of *A. testudineus* in the Gajner *Beel* wetland including length-frequency distribution, length-weight and length-length relationships, condition factors (allometric, Fulton's, relative, and relative weight), form factor, first sexual maturity, and natural mortality. The findings from this study can be used as an important tool for fishery biologists, conservationists, and managers to initiate management and fishery regulations for the sustainable conservation of the remaining stocks of this species. Additionally, information on the life history of *A. testudineus* is clearly lacking in the literature and databases, including FishBase. Therefore, the results of the current study provide fundamental information for the online FishBase database, and offer an important baseline as well for future studies within South Asian wetland ecosystems.

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Conflicts of Interest

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

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