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Life history traits of the Barred spiny eel *Macrognathus pancalus* (Hamilton, 1822) in a wetland ecosystem

Md. Ataur Rahman[1], Md. Abul Bashar[3], Zannatul Mawa[1], Obaidur Rahman[1], Md. Abdus Samad[2], Md. Sarower-E-Mahfuj[2], Md. Akhtarul Islam[1], Most. Shakila Sarmin[1], Md. Raqibul Islam[1] and Md. Yeamin Hossain[1]*

[1]Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Bangladesh
[2]Department of Fisheries and Marine Bioscience, Jashore University of Science and Technology, Jashore-7408, Bangladesh
[3]Bangladesh Fisheries Research Institute, Riverine Station, Chandpur-3602, Bangladesh
*Corresponding Author: yeamin.fish@ru.ac.bd; hossainyeamin@gmail.com

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ABSTRACT

The Barred spiny eel *Macrognathus pancalus* (Hamilton, 1822), is a very popular and nutritious fish food in south Asia. Life history traits including LFD, growth types, conditions (K_A, K_F, K_R), relative weight (W_R), form factor ($a_{3.0}$), sexual maturity (L_m), and natural mortality (M_W) of *Macrognathus pancalus* were estimated from 484 specimens collected (January to December 2018) at Wetland ecosystem known as Gajner *Beel*, in northwestern Bangladesh through different types of local fishing gear. Biometric measurements (Lengths, Weight) were measured through digital slide calipers and electronic weight balance with 0.01 cm and 0.01 g precision. In our study total length ranged from 6.00-18.80 cm and body weight ranged from 0.53-27.56 g for M. pancalus. The growth pattern was indicated positive allometric based on the estimated *b* values for this species. Allometric condition factor *(KA) was* the best condition factor among other types of condition factors for the wellbeing of *M. pancalus. The observed* $a_{3.0}$ was 0.0055,L_m was 11.16 cm TL, and M_W was 0.79for *M. pancalus* Gajner *Beel*. Finally, we conclude that the finding of this research will be supportive of the sustainable conservation of *M. pancalus* in Bangladeshi and neighboring waters.

INTRODUCTION

Synbranchioformes is one of the greatest groups of fishes among the major species of freshwater and coastal water fisheries in Bangladesh (**Craig *et al.*, 2004**). The Barred spiny eel, *Macrognathus pancalus* (**Hamilton, 1822**) is one of the dominant members under the family of Mastacembelidae. *M. pancalus* is abundant in all over Bangladesh, India (Ganges and Brahmaputra), Nepal and Pakistan (Indus) (**Talwar and Jhingran, 1991**). This species is mainly found in fresh and brackish waters environment and benthopelagic in their habitat. It is found in canals, small rivers, streams, *Beels*, ponds and swamped fields (**Bhuiyan, 1964; Rahman 1989**). It stays on the bottom and spawns in the upper water level.

This species is known as Guchi in Bangladesh, Baim in India, and Indian spiny eel in U.S.A (**Froese and Pauly, 2018**). Usually *M. pancalus* feeds on sands, debris, entomostracans, insect larvae and small amount of Nymphula (**Shafi and Quddus, 1982**). This species is considered as commercially important species as it has high market value as well as consumer preferences as a delicious food fish in Southeast Asia. Furthermore, it is an important small indigenous commercial target fish and vital source of subsistence for different levels of fishers who lease a variety of old-fashioned fishing gears (**Craig *et al.*, 2004; Hossain *et al.*, 2013a,b; Hossen *et al.*, 2019a, b**). Although this species is facing some potential threats like habitat destruction, drying of its habitats but as a very hardy fish with wide range of habitats, the species is categorized as least concern in Bangladesh (**Ahmed, 2015**).

The knowledge of life history traits of fish species is very significant to execution of proper management policies for protecting the economically important small fish like *M. pancalus* (**Hossain *et al.*, 2017**). Studies of length frequency distributions (LFDs) usually express the ecology and life-history traits of fish (**Khatun *et al.*, 2019**). Length-weight relationships (LWRs) are considered as a useful tool for the estimation of stock status, biomass, and maximum sustainable yield in fisheries studies (**Anderson and Gutreuter, 1983; Froese, 2006**). Moreover, condition factors helps to evaluate the status of fish from which the current and upcoming population success can be predetermined (**Rypel and Richter, 2008**). Additionally, relative weight (W_R) is the most accepted index to recognize the pre-predator status of fishes in the worldwide since long time (**Rypel and Richter, 2008**) and now it is using in Bangladesh for assessing the pre-predator status of freshwater fishes (**Hossain *et al.*, 2013c; Rahman *et al.*, 2019a,b**).

Hence, several authors reported on growth pattern (**Hossain *et al.*, 2006; Abujam and Biswas, 2016; Hossain *et al.*, 2017; Islam *et al.*, 2017: Karna *et al.*, 2018**), maturity and fecundity (**Suresh *et al.*, 2006; Pathok *et al.*, 2012**), truss morphometric studies (**Mahfuj *et al.*, 2019**). Considering the economic importance of this species, no prior research on life history traits of *M. pancalus* from Bangladesh and elsewhere. Thus, the main objectives of the study is the complete information on life-history traits - including length frequency distributions, growth pattern, condition factors, relative weight, form factor, size at fist sexual maturity and natural mortality of *M. pancalus* from the Gajner *Beel* ecosystem, northwestern Bangladesh over a study period of one year.

MATERIALS AND METHODS

Study site and fish sampling

This research work was carried out from the Gajner *Beel* (23^o 55′ N; 89^o 33′ E), NW Bangladesh. This *Beel* is one of the biggest wetlands (floodplain) of Bangladesh which is considered as an important breeding and feeding habitat for many freshwater small indigenous fishes (Hossain *et al.,* 2017), situated in Sujanagar Sub-district, Pabna, Bangladesh. A number of 480 individuals of *M. pancalus* were harvested monthly from the Gajner *Beel* during January to December 2018 through various types of fishing gears including mosquito net (mesh size < 1.0 cm), and seine net (mesh size: 1.0–2.0 cm). Fish samples were rapidly frozen in ice on specific sites and preserved with 10% buffered formalin as well as immediately brought in the laboratory. Biometric parameters such as, total length (TL) and standard length (SL) were measured by digital calipers and

whole body weight (BW) was taken with an electronic weight balance to the nearest 0.01 cm and 0.01 g precision, respectively.

Length-frequency distribution (LFD)

LFDs of *M. pancalus* were built via 1.0 cm class intervals of TL. The normal frequency distribution was fixed to the total length frequency distribution of *M. pancalus* through a computer program Microsoft Excel-add-in-solver depend on Hasselblad′s maximum-likelihood system (**Hasselblad, 1966**).

Growth pattern

The growth pattern was estimated through LWRs with the equation: $W= a*L^{b,}$ where W is 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 curtailed 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 the slope, and s_b the standard error of the slope (b). Additionally, on the basis of the b values of LWRs (TL *vs*. BW and SL *vs.* BW), growth pattern of *M. pancalus* was evaluated. In addition, the LLR for TL vs. SL was estimated through linear regression analysis (**Hossain *et al.*, 2006**). Additionally, linear regression analysis was conducted using untransformed TL-SL data to recognize the growth type in case of LLR. Significant deviation of the b value from the theoretical isometric value (b = 1) specify the growth type either positive (b>1) or negative (b<1) allometric in case of LLRs that was definite with Student's t-tests in accordance with Sokal and Rohlf (1987) equation as $t_s= (b\text{-}1) / s_b$.

Condition factors

According to **Tesch (1968):** W/L^b, (where W is the body weight (g), L is the TL (cm), and b is the LWR parameter), the allometric condition factor (K_A) was estimated. Based on 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), Fulton′s condition factor (K_F) was calculated. The scaling factor of 100 was used to bring the K_F close to unit. Furthermore, the relative condition factor (K_R) was analyzed following the formula 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 achieved from the correlation between TL *vs.* BW.

Form factor $(a_{3.0})$

The $a_{3.0}$ of *M. pancalus* was estimated by the formula 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*. We 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*.

Size at first sexual maturity *(L_m)*

The L_m for *M. pancalus* was estimated by the empirical formula, log (L_m) = -0.1189 + 0.9157 * log (L_{max}), where L_{max} is the observed maximum TL (**Binohlan and Froese, 2009**).

Natural mortality (M_w)

The M_w of M. pancalus was assessed through the model (**Peterson and Wroblewski, 1984**) M_w =1.92 year^{-1} *(W)-0.25, where, MW = natural mortality at mass W; and W = a*L^b, where a and b are the regression parameters of LWR.

Statistical analysis

For statistical analysis, Microsoft® Excel-add-inDDXL and GraphPad Prism 6.5 software was used. The Spearman rank test was applied to analyze the relationship of condition factors with total length and body weight. We used Wilkoxon sign ranked test to link with the average relative weight (W_R) with 100 (**Anderson and Neumann, 1996**). At 5% (p<0.05) significant level, all statistical analyses were done.

RESULTS

Length-frequency distribution (LFD)

A total number of 480 *M. pancalus* were captured from the fishermen in various parts of the Gajner *Beel*, Pabna Bangladesh during the study period (January to December 2018). Table 1 shows the descriptive statistics of maximum and minimum total length and total body weight measurement and also 95% confidence interval (CI) of *M. pancalus*. The LFD showed that the largest individual was 18.8 cm TL and smallest individual was 6.00 cm TL respectively (Figure 1) and the body weight was ranged from 7.89 to 63.78 g BW, respectively in the Gajner *Beel*. The 13.00-13.99 cm TL size range group was statistically dominant and created 57.70% of the total population (Figure 1).

Growth pattern

In this study, the calculated allometric coefficient (b) of TL *vs.* BW indicates positive allometric growth pattern (Figure 2). The sample size (n), regression parameter, 95% confidence interval of a and b, coefficient of determination (r^2), and fish growth type (GT), of *M. pancalus* are shown in Table 2. Moreover, the SL-BW relationship indicated alike pattern of growth (Table 2 and Figure 3) for *M. pancalus in* the Gajner *Beel*. The LWRs were significant (p<0.001) with r^2 values > 0.940. The relationship between TL and SL of *M. pancalus*, beside the assessed 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 isometric growth pattern. The LLR were greatly significant (p<0.001) with a coefficient of determination values was 0.995.

Condition factors

Allometric condition factor (K_A)

The estimated K_A of *M. pancalus* ranges from 0.245 -0.662 (Mean ± SD, 0.4387±0.0583) are shown in Table 3. According to Pearson's correlation test there were highly significant relations between TL *vs.* K_A (Pearson's, r = 0.3476 and P < 0.0001) nevertheless there were highly significant relationships between BW *vs.* K_A (Pearson's, r = 0.6087 and P < 0.0001) (Table 4).

Fulton's condition factor (K_F)

The calculated K_F ranged from 0.601 -1.590 (Mean ± SD, 1.017±0.124 (Table 3). According to Pearson's correlation test there were insignificant relations between TL *vs.* K_F (Pearson's, r = -0.01336 and P = 0.7704) nevertheless there were highly significant correlation between BW *vs*. K_F (Pearson's, r = 0.2740 and $P < 0.0001$) (Table 4).

Relative condition factor (K_R)

The K_R of *M. pancalus* ranged from 0.001 -0.003 (Mean ± SD, 0.0017± 0.0002) during this study (Table 3). According to Pearson's correlation test, there were insignificant relations between TL *vs.* K_R (Pearson's, r = -0.0151 and P = 0.7414) nevertheless there were highly significant correlation between BW *vs.* K_R (Pearson's, r = 0.2694 and $P <$ 0.0001) (Table 4).

Relative weight (W_R)

The W_R of *M. pancalus* ranged from 60.05 to 159.03 (Mean ± SD, 101.741±12.442) during this study (Table 3). According to Pearson's correlation test there were insignificant correlation between TL *vs.* W_R (Pearson's, r = -0.01337 and P= 0.7701) nevertheless there were highly significant correlation between BW *vs.* W_R (Pearson's, r = 0.2740 and $P < 0.0001$) (Table 4).

Form factor ($a_{3.0}$)

During this work, the $a_{3.0}$ was estimated as 0.0055 for combined sex of *M. pancalus in* the Gajner *Beel,* Pabna, Bangladesh, and this value indicating this fish is eel like in shape (Table 5).

Size at sexual maturity (L_m)

The L_m for *M. pancalus was* estimated as 11.16 (95% CL= 8.84 to 14.10.) cm TL in the Gajner *Beel* (Table 5).

Natural mortality (M_W)

During this study, the calculated M_W for the *M. pancalus* population was calculated as 0.79 year-1 in the Gajner *Beel* (Table 5 & Figure 5).

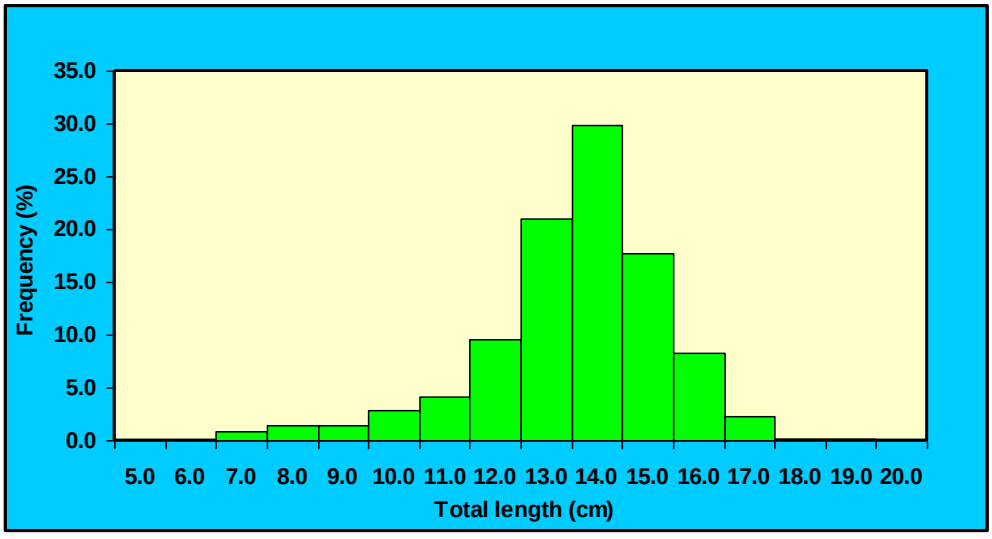

Fig.1. Total length frequency distribution of *Macrognathus pancalus* in a wetland (Gajner *Beel,* Pabna, Bangladesh) ecosystem.

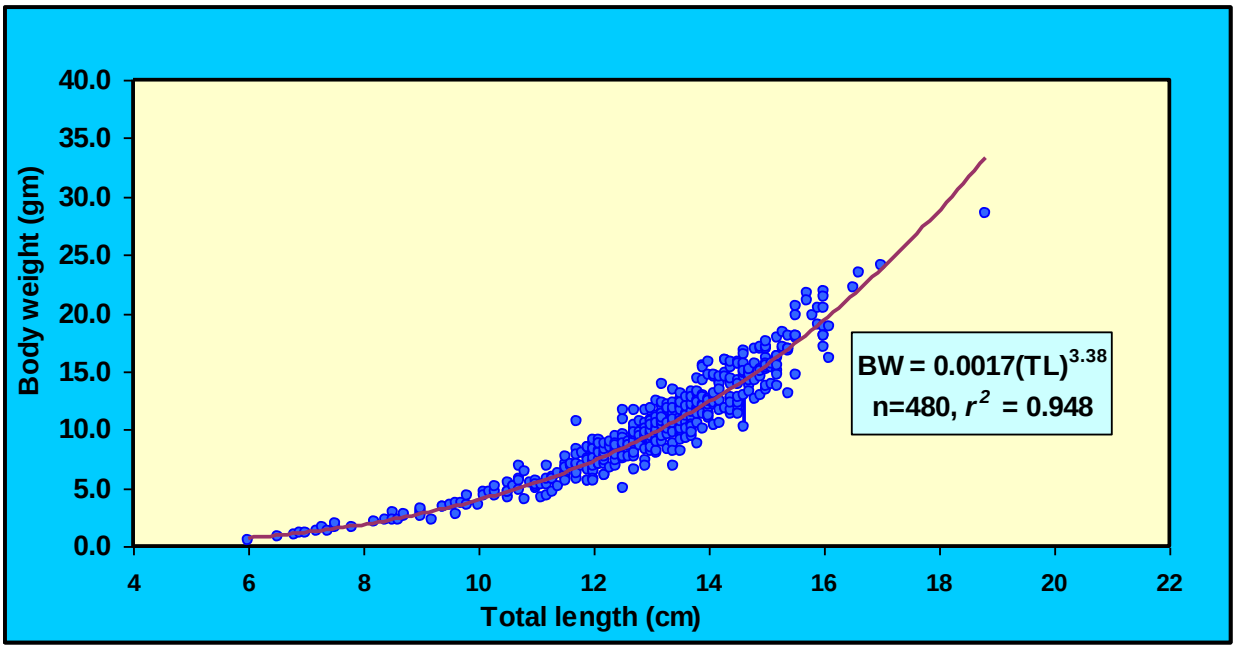

Fig. 2. Total length-body weight relationship of *Macrognathus pancalus* in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem

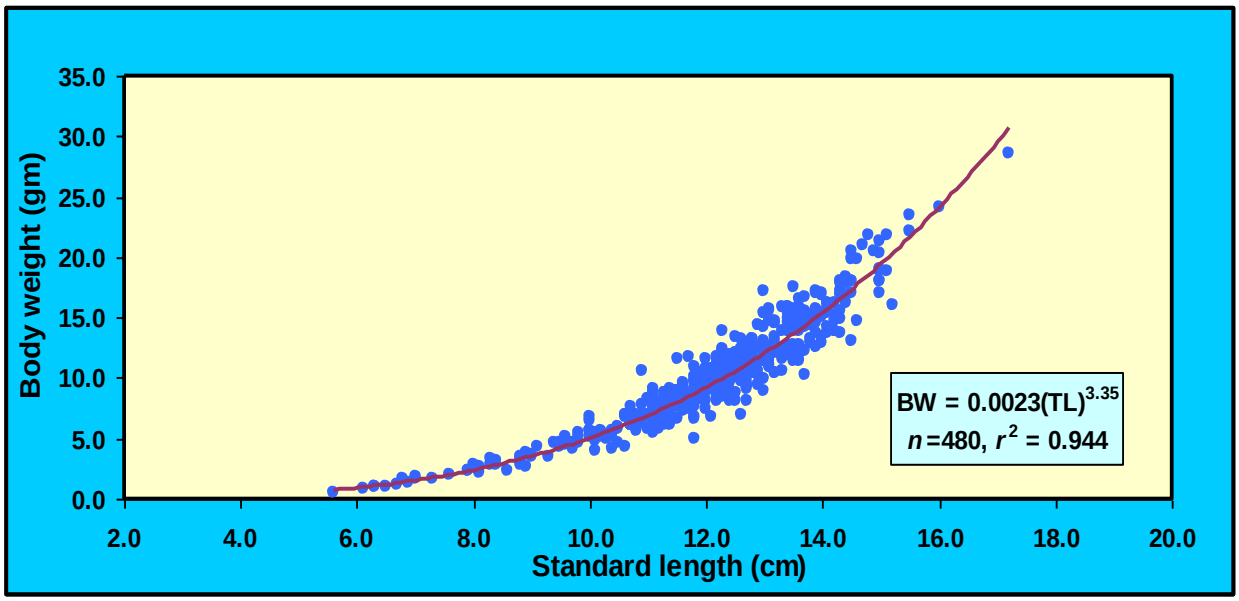

Fig. 3. Standard length-body weight relationship of *Macrognathus pancalus* in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem

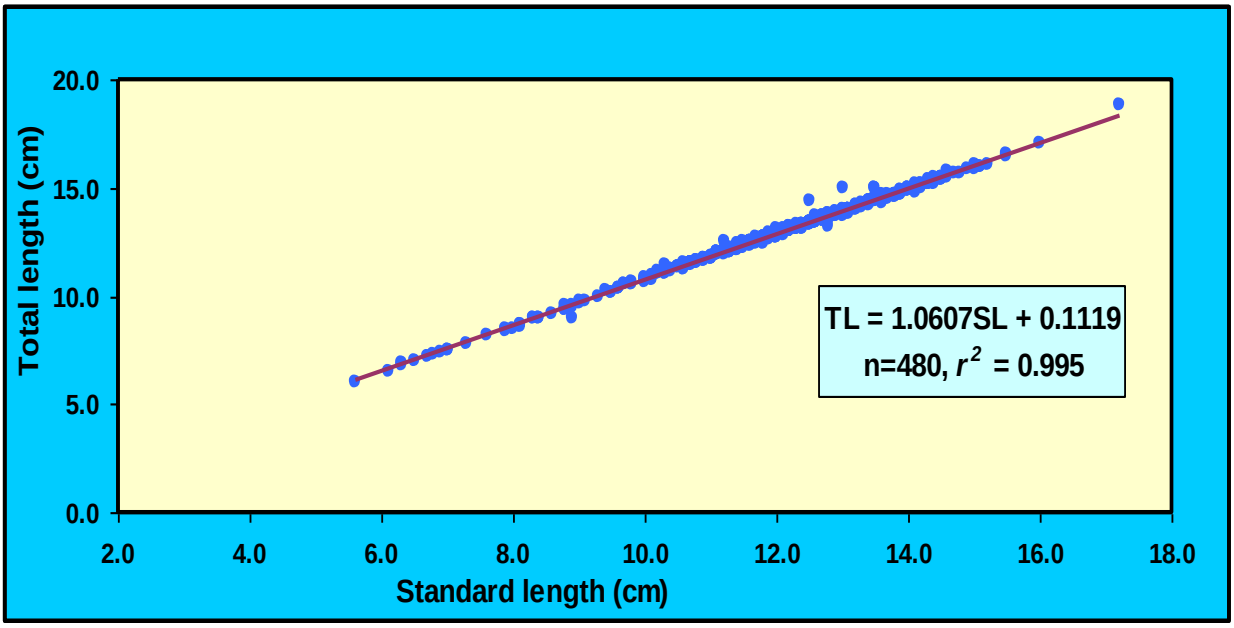

Fig. 4. Total length- standard length relationship of *Macrognathus pancalus* in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem

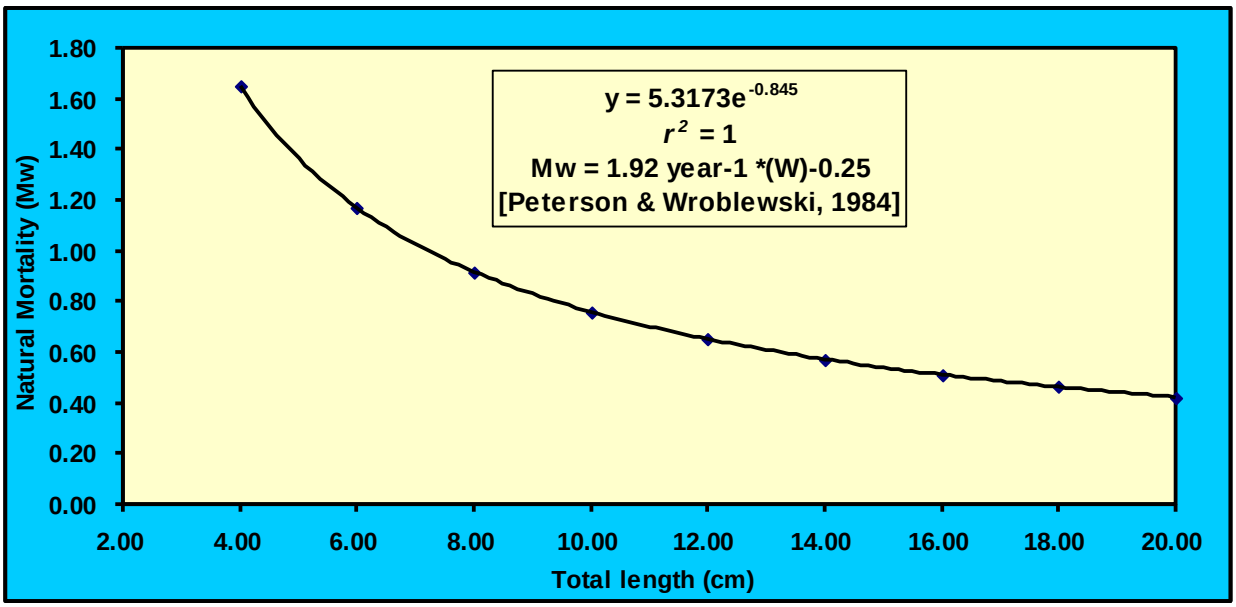

Fig. 5. Natural mortality of *Macrognathus pancalus* in a wetland (Gajner *Beel*, Pabna, Bangladesh) ecosystem

Table 1. Descriptive statistics on length and weight measurements and their 95% confidence interval (Cl) of the *Macrognathus pancalus* in the Gajner *Beel*, Pabna, Bangladesh.

Measurement	***n***	**Total length (cm)**			
		Min	**Max**	**Mean ± SD**	**95% CI**
Total length (cm)	480	6.00	18.80	12.984±1.811	12.821 to 13.146
Satndard length (cm)	480	5.60	16.50	12.135 ± 1.703	11.983 to 12.288
Body weight (g)	480	0.53	27.56	10.315± 4.294	9.929 to 10.700

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

Table 2. Descriptive statistics and estimated parameters of the total length and body weight relationships of the *Macrognathus pancalus* in the Gajner *Beel*, Pabna, Bangladesh.

Equation	***n***	***a***	***b***	**95% CI of *a***	**95% CI of *b***	r^2	**GT**
$BW=a*TL^b$	480	0.0017	3.38	0.0014 to 0.0020	3.31 to 3.45	0.948	A+
$BW=a*SL^b$	480	0.0023	3.35	0.0019 to 0.0027	3.27 to 3.42	0.944	A+
$TL=a+b(SL)$	480	0.112	1.06	0.028 to 0.196	1.05 to 1.07	0.995	A+

a, intercept; *b*, slope; CI, confidence interval for mean values; r_2, coefficient of determination; GT, growth type; A+, positive allometric

Table 3. Descriptive statistics on condition factors measurements and their 95% confidence limits of the *Macrognathus pancalus* in the Gajner *Beel*, Pabna, Bangladesh

Water body	***n***	**Min**	**Max**	**Mean ± SD**	**95% CI**
Fulton Condition Factor (K_F)	480	0.601	1.590	1.017±0.124	1.006 to 1.029
Relative Condition Factor (K_R)	480	0.001	0.003	0.0017±0.0002	0.0017 to 0.0018
Allometric Condition Factor (K_A)	480	0.245	0.662	0.4387±0.0583	0.4334 to 0.4439
Relative Weight (W_R)	480	60.050	159.030	101.7408±12.442	100.625 to 102.857

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

Table 4. Relationships of condition factor with total length (TL), standard length (SL) and body weight (BW) of *Macrognathus pancalus* in the Gajner *Beel*, Pabna, Bangladesh.

Relationship	r_s value	95% CI of r_s	*P* values	Significance
TL *vs.* K_A	0.3476	0.2639 to 0.4261	< 0.0001	***
TL *vs.* K_F	-0.0134	-0.1054 to 0.0789	0.7704	Ns
TL *vs.* K_R	-0.0151	-0.1071 to 0.0772	0.7414	Ns
TL *vs.* W_r	-0.0134	-0.1054 to 0.0789	0.7701	Ns
SL *vs.* K_A	0.3961	0.3179 to 0.4690	< 0.0001	***
SL *vs.* K_F	-0.0034	-0.0929 to 0.0861	0.9404	Ns
SL *vs.* K_R	-0.0039	-0.0934 to 0.0856	0.9315	Ns
SL *vs.* W_r	-0.0034	-0.0929 to 0.0861	0.9400	Ns
BW *vs.* K_A	0.6087	0.5472 to 0.6636	< 0.0001	***
BW *vs.* K_F	0.2740	0.1866 to 0.3571	< 0.0001	***
BW *vs.* K_R	0.2694	0.1818 to 0.3528	< 0.0001	***
BW *vs.* W_R	0.2740	0.1865 to 0.3571	< 0.0001	***

TL, total length; SL, standard 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; CI, confidence interval; p, shows the level of significance; Ns, not significant; * significant; ** highly significant; ***very highly significant.

Table 5. The calculated form factor ($a_{3.0}$), size at first sexual maturity (L_m) and natural mortality (*Mw*) of *Macrognathus pancalus* in the Gajner *Beel*, Pabna, Bangladesh.

Water body	Sex	Regression parameter		L_{max}	$a_{3.0}$	L_m (95% CI of L_m)	M_w
		a	*b*				
Gajner *Beel*, Bangladesh		0.0017	3.38	18.8	0.0055	11.16 (8.84 to 14.10)	0.79

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.

DISCUSSION

The research on the life-history of *M. pancalus* is very scarce in literature from Bangladesh and globally. Therefore, this study focuses on complete depiction on life history traits including LFD, growth types, conditions (K_A, K_F, K_R), Relative weight (W_R), $a_{3.0}$, L_m and M_W of *M. pancalus* using a great number of specimen of a variety of body shapes and sizes from the Gajner *Beel*, NW Bangladesh.

In this present study, we observed that the minimum length is 6.00 cm in TL and maximum length is 18.80 cm in TL of individuals. In this regard, we strongly assumed that the lower sizes compare to 6.00 cm in TL of individuals may be escaped due to inappropriate selection of fishing gear or the fishermen did not capture the specific locations of the Gajner *Beel* (**Parvin *et al*., 2018; Rahman *et al*., 2019a, b**). In addition, fishermen's propensity to discard small sized fishes might be another cause for this phenomenon as well as might be previously informed their sustainability to the habitat (**Nima *et al.*, 2020**). Therefore, in the present study, the maximum length of *M. pancalus* is found 18.8 cm in TL, which is bigger than FishBase value as 18.0 cm in TL and this recorded size would be effectively used for determining the asymptotic length and growth co-efficient of wild populations.

The allometric co-efficient *b* may differ from 2 to 4 (**Carlander, 1969**), however based on **Froese (2006)**, values from 2.5 to 3.5 are optimum range for fishes. In overall, despite a lot of differences in fish forms between individual species, *b* values adjacent to 3, representing that fish grow isometrically and dissimilar from 3.0 indicate allometric growth (> 3 positive allometry and < 3 negative allometry) (**Tesch, 1968**). In this context, the regression parameter *b* of the LWRs ranged from 3.31 to 3.45. Based on the the *b*-values, this fish reveals positive allometric growth in all of the studied months. Parallel growth patterns were revealed in the species (*b*=3.19) by **Hossain *et al*. (2017)** in Gajner *Beel* and in the Mathabhanga River (*b*=3.03), southwestern Bangladesh (**Hossain *et al*., 2006**). A similar finding of the b value was reported as 3.17 in the Gomti River, India (**Abujam and Biswas, 2016**). On the flip of site, *b* value was reported as 2.85 indicating negative allometric growth in the Gurgon *Beel*, India (**Abujam and Biswas, 2016**) which is entirely unparalleled with the present finding. Moreover, negative allometric growth was reported from the Atrai and Brahmaputra River, Bangladesh (b > 3.0) observed by **Islam *et al.* (2017)** which is also unlike with the present finding. The differences of *b* value for the same species due to growth increment, variations in age and phase of maturity, feeding habit, abiotic parameters (i.e. water quality parameters, temperature, salinity) as well as biotic parameters (i.e. microbial and parasitic invasions to the host) (**Snieszko, 1974; Bandilla *et al*., 2006**).

Condition factors (Fulton's, Relative; Allometric, and also Relative weight) were used to assess the health status and habitat condition of *M. pancalus* during this research work, yet most of the works deals with a only single condition features. It is the first study on condition factor for *M. pancalus*, so it was not possible to compare with other findings. Spearman rank-correlation test specified that, among these condition factors, Allometric condition factor (K_A) was significantly correlated with TL, SL and BW (Table 4), so K_A is the best condition index for evaluating the wellbeing of *M. pancalus* in the Gajner *Beel* and surrounding ecosystems.

Rypel and Richter (2008) recommend the W_R assists to evaluate the general health condition and fitness including ecosystem disturbances up to the population-level. During our study the mean W_R was significantly different from 100 for *M. pancalus* representing a disparity territory with food accessibility comparative to the occurrence of predators (**Anderson and Neumann, 1996**) for *M. pancalus* in the Gajner *Beel*. However, due to lack of available literature regarding W_R of *M. pancalus* restrains the comparison with the others.

According to **Froese (2006)**, form factor ($a_{3.0}$) can be employed to designate whether the body dimension of individuals in a particular population or specific species is extensively unlike from others. Based on this study, the calculated value of $a_{3.0}$ was 0.0055 indicating eel like body shape for *M. pancalus* in the Gajner *Beel*, northwestern Bangladesh. We cannot find any related reference dealing with form factor of this species and it will be offered as baseline information for additional research to the scientific community.

The sexual maturity is important features in fisheries resource management which is important indicator for minimum acceptable capture size (**Khatun *et al.*, 2019**: **Hossain *et al.*, 2019**). This study revealed that the length at first sexual maturity for *M. pancalus* was 11.16 cm in the Gajner *Beel*. This is the first study conducted for this species in Bangladeshi waters. Though, **Pathok *et al.* (2012)** reported that the size at first sexual maturity of barred spiny eel (*M. pancalus*) in both the regions (lentic and lotic) was 13.1 cm during the reproductive period, which is higher than the findings of the present study. Even though, **Suresh *et al*. (2006)** recorded size at first sexual maturity as 10.80 cm (males) and 12.30 cm (females) in TL for *M. pancalus* which is also unrelated with the present study. This breakthrough may be due to the seasonal variation in the water depth that also impact on nutrient cycling, and energy cycling of aquatic habitat that influence the reproductive ability of fish (**Lowerre-Barbieri, 2011**).

The calculated M_W for the population of *M. pancalus* was estimated as 0.79 year^{-1} in the Gajner *Beel*. This is the first study dealing with natural mortality of this species and it will be reference point for future study.

In fine, the present results provide first comprehensive information on the life history traits of *M. pancalus* in the Gajner *Beel* wetland. Our findings would be an important data for fisheries biologists, conservationists, and managers to implement management approach and guidelines in case of sustainable resource conservation of the lasting stocks of this fish species. Therefore, our results will present fundamental data for the online database and also to offer an important model for further studies within wetland ecosystems.

CONCLUSION

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