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Growth, Condition, Maturity and Mortality of the Gangetic Leaffish *Nandus nandus* (Hamilton, 1822) in the Ganges River (Northwestern Bangladesh)

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Abstract

The Gangetic leaffish, *Nandus nandus* (Hamilton, 1822) is an important nutritionally precious food fish in south Asian countries. This is the first inclusive explanation on population parameters of *N. nandus* i.e., population structure (Length-Frequency Distributions, LFDs), growth (Length-Weight and Length-Length Relationships; LWRs, LLRs), condition factors (allometric, K_A; Fulton′s, K_F; relative, K_R; relative weight, W_R; and form factor, $a_{3.0}$), reproduction (first sexual maturity, L_m) and natural mortality (M_W) in the Ganges River, northwestern (NW) Bangladesh. Samples were collected using different fishing gears from April 2014-March 2015. Total Length (TL) and Standard Length (SL) were measured for each individual by digital slide calipers, while individual Body Weight (BW) was weighed by a digital balance. A total of 125 individuals ranging from 3.0-15.1 cm TL and 0.30-52.10 g BW were analyzed in the present study. The 7.00-8.99 cm TL was numerically leading group of the total population. Allometric coefficient (*b*) of LWRs indicate positive allometric growth (b>3.0) for TL *vs.* BW and isometric growth (b=3.0) for SL *vs.* BW relationship. Additionally, the *b* value for LLR also shows the same growth pattern. In the present study, among four types of condition factors K_F (ranged from 1.258 to 1.336) was best for wellbeing of *N. nandus* in the Ganges River. Wilcoxon signed rank test indicated that, the W_R did not show any significant difference from 100 (p = 0.325), representing the balanced habitat for *N. nandus*. The $a_{3.0}$ was 0.0159 indicating this fish is short and deep in body shape and the L_m was 9.10 (~ 9.00) cm TL and the M_W was estimated as 1.33 y^{-1}. The results would be good strategy for conservation of this species in the Ganges River and surrounding ecosystem.

Keywords: *Nandus nandus,* Growth, Condition, Maturity, Mortality, Ganges River.

1. Introduction

The Gangetic leaffish, *Nandus nandus* is a fresh- and brackish-water benthopelagic species of the family Nandidae. This fish is known as Meni and Bheda in Bangladesh; Nandosh in India and Dalahai in Nepal (Froese and Pauly, 2016). It is distributed throughout the Indian sub-continent including Bangladesh, India, Malaysia, Myanmar, Pakistan, Thailand and Viet Nam (Froese and Pauly, 2016). This fish mainly inhabits streams, rivers, pools, lakes, canals and reservoir (Rainboth, 1996). The *N. nandus* is important for food fish, aquarium trade and they have high market need (Talwar and Jhingran, 1991). However, unfortunately the natural populations are declining fatally due to reckless fishing, habitat destruction (IUCN Bangladesh, 2000; Hossain, 2014; Hossain *et al*., 2015a, b); pollution and other ecological changes to their territory (Mijkherjee *et al*., 2002; Hossain *et al*., 2015c; Hossen *et al*., 2015). As a result, this fish is categorized as vulnerable in Bangladesh (IUCN Bangladesh, 2000) although globally categorized as least concern (IUCN, 2014).

Information on population parameters i.e., growth, reproduction, recruitment as well as mortality of fishes is vital to the implementation of sustainable management strategies for their better conservation (Hossain *et al*., 2009). However, to the best of the authors' knowledge, there are no earlier studies on population parameters of *N. nandus.* Nevertheless, few works on length-weight relationships (Hossain *et al*., 2006), morphometrics and meristics traits (Goswami *et al*., 2007), biology (Das *et al*., 2002), and pathological investigation (Marma *et al*., 2007) have been done.

Therefore, studies on population parameters are immediately needed for proper management policies for this important fishery. Hence, the objective of the present study is to depict the population parameters of *N. nandus*

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including growth pattern (Length-Weight Relationships, LWRs), reproduction (size at sexual maturity, L_m), and natural mortality (M_W) from the Ganges River, northwestern (NW) Bangladesh using a number of specimens with small to big sizes over a one-year study period. Also, the condition of *N. nandus* was estimated through multi-models.

2. Material and Methods

2.1. Study Site and Sampling

The present study was carried out in the Ganges River (Lat. 24° 35′ N; Long. 88° 64′ E) NW Bangladesh. A total 125 individuals of *N. nandus* were occasionally collected from the fishermen during April 2014 to March 2015. The fishes were caught using different types of traditional fishing gears i.e., gill net, cast net, square lift net etc. Samples were instantly chilled in ice on site and preserved with 10% buffered formalin upon arrival in the laboratory.

2.2. Fish Measurement

Total Length (TL) and Standard Length (SL) were measured to the nearest 0.01 cm using digital slide calipers and total Body Weight (BW) was weighed by an electronic balance with 0.01 g accuracy for each individual.

2.3. Growth Pattern

The length-frequency distribution for *N. nandus* was constructed using 1 cm intervals of TL. The growth pattern was determined through LWR with the equation: $BW = a*(TL)^b$ where BW is the total body weight (g) and TL is the total length (cm). The parameters *a* and *b* were calculated by linear regression analyses based on natural logarithms: ln (*W*) = ln(*a*) + *b* ln(*L*). Extremes outliers were deleted from the regression analyses according to Froese (2006). Additionally, on the basis of the *b* values of LLR (TL *vs.* SL) growth pattern of *N. nandus* was determined.

2.4. Condition Factors

The allometric condition factor (K_A) was estimated using the equation of Tesch (1968): W/L^b, where *W* is the body weight (g) and *L* is the TL (cm), and *b* is the LWR parameter. The 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. Moreover, the relative condition factor (K_R) was calculated following the equation of Le Cren (1951): $K_R = W/(a \times L^b)$, where *W* is the body weight (g), *L* is the TL (cm) and *a* and *b* are LWRs parameter. For assessing the relative weight (W_R), the equation of Froese (2006): $W_R = (W / W_s) \times 100$, were used, where *W* is the weight of a particular individual and W_s is the predicted standard weight for the same individual as calculated by $W_s = a \times L^b$ where the *a* and *b* values are gained from the relationships between TL *vs.* BW.

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

The $a_{3.0}$ of *N. nandus* was calculated according to the equation of Froese (2006) as: $a_{3.0} = 10^{\log a - s\,(b-3)}$, where *a* and *b* are the regression parameters of LWRs and *s* is the regression slope of *ln a vs. b*. In the present study, a mean slope $S = -1.358$, was used for estimating the form factor because information on LWRs is not available for this species for estimation the regression (S) of *ln a vs. b*.

2.6. Size at First Sexual Maturity (Lm)

The L_m was calculated using the empirical equation, $\log (L_m) = -0.1189 + 0.9157 * \log (L_{max})$, where L_{max} is the maximum observed length (Binohlan and Froese, 2009).

2.7. Natural Mortality (M_W)

The M_W of *N. nandus* was calculated 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 $W = a*L^b$, *a* and *b* are the regression parameters of LWR.

2.8. Statistical Analysis

For statistical analysis, GraphPad Prism 6.5 Software was used. The Spearman rank correlation test was applied to analyze the relationship of condition factors with TL, and BW. The one sample t-test was applied 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 Distribution (LFDs)

A total 125 individuals of *N. nandus* were collected from the fishermen at different parts of the River in Rajshahi region during the present study. The LFDs showed that the smallest and largest individuals were 3.0 cm and 15.1 cm in TL, respectively; whereas the BW ranges from 0.30-52.10 g. The 7.00-8.99 cm TL size group was numerically dominant and constituted 24.0% of the total population (Figure 1).

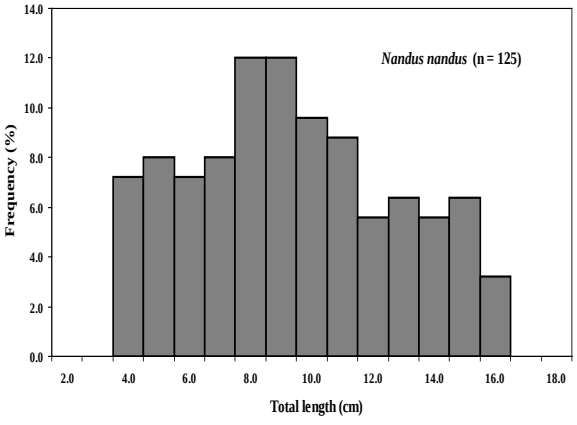

Figure 1. Length-frequency distribution of *Nandus nandus* from the Ganges River, northwestern Bangladesh

3.2. Growth Patterns

The regression parameters (*a* and *b*) of the LWR, 95% CL of *a* and *b*, the coefficient of determination (r^2) and growth pattern of *N. nandus* are given in Table 1 and in Figure 2. The *b* value of TL *vs.* BW indicates positive allometric growth. Also, the *b* value of LLR (TL *vs.* SL) indicates same growth pattern (positive allometric) and it is presented in Figure 2.

Table 1. Descriptive statistics and estimated parameters of the length-weight relationships ($W = a \times TL^b$), size at first sexual maturity (L_m) and form factor ($a_{3.0}$) of *Nandus nandus* (Hamilton, 1822) (n= 125) from the Ganges River, northwestern Bangladesh

Equation	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT	L_m	95% CL of L_m	$a_{3.0}$
	a	*b*							
$W = a \times TL^b$	0.0080	3.22	0.0069-0.0092	3.16-3.29	0.987	+A	9.1	7.3-11.5	0.0159
$W = a \times SL^b$	0.0260	3.04	0.0230-0.0295	2.97-3.01	0.986	I	7.5	6.0-9.3	0.0295

n, sample size; *a*, intercept; *b*, slope; CL, confidence limit for mean values; r^2, coefficient of determination; GT, growth type; +A, positive allometric; I, Isometric growth, L_m, Size at first sexual maturity; $a_{3.0}$, form factor

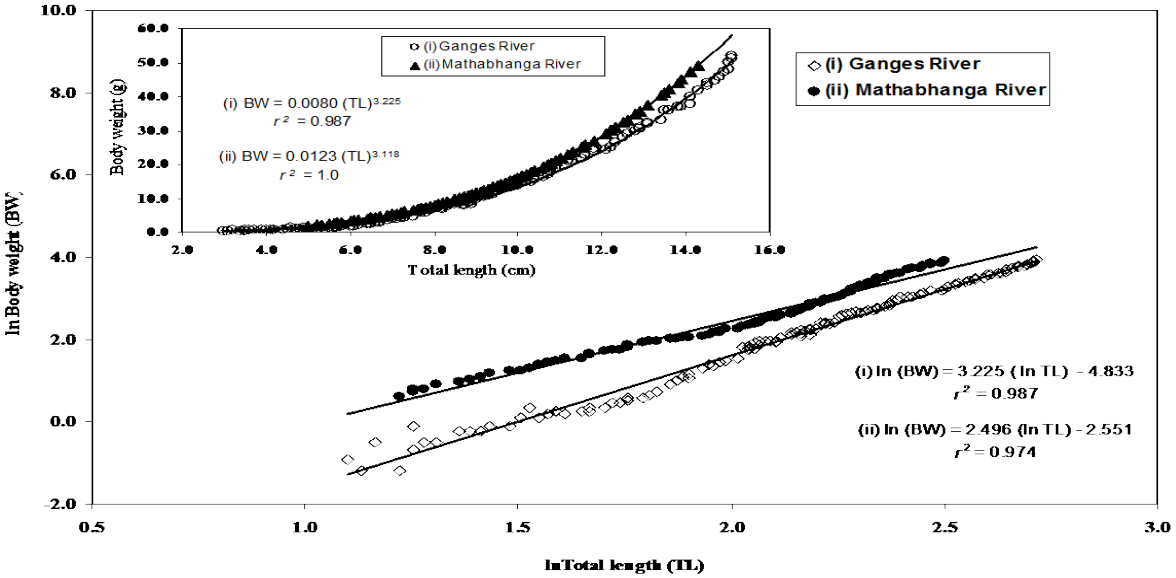

Figure 2. Total length (cm) and body weight (g) relationships ($W = a \times TL^b$) of *Nandus nandus* in the (i) Ganges River, NW Bangladesh (Present study), (ii) Mathabhanga River, southwestern Bangladesh (Hossain *et al*., 2006)

3.3. Condition Factors

The values of all condition factors (K_A, K_F, K_R, and W_R) are given in Table 2. On the basis of Spearman rank correlation test, there were significant co-relationships of K_F with TL and BW (Table 3). There was no significant different of W_R from 100 (p=0.075) indicating a balanced population for *N. nandus* in the Ganges River (Figure 3).

Table 2. Condition factors; Allometric condition factor (K_A), Fulton′s condition factor (K_F), Relative condition factor (K_R) and Relative weight (W_R) of *Nandus nandus* (Hamilton, 1822) (n= 125) from the Ganges River, northwestern Bangladesh

Condition factors	Min	Max	Mean ± SD	95% CL
Allometric condition	0.0056	0.0159	0.008± 0.001	0.008-0.008
Fulton′s condition	0.7633	2.0991	1.297± 0.219	1.258-1.336
Relative condition	0.7023	1.9918	1.018± 0.169	0.988-1.047
Relative weight	70.2321	199.1835	101.756± 16.850	98.772-104.73

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

Table 3. Relationships of condition factor with total length (TL) and body weight (BW) of *Nandus nandus* (Hamilton, 1822) from the Ganges River, northwestern Bangladesh

Relationships	r_s values	95% CL of r_s	*P* values	Significance
TL *vs.* K_A	0.0896	-0.0926 to 0.2660	*P* = 0.320	*Ns*
TL *vs.* K_F	0.6559	0.5391 to -0.7480	*P* < 0.001	****
TL *vs.* K_R	0.0889	-0.0933 to 0.2654	*P* = 0.324	*ns*
TL *vs.* W_R	0.0890	-0.0932 to 0.2655	*P* = 0.324	*ns*
BW *vs.* K_A	0.1101	-0.0721 to 0.2851	*P* = 0.221	*ns*
BW *vs.* K_F	0.6751	0.5631 to 0.7628	*P* < 0.001	****
BW *vs.* K_R	0.1095	-0.0727 to 0.2846	*P* = 0.224	*ns*
BW *vs.* W_R	0.1096	-0.0726 to 0.2847	*P* = 0.223	*ns*

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; **** Extremely significant

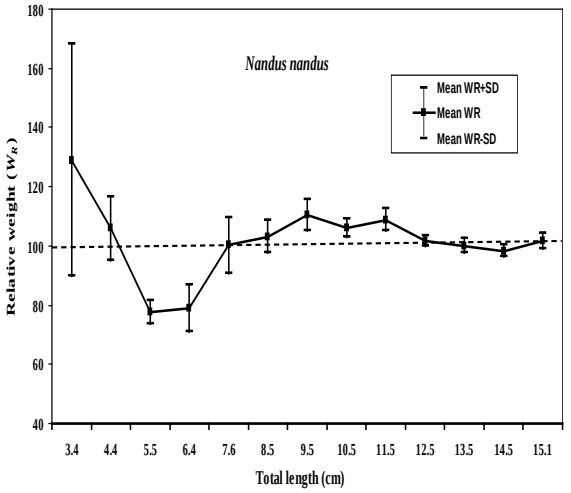

Figure 3. Relationships between total length (TL) and relative weight *(W_R)* of *Nandus nandus* from the Ganges River, northwestern Bangladesh

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

The $a_{3.0}$ was calculated as 0.0159 for *N. nandus* in the Ganges River, NW Bangladesh. The present study also estimates the $a_{3.0}$ of *N. nandus* from world over different water bodies using available data (Table 1).

3.5. Size at First Sexual Maturity (L_m)

The L_m for the *N. nandus* was estimated as 9.10 cm TL in the Ganges River, NW Bangladesh. Moreover, the present calculates the L_m of *N. nandus* from world-wide different water bodies using available studies (Table 1).

3.6. Natural Mortality (Mw)

The present study revealed that M_W for the population of *N. nandus* was 1.33 year^{-1} in the Ganges River, NW Bangladesh and it is shown in Figure 4.

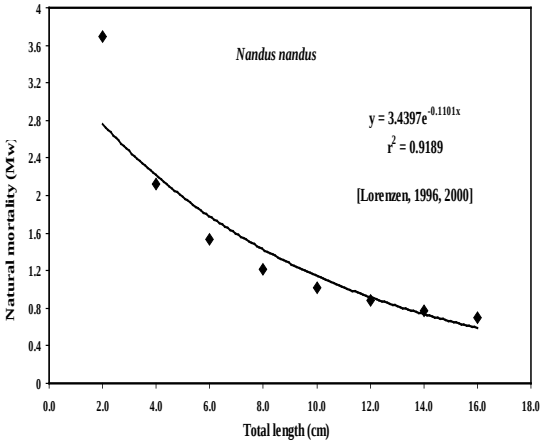

Figure 4. The natural mortality (Mw*)* of *Nandus nandus* from the Ganges River, northwestern Bangladesh

4. Discussion

Information on population parameters of *N. nandus* from Bangladesh is not available, except for Hossain *et al*. (2006) from the Mathabhanga River, southwestern Bangladesh. However, the present study focuses on growth patterns, condition factors, form factor, reproduction and mortality of *N. nandus* from the Ganges River.

In the present study, it was not possible to sample *N. nandus* smaller than 3.0 cm in TL which may due to the absence of smaller size individual in the fishing ground or selectivity of fishing gears (Hossain *et al*., 2015d, 2016a,b,c). The maximum size was 15.1 cm in TL which is lower than the maximum recorded value of 20 cm TL (Talwar and Jhingran, 1991), but higher than 14.20 cm TL by Hossain *et al*. (2006). Information on maximum length is very significant to estimate the asymptotic length and growth coefficient of fishes, also helpful for fisheries resource planning and management (Hossain *et al*., 2012, 2016d).

In the present study, the calculated b values lies between 3.04-3.22. However, the b values ranging from 2.5 to 3.5 are more common (Froese, 2006). According to Tesch (1971) *b* values were close to 3, indicating isometric growth of fish and different from 3.0 indicating allometric growth (>3 positive allometric and <3 negative allometric). In the present study, the *b* values were greater than 3.0 for TL *vs.* BW and SL *vs.* BW relationships, which indicates a positive allometric growth of *N. nandus* in the Ganges River ecosystem. In addition, the *b* values (*b*=1.25) of LLR, indicate positive allometric growth. Since the present study is the first assessment on LLR, it was not possible to compare its results with other findings.

During the present study, we have worked on four condition factors (K_A, K_F, K_R and W_R) to assess the physical and environmental condition of *N. nandus* in the Ganges River. Spearman rank correlation test expressed that the K_F was significantly correlated with TL and BW. Therefore, it can be assumed that, the Fulton′s condition factor (K_F) is the best for determining the wellbeing of *N. nandus* in the Ganges River and adjacent ecosystem.

Wilcoxon signed rank test specify that W_R was not significantly different from 100 (p = 0.325) indicating the

population of *N. nandus* in the Ganges River was in balanced condition with availability of food and lower predators.

The $a_{3.0}$ was 0.0159 for *N. nandus* indicating this fish is short and deep in body shape in the Ganges River. The $a_{3.0}$ can be used to prove whether the body shape of individuals in a given population or species is extensively different from others or not (Froese, 2006).

The L_m for *N. nandus* was 9.10 cm in TL. For the fishes of Bangladesh, Studies on L_m are very atypical (except Hossain *et al*., 2010, 2016b). The present study offers the first effort to assess the size at sexual maturity for *N. nandus* from the Ganges River. Thus, the present study will be base for more thorough studies to find out the factors affecting the first sexual maturity and spawning size.

The M_w for the population of *N. nandus* was estimated as 1.33 year^{-1} in the Ganges River, NW Bangladesh. There are no earlier studies on the M_W to compare with the present findings.

5. Conclusion

Our findings describe the population patterns of *N. nandus* including length-frequency distribution, growth pattern based on LWRs, size at sexual maturity, natural mortality, best suited condition factor, relative weight and form factor. The results of the present study would be a valuable means for fishery managers, fish biologists and conservationists to begin early management policies and regulations for the sustainable conservation of the enduring stocks of this fish species in the Ganges River and neighboring ecosystem.

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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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