

Seasonal Variations of Growth Pattern and Condition of Paradise threadfin *Polynemus paradiseus* (Polynemidae) from Tetulia River in Southern Bangladesh

Md. Alomgir Hossen¹, Md. Yeamin Hossain^{1*}, Mir Mohammad Ali², Md. Nasir Uddin Pramanik¹, Fairuz Nawer¹,
Md. Ariful Islam¹, Md. Akhtar Hossain¹, Ali H. Bahkali³ & Abdallah M. Elgorban³

¹Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi 6205, Bangladesh

²Faculty of Fisheries, Patuakhali Science and Technology University, Patuakhali 8602, Bangladesh

³Department of Botany and Microbiology, College of Science, King Saud University, Riyadh 11451, Saudi Arabia

*[E-mail: yeamin.fish@ru.ac.bd; hossainyeamin@gmail.com]

Received 16 July 2015; revised 21 January 2016

A total of 900 individuals (pre-monsoon = 250, monsoon = 350, post-monsoon = 300) of *P. paradiseus* were collected from the fishers catches during January to December 2014. For each individual, TL (total length) and BW (body weight) were measured with 0.1 cm and 0.1 g accuracy, respectively. Length weight relationship (LWR) was estimated by the equation, $W = a \times L^b$. Length-frequency distributions (LFD) were significantly different between the seasons ($P < 0.001$). Allometric coefficient (b values) of LWRs (TL vs. BW) indicated isometric growth in pre-monsoon and post-monsoon ($b \approx 3$), but negative allometric growth was found in monsoon ($b < 3$). All LWRs were highly significant ($P < 0.001$) with all r^2 values ≥ 0.984 . The LWRs were significantly difference between the seasons (ANCOVA, $P < 0.001$). The K_F is highly correlated with TL (Spearman rank test, $P < 0.001$) in all the seasons, thus suggesting the best condition factor for assessing the wellbeing of this fish in our study area. Additionally, the W_R was significantly different from 100 (Wilcoxon rank test, $P = 0.003$) in pre-monsoon, which indicates the habitat was in poor condition for *P. paradiseus*, nevertheless it was not significantly differed in monsoon ($P = 0.0186$) and post-monsoon ($P = 0.423$). The calculated L_m was 12.1 cm in TL and form factor was 0.0061 for *P. paradiseus* in the Tetulia River.

[Key words: *Polynemus paradiseus*, growth, condition, relative weight, Tetulia River, Bangladesh]

Introduction

The Paradise threadfin, *Polynemus paradiseus* (Linnaeus, 1758), is a marine, fresh- and brackish-water fish species of the family Perciformes¹. This species is commonly known as Tapasi, Paradise threadfin in Bangladesh^{2,3}; Tapsee-machh, and Paradise threadfin in India^{4,5}; Striped threadfin, and Tassel fish in Malaysia⁶; Buka-dulce, and Kulampiros in Philippines⁷ but it is globally known as Paradise threadfin⁸. This fish is found in Bangladesh, India, Malaysia, Myanmar, Thailand, Pakistan and Cambodia⁹. It lives over sandy bottoms, regularly enters in freshwaters during spawning season¹⁰. The *P. paradiseus* feeds mainly on crustaceans (especially shrimps), small fishes and benthic organisms¹⁰. Flesh of this fish is very oily and tasty and preferred by the consumers². However, the wild population of the species could be declining

due to heavy harvest, habitat loss and other ecological changes to their habitat in Bangladeshi water-bodies^{11,12}.

Biological aspects including the length frequency distribution (LFD) reflects the interactions of the dynamic rates of recruitment, growth and mortality¹³; and also it helps to determine the river health, stock conditions and breeding period of the fish¹⁴. In addition, the length-weight relationship (LWR) is frequently used to find out the seasonal variations in fish growth and condition indices^{15,16,17}. Furthermore, it is essential for the calculation of production and biomass of a fish population^{15,16,18,19}. Moreover, the length-length relationship (LLR) is very useful to detect the affect of ecological and physiological factors on fish growth²⁰. Condition factor e.g. Fulton's condition factor has a significant role to assess the gonadal maturity and environmental condition of

fish^{21,22}. Additionally, relative condition factor could be helpful in determining the pollution or any situation that resulted in prolonged physiological stress of a fish population²³. Furthermore, the relative weight can be used to estimate the habitat health based on prey-predator status^{24,25}.

Only a few studies on *P. paradiseus* including biology, ecology and dynamics have been conducted^{10,26}. Nevertheless, a number of studies have been conducted on LFDs, LWRs and condition factors of several fish species from the north-western Bangladesh^{27,28,29,30,31,32,33}. However to the best of the authors' knowledge, there is no detailed information on *P. paradiseus* from Bangladesh or else. Therefore, our study focuses on seasonal variations of LFD, LWRs, LLRs, condition factors (allometric K_A ; Fulton's K_F ; relative, K_R and relative weight, W_R) of *P. paradiseus* from the coastal Tetulia River, southern Bangladesh. Also, the size at first sexual maturity (L_m) and form factor ($a_{3,0}$) were estimated.

Materials and Methods

Sampling was conducted in the Tetulia River, southern Bangladesh, connect to marine ecosystem. The River Tetulia is one of the largest rivers in southern part of Bangladesh and acts as an important spawning and feeding ground for freshwater and marine water fish species. Samples were collected during daytime on a seasonal basis (pre-monsoon = 250, monsoon = 350 and post-monsoon = 300) from fishermen's catches landed at different parts (Kalia: latitude 22° 39' N and longitude 90° 63' E; Najir pur: latitude 22° 40' N and longitude 90° 62' E; Jafrabad: latitude 22° 41' N and longitude 90° 60' E and Sominpur: latitude 22° 42' N and longitude 90° 59' E) of the River during January to December 2014. The gear used by the fishers includes seine net, cast net, square lift net and monofilament fixed gill net. The fresh samples were immediately chilled in ice on site and fixed with 10% buffered formalin upon arrival at the laboratory. All morphometric characters e.g. total length (TL), fork length (FL) and standard length (SL) were measured to the nearest 0.1 cm using digital slide calipers (Mitutoyo, CD-15PS) and total body weight (BW) was taken using an electronic balance (Shimadzu, EB-430DW) with 0.1 g accuracy.

The LWR was calculated using the equation: $W = a \times L^b$, where W is the body weight (g) and L is the total length (cm). Parameters a and b were estimated by linear regression analyses based on natural logarithms: $\ln(W) = \ln(a) + b \ln(L)$. Additionally, 95% confidence limits of a and b and the co-efficient of determination r^2 were estimated. Earlier to the

regression analyses of $\ln BW$ on $\ln TL$, \ln - \ln plots of length and weight values were performed for visual inspection of outliers, with extremes being omitted from the regression analyses³⁴. A t-test was used to confirm whether b values obtained in the linear regressions were significantly different from the isometric value ($b = 3$)³⁵. Furthermore, LLRs including TL vs. SL and TL vs. FL were estimated by linear regression²⁰. The LFD was constructed using 1 cm intervals of TL.

Allometric condition factor (K_A) was calculated using the equation³⁶, $K_A = W/L^b$, where W is the body weight (BW, g), L is the total length (TL, cm) and b is the LWRs parameter. Fulton's condition factor (K_F) was calculated using the equation³⁷: $K_F = 100 \times (W/L^3)$, where W is the BW (g), and L is the TL (cm). Scaling factor of 100 was used to bring the K_F close to unit and the relative condition factor (K_R) for each individual was calculated via the equation³⁸, $K_R = W/(a \times L^b)$ where W is the BW (g), L is the TL (cm), a and b are the LWRs parameter. Relative weight (W_R) was calculated by the equation³⁴ as: $W_R = (W/W_S) \times 100$, where W is the weight (g) 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 a and b values were obtained from the relationships between TL and BW.

The L_m for *P. paradiseus* in the Tetulia River was calculated using the equation³⁹, $\log(L_m) = -0.1189 + 0.9157 * \log(L_{max})$. In addition, the form factor ($a_{3,0}$) of this species was calculated using the equation³⁴ as: $a_{3,0} = 10^{\log a - s(b-3)}$, where a and b are regression parameters of LWRs and s is the regression slope of $\ln a$ vs. b . During this study, a mean slope $S = -1.358$ ³⁴ was used for estimating the form factor ($a_{3,0}$) because information on LWRs is not available for this species for estimation of the regression (S) of $\ln a$ vs. b .

Statistical analyses were performed using Graph Pad Prism 6.5 software (GraphPad Software, Inc., San Diego, CA). Tests for normality of each group were conducted by visual assessment of histograms and box plots and confirmed with the Saprio-Wilk normality-test. Wilcoxon signed rank test was used to compare the mean relative weight (W_R) with 100⁴⁰. Spearman rank correlation test was used to analyze the relationship between the morphometric indices (condition factors) with TL and BW. The analyses of covariance (ANCOVA) were used to compare the LWRs and TL vs. K_F between the seasons. All statistical analyses were considered significant level at 5% ($P < 0.05$).

Results

Table 1 illustrates the descriptive statistics and 95% confidence limit (CL) for length and weight measurements of *P. paradiseus* from the Tetulia River, southern Bangladesh. The TL ranged from 9.40 to 18.30 cm (mean \pm SD = 14.01 \pm 2.44) in pre-monsoon, 7.30 to 18.90 cm (mean \pm SD = 13.93 \pm 2.75) in monsoon and 10.20 to 21.70 cm (mean \pm SD = 15.38 \pm 3.10) in post-monsoon. The Mann Whitney *U*-test indicated that there were significant difference for TL frequency distribution in pre-monsoon and monsoon ($U = 43529$, $P < 0.001$), pre-monsoon and post-monsoon ($U = 30414$, $P < 0.001$) and monsoon and post-monsoon ($U = 43134$, $P < 0.001$).

Additionally, the BW was ranged from 5.80 to 40.70 g (mean \pm SD = 20.07 \pm 9.79) in pre-monsoon, 3.80 to 40.25 g (mean \pm SD = 18.86 \pm 9.18) in monsoon and 8.10 to 69.60 g (mean \pm SD = 26.43 \pm 12.11) in post-monsoon. The Mann Whitney *U*-test expressed that, there was no significant differences for BW between pre-monsoon and monsoon ($U = 41066$, $P = 0.200$). However, there was significant differences between pre-monsoon and post-monsoon ($U = 31794$, $P = 0.002$) also in monsoon and post-monsoon ($U = 42404$, $P < 0.001$). Furthermore, the LFD showed that 32.4% (maximum in pre-monsoon) stands on 14.0 - 15.0 and 15.0 - 16.0 cm in TL size group in pre-monsoon, 20.0% (maximum in monsoon) on 16.0 - 17.0 cm in TL size group in monsoon and 39.7% (maximum in post-monsoon)

stands on 13.0 - 14.0 and 14.0 - 15.0 cm in TL size group in post-monsoon period (Fig. 1) for *P. paradiseus* in the Tetulia River.

The sample size (n), regression parameters (a and b) and 95 % CL of a and b of the LWR, coefficient of determination (r^2) and growth type (GT) of *P. paradiseus* are given in Table 2 and Fig. 2. All LWRs were highly significant ($P < 0.001$) with all r^2 values ≥ 0.984 . Calculated b value of the LWR (TL vs. BW) indicated isometric growth in pre-monsoon and post-monsoon ($b = 3$), but negative allometric growth found in monsoon ($b < 3$). The ANCOVA stated that, the slopes were extremely different in pre-monsoon and monsoon (df = 596, $F = 210.90$, $P < 0.001$), monsoon and post-monsoon (df = 646, $F = 227.57$, $P < 0.001$) (Figure 3). Furthermore, in pre-monsoon and post-monsoon the slopes were not significantly different (df = 546, $F = -0.009$, $P = 0.984$), but the intercepts were extremely different (df = 547, $F = 117.74$, $P < 0.001$) for *P. paradiseus* in the Tetulia River, southern Bangladesh.

Moreover, the LLR including TL vs. SL and TL vs. FL (in pre-monsoon, monsoon and post-monsoon) for *P. paradiseus* along with estimated parameters and the coefficient of determination (r^2) are presented in Table 3. All LLRs were highly significant ($P < 0.001$) and most of the coefficients of determination values were ≥ 0.990 .

Table 1– Descriptive statistics on the length (cm) and weight (g) measurements of the *Polynemus paradiseus* (Linnaeus, 1758) in the Tetulia River, southern Bangladesh

Measurements	Sex	n	Min	Max	Mean \pm SD	CL _{95%}
Pre-monsoon	C	250				
TL			9.40	18.30	14.01 \pm 2.44	13.71-14.31
FL			7.30	15.10	11.10 \pm 1.99	10.85-11.34
SL			6.30	13.80	10.02 \pm 1.98	9.77-10.27
BW			5.80	40.70	20.07 \pm 9.79	18.85-21.29
Monsoon	C	350				
TL			7.30	18.90	13.93 \pm 2.75	13.64-14.22
FL			5.80	15.90	11.18 \pm 2.42	10.93-11.44
SL			5.10	14.00	9.93 \pm 2.12	9.70-10.15
BW			3.80	40.30	18.86 \pm 9.18	17.90-19.83
Post-monsoon	C	300				
TL			10.20	21.70	15.38 \pm 3.10	15.03-15.74
FL			7.90	18.50	12.26 \pm 2.84	11.94-12.59
SL			7.00	17.20	11.26 \pm 2.75	10.94-11.57
BW			8.10	69.60	26.43 \pm 12.11	24.49-28.38

n , sample size; C, combined sex; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit; TL, total length; FL, fork length; SL, standard length; BW, body weight

The different condition factors (allometric, K_A ; Fulton's K_F ; relative K_R) and relative weight (W_R) of *P. paradiseus* with minimum, maximum, mean values and 95% CL in the Tetulia River are shown in Table 4. The K_F values ranged from 0.600-0.722 in pre-monsoon, 0.573-0.990 in monsoon and 0.576-0.768 in post monsoon.

In addition, the relationships of condition factors with TL of *P. paradiseus* in the Tetulia River are presented in Table 5. Based on the Spearman rank correlation test, the K_F is highly correlated with TL ($P < 0.001$) in all the seasons, thus suggesting the best condition factor for assessing the wellbeing of this fish in our study area throughout the year. In addition, the ANCOVA revealed that the relationships of $\ln TL - \ln K_F$ were not significantly different between pre- and post monsoon ($P = 0.560$), but it was extremely different between monsoon vs. pre-monsoon, and monsoon vs. post-monsoon ($P < 0.001$) (Fig. 3). On the other hand, the slopes for TL vs. K_F were extremely different in monsoon and post-monsoon ($df = 396$, $F=12.10$, $P = 0.001$).

Furthermore, the Wilcoxon signed rank test revealed that the W_R was significantly different from 100 ($P = 0.003$) in pre-monsoon indicating that habitat is in problem before starting spawning, but it was not significantly different in monsoon ($P = 0.186$) and post-monsoon ($P = 0.423$). The estimated L_m was 12.10 cm (95% CL = 8.6 - 17.2 cm TL) in TL and the calculated form factor (a_{30}) was 0.0061 for *P. paradiseus* in the Tetulia River.

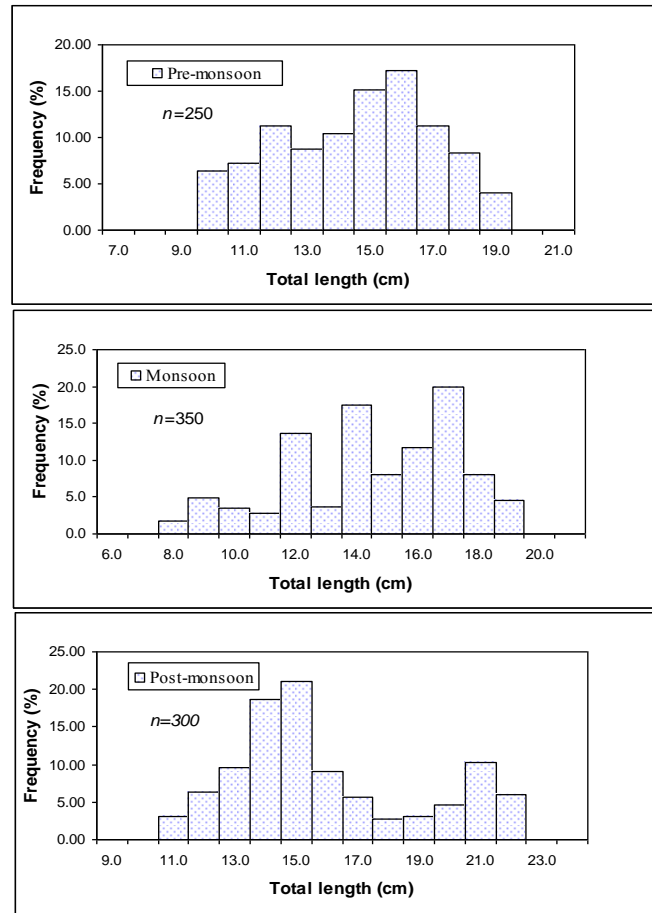


Fig. 1– Length-frequency distributions of *Polynemus paradiseus* (Linnaeus, 1758) in the Tetulia River, southern Bangladesh

Table 2– Descriptive statistics and estimated parameters of the length-weight relationships of the *Polynemus paradiseus* (Linnaeus, 1758) in the Tetulia River, southern Bangladesh

Equation	Sex	n	Regression parameters		95% CL of a	95% CL of b	r ²	GT
			a	b				
Pre-monsoon	C	250						
BW=a × TL ^b			0.0061	3.032	0.0057-0.0066	3.005-3.058	0.995	I
BW=a × FL ^b			0.0152	2.949	0.0136-0.0170	2.902-3.000	0.984	-A
BW=a × SL ^b			0.0411	2.651	0.0377-0.0447	2.614-2.688	0.987	-A
Monsoon	C	350						
BW=a × TL ^b			0.0127	2.737	0.0119-0.0136	2.711-2.762	0.992	-A
BW=a × FL ^b			0.0410	2.504	0.0390-0.0431	2.484-2.525	0.994	-A
BW=a × SL ^b			0.0553	2.504	0.0523-0.0584	2.479-2.528	0.992	-A
Post-monsoon	C	300						
BW=a × TL ^b			0.0058	3.035	0.0054-0.0063	3.007-3.063	0.993	I
BW=a × FL ^b			0.0293	2.668	0.0273-0.0314	2.640-2.695	0.992	-A
BW=a × SL ^b			0.0541	2.511	0.0510-0.0575	2.485-2.536	0.992	-A

n, sample size; C, combined sex; BW, body weight; TL, total length; FL, fork length; SL, standard length; a, intercept; b, slope; CL, confidence limit; r², co-efficient of determination; GT, growth type (I, isometric; -A, negative allometric)

Table 3– The estimated parameters of the length-length relationships ($Y = a + b \times X$) of the *Polynemus paradiseus* (Linnaeus, 1758) in the Tetulia River, southern Bangladesh

Equation	Sex	n	Regression parameters		95% CL of a	95% CL of b	r ²
			a	b			
Pre-monsoon	C	250					
TL = a + b × SL			1.700	1.228	1.566-1.834	1.216-1.242	0.993
TL = a + b × FL			0.442	1.222	0.271-0.612	1.208-1.238	0.990
Monsoon	C	350					
TL = a + b × SL			1.092	1.294	0.998-1.185	1.284-1.303	0.996
TL = a + b × FL			1.268	1.132	1.177-1.356	1.124-1.140	0.996
Post-monsoon	C	300					
TL = a + b × SL			2.690	1.128	1.620-2.760	1.122-1.134	0.998
TL = a + b × FL			1.990	1.092	1.898-2.082	1.085-1.099	0.997

n, sample size; C, combined sex; TL, total length; FL, fork length; SL, standard length; a, intercept; b, slope; CL, confidence limit; r², coefficient of determination

Table 4– Condition factors of the *Polynemus paradiseus* (Linnaeus, 1758) in the Tetulia River, southern Bangladesh

Condition factors	Sex	n	Min	Max	Mean ± SD	CL _{95%}
Pre-monsoon	C	250				
K _A			0.006	0.007	0.006±0.0002	0.0061-0.0062
K _F			0.600	0.722	0.668±0.026	0.665-0.671
K _R			0.907	1.102	1.007±0.038	1.002-1.011
W _R			90.91	110.23	100.65±3.83	100.17-101.12
Monsoon	C	350				
K _A			0.011	0.017	0.013±0.001	0.012-0.013
K _F			0.573	0.990	0.643±0.056	0.637-0.648
K _R			0.867	1.314	1.004±0.054	0.998-1.010
W _R			86.70	131.44	100.40±5.39	99.83-100.96
Post-monsoon	C	300				
K _A			0.005	0.007	0.006±0.001	0.005-0.006
K _F			0.576	0.768	0.640±0.032	0.637-0.644
K _R			0.907	1.221	1.004±0.050	0.998-1.010
W _R			90.71	122.08	100.40±4.97	99.83-100.96

n, sample size; C, combined sex; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit; K_A, allometric condition factor; K_F, fulton’s condition factor; K_R, relative condition factor; W_R, relative weight

Table 5– Relationships of condition factors with total length (TL, cm) of *Polynemus paradiseus* (Linnaeus, 1758) in the Tetulia River, southern Bangladesh

Correlation	r _s - values	95% CL of r _s	P- values	Level of significance
Pre-monsoon				
TL vs. K _A	0.0207	-0.1074 to 0.1480	P=0.745	ns
TL vs. K _F	0.1563	0.0291 to 0.2784	P=0.013	*
TL vs. K _R	0.0216	-0.1064 to 0.1489	P=0.734	ns
TL vs. W _R	0.0215	0.1065 to 0.1488	P=0.735	ns
Monsoon				
TL vs. K _A	0.3730	0.2762 to 0.4623	P<0.001	***
TL vs. K _F	-0.5516	-0.6225 to -0.4717	P<0.001	***
TL vs. K _R	0.3729	0.2761 to 0.4622	P<0.001	***
TL vs. W _R	0.3729	0.2761 to 0.4622	P<0.001	***
Post-monsoon				
TL vs. K _A	0.1768	0.0614 to 0.2874	P=0.002	**
TL vs. K _F	0.2972	0.1871 to 0.4000	P<0.001	****
TL vs. K _R	0.1764	0.0611 to 0.2871	P=0.002	**
TL vs. W _R	0.1766	0.0612 to 0.2872	P=0.002	**

TL, total length; 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 coefficient; CL, confidence limit; ns, not significant; *, significant; **, highly significant; ***, extremely significant, and P, shows the level of significance

Discussion

Information on seasonal variations of length-weight and length-length relationships, condition factors, form factor, and size at sexual maturity for *P. paradiseus* is quite deficient from Bangladesh or any other country of the world except a recent study²⁶. Nevertheless, a number of studies on different species have been conducted in Asian countries^{10,41,42,43,44,45}. In this study a total of 900 individuals were sampled and it was not possible to catch *P. paradiseus* smaller than 7.30 cm in TL and 3.80 g in BW, which can be attributed due to absence of smaller size individuals (<7.30 cm and <3.80 g) or selectivity of fishing gear or fishermen did not go where smaller size exist²⁹. The larger size individual was found 21.70 cm in TL and 69.60 g in BW, which is approximate with a study⁴⁶, where maximum size was 22.50 cm in TL and 61.65 g in BW. It is reported that the information on maximum length is necessary to estimate the population parameters including asymptotic length and growth coefficient of fishes, which is important for fisheries resource planning and management^{31,12}. From the LFDs, it was found that minimum sized population exists in monsoon period and maximum sized population exists in the post-monsoon period in the Tetulia River.

The *b* values ranging from 2.5 to 3.5 are more common^{47,34}. In our study *b* value is close to 3 indicating isometric growth in pre-monsoon and post-monsoon, but in monsoon period negative allometric (*b*<3) growth was estimated for *P. paradiseus* in the Tetulia river. Recently a study found positive allometric growth (*b*=3.389 for male and *b*=3.512 for female) for *P. paradiseus*⁴⁶, which is not accordance with our findings. Such differences in growth pattern for the same species may be recognized due to influence of several factors including sex, maturity, seasonal effect, food and feeding habit, habitat area, preservation techniques and differences in observed length^{48,49}, all these factors were not considered during this study except seasonal changes.

Although most of the studies deals with a single condition factor and we have worked on four condition factors (*K_A*; *K_F*; *K_R* and *W_R*) to assess the health and habitat condition of *P. paradiseus* in the Tetulia River. This study also revealed that the Fulton's condition factor is the best for assessing the wellbeing of this *P. paradiseus* in the Tetulia River and surrounding ecosystem through-out the year.

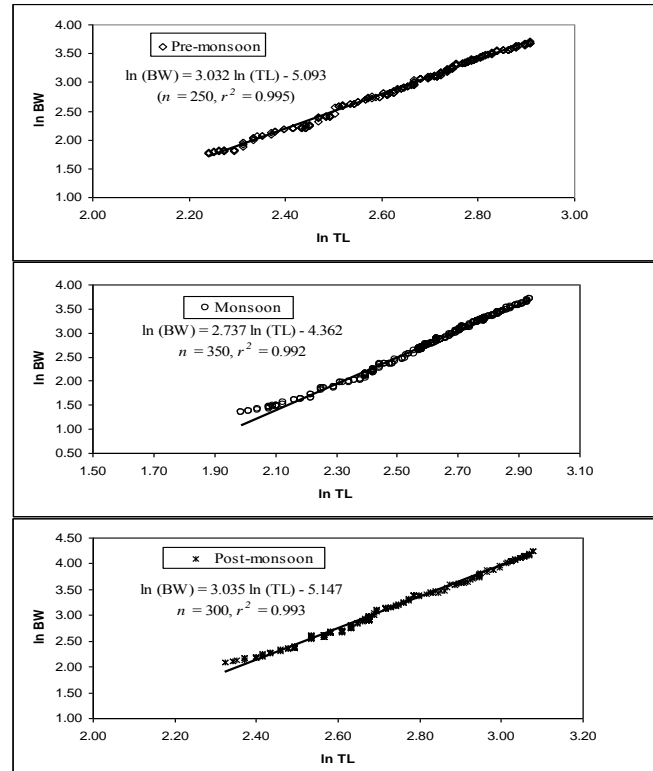


Fig. 2– Length-weight relationships ($\ln W = \ln a + b \ln L$) of *Polynemus paradiseus* (Linnaeus, 1758) in the Tetulia River, southern Bangladesh

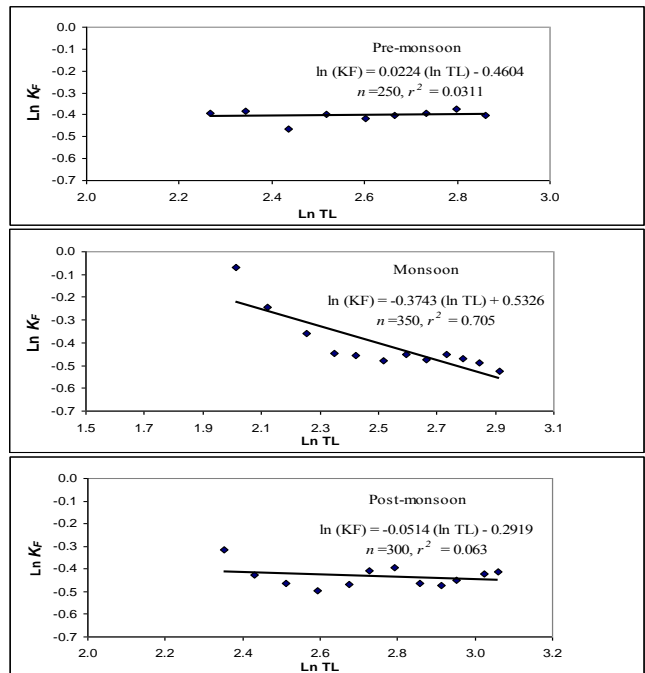


Fig. 3– Relationship between Fulton's condition factor (*K_F*) and total length (TL) of *Polynemus paradiseus* (Linnaeus, 1758) in the Tetulia River, southern Bangladesh

The K_F of monsoon was different from pre- and post-monsoon, and it might be due to the gonadal development. However, there is no previous published data on K_F , thus prohibited us to compare the current results. This study presents the first attempt to determine the size at first sexual maturity (~12.10 cm in TL) for *P. paradiseus* from the Tetulia River. The value of K_F decreases with increasing the TL. When *P. paradiseus* attains around 12 cm TL (~11.90 cm TL), then mean value of K_F was dropped down in monsoon (Figure 3), indicating that K_F might be highly allied with size at first sexual maturity.

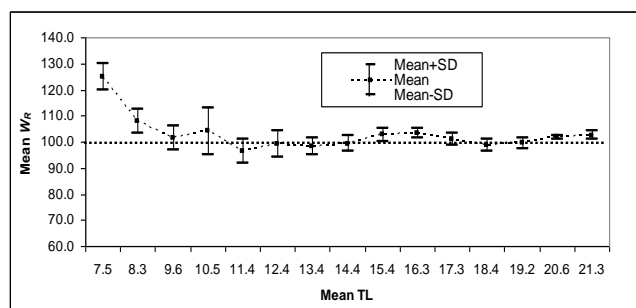


Fig. 4— Relationships between total length (TL) and relative weight (W_R) of *Polynemus paradiseus* (Linnaeus, 1758) in the Tetulia River, southern Bangladesh

Furthermore, the mean W_R was significantly different from 100 in pre-monsoon in our study which indicates the habitat was not suitable with the presence of low prey-high predator or high prey-low predator. The values of W_R falling below 100 for an individual or population recommend problems such as low prey accessibility or high predator density; whereas values above 100 indicates a prey surplus or low predator density²⁴. No available literature or references dealing with the condition factors for *P. paradiseus* prevents the comparison with our findings.

The calculated form factor ($a_{3,0}$) was 0.0061 for *P. paradiseus* in the Tetulia River. Also using the LWRs parameter we have calculated the $a_{3,0}$ as 0.0070 in the Tetulia River and 0.0039 from the Chittagong and Cox's bazar coastal region from the published data^{26, 33}. The $a_{3,0}$ can be used to verify whether the body shape of individuals in a given population or species is significantly different from others³⁴.

Conclusion

The findings of the present study would be very crucial for sustainable fishery of *P. paradiseus* in the Tetulia River and adjoining ecosystems.

Acknowledgement

Authors would like to extend their sincere appreciation to the Deanship of Scientific Research at King Saud University for its funding this Research group NO (RG-1436-025).

References

- Riede, K., *Global register of migratory species - from global to regional scales*. Final Report of the R & D-Projekt 808 05 081, Federal Agency for Nature Conservation, Bonn, Germany, (2004) pp. 329.
- Rahman, A. K. A., *Freshwater fishes of Bangladesh*. Zoological Society of Bangladesh, Department of Zoology, University of Dhaka, (1989) pp. 364.
- Ahmed, M., *A model to determine benefits obtainable from the management of Riverine fisheries of Bangladesh*. ICLARM Technical Report, 28 (1991) pp. 133.
- Talwar, P. K. and Kacker, R. K., *Commercial sea fishes of India*, *Zool. Surv. Ind.*, (1984), pp. 997.
- Talwar, P. K. and Jhingran, A. G., *Inland fishes of India and adjacent countries, Volume 2*. A.A. Balkema, Rotterdam, (1991) pp. 541.
- Department of Fisheries Malaysia., *Valid local name of Malaysian marine fishes*. Department of Fisheries Malaysia, Ministry of Agriculture and Agro-based Industry, (2009) pp. 180.
- Ganaden, S. R. and Gonzales, F. L., *Common and local names of marine fishes of the Philippines*, Bureau of Fisheries and Aquatic Resources, Philippines, (1999) pp. 385.
- FAO-FIES., *Aquatic Sciences and Fisheries Information System (ASFIS) species list*, Retrieved from <http://www.fao.org/fishery/collection/asfis/en>, April, (2014).
- Froese, R. and Pauly, D. (Eds.), *Fishbase 2015*. World Wide Web electronic publication, Available at: <http://www.fishbase.org> (Accessed on 20 February 2015).
- Menon, A. G. K. and Rao, M. B., *Polynemidae*. In Fischer, W. and Bianchi, G. (eds.), *FAO species identification sheets for fishery purposes, Western Indian Ocean (Fishing Area 51)*. Vol. 3. *FAO, Rome. pag. var.*, (1984).
- Hossain, M. Y., Hossen, M. A., Ahmed, Z. F., Yahya, K., Rahman, M. M., Ahmed, F. and Ohtomi, J., *Threatened Fishes of the World: Botia dario* (Hamilton, 1822) (Cypriniformes: Cobitidae). *Croatian J. Fish.*, 73 (2015a): 86-88.
- Hossen, M. A., Hossain, M. Y., Yahya, K. and Pramanik, M. N. U., *Threatened Fishes of the World: Labeo bata* (Hamilton, 1822) (Cypriniformes: Cyprinidae). *Croatian J. Fish.*, 73 (2015): 89-91.
- Neumann, R. M. and Allen, M. S., *Analysis and Interpretation of Freshwater Fisheries Data*. Department of Natural Resources Management and Engineering, University of Connecticut, (2001).
- Ranjan, J. B., Herwig, W., Subodh, S. and Michael, S., *Study of the length frequency distribution of sucker head, Garra gotyla gotyla* (Gray, 1830) in different rivers and seasons in Nepal and its applications, *Kathmandu Univ. J. Sci. Eng. Technol.*, 1(2005): 1-14.
- Anderson, R. and Gutreuter, S., *Length, weight and associated structural indices*. In: *Fisheries Techniques*. L. Nielsen, D. Johnson (eds). *Am. Fish. Soc.*, Bethesda, MD, (1983): 283-300.

- 16 Safran, P., Theoretical analysis of the weight-length relationships in fish juveniles. *Mar. Biol.*, 112 (1992): 545-551.
- 17 Richter, H. C., Luckstadt, C., Focker, U. and Becker, K., An improve to access fish condition on the basis of length weight relationship. *Arch. Fish. Mar. Res.*, 48 (2000): 255-264.
- 18 Petrakis, G. and Stergiou, K. I., Weight-length relationships for 33 fish species in Greek waters, *Fish Res.*, 21 (1995): 465-469.
- 19 Moutopoulos, D. K. and Stergiou, K. I., Length-weight and length-length relationships of fish species from the Aegean Sea (Greece), *J. Appl. Ichthyol.*, 18 (2002): 200-203.
- 20 Hossain, M. Y., Ahmed, Z. F., Leunda, P. M., Islam, A. K. M. R., Jasmine, S., Oscoz, J., Miranda, R. and Ohtomi, J., Length-weight and length-length relationships of some small indigenous fish species from the Mathabhanga River, southwestern Bangladesh. *J. Appl. Ichthyol.*, 22 (2006a): 301-303.
- 21 Hossain, M. Y., Arefin, M. S., Mohmud, M. S., Hossain, M. I., Jewel, M. A. S., Rahman, M. M., Ahamed, F., Ahmed Z. F. and Ohtomi J., Length-weight relationships, condition factor, gonadosomatic index-based size at first sexual maturity, spawning season and fecundity of *Aspidoparia morar* (Cyprinidae) in the Jamuna River (Brahmaputra River distributary), northern Bangladesh. *J. Appl. Ichthyol.*, 29 (2013a): 1166-1169.
- 22 Lavergne, E., Zajonz, U. and Sellin, L., Length-weight relationship and seasonal effects of the Summer Monsoon on condition factor of *Terapon jarbua* (Forsska, 1775) from the wider Gulf of Aden including Socotra Island. *J. Appl. Ichthyol.*, (2012): 1-4.
- 23 Swingle, W. E. and Shell, E. W., Tables for computing relative conditions of some common freshwater fishes. Alabama Agricultural Experiment Station, Auburn University, Circular 183 (1971).
- 24 Rypel, A. L. and Richter, T. J., Empirical percentile standard weight equation for the Blacktail Redhorse, *N. Am. J. Fish. Manage.*, 28 (2008): 1843-1846.
- 25 Rose, C. J., *Relationship between relative weight (Wr) and body composition in immature walleye*. M. S. Thesis, Texas A&M University, College Station, (1989).
- 26 Nabi, M. R., Hoque, M. A., Rahman, R. A., Mustafa, S. and Kader, M. A., Population Dynamics of *Polynemus paradiseus* from Estuarine Set Bag Net Fishery of Bangladesh. *Chiang Mai. J. Sci.*, 34 (2007): 355-365.
- 27 Hossain, M. Y., Ahmed, Z. F., Leunda, P. M., Jasmine, S., Oscoz, J., Miranda, R. and Ohtomi, J., Condition, length-weight and length-length relationships of the Asian striped catfish *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhanga River, southwestern Bangladesh. *J. Appl. Ichthyol.*, 22 (2006b): 304-307.
- 28 Hossain, M. Y., Leunda, P. M., Ohtomi, J., Ahmed, Z. F., Oscoz, J. and Miranda, R., Biological aspects of the Ganges River sprat *Corica soborna* (Clupeidae) in the Mathabhanga River (SW Bangladesh). *Cybium*, 32 (2008): 241-246.
- 29 Hossain, M. Y., Ohtomi, J. and Ahmed Z. F., Morphometric, meristic characteristics and conservation of the threatened fish, *Puntius sarana* (Hamilton 1822) (Cyprinidae) in the Ganges River, northwestern Bangladesh. *Turk. J. Fish. Aquat. Sc.*, 9 (2009): 223-225.
- 30 Hossain, M. Y., Length-weight, length-length relationships and condition factor of three Schibid catfishes from the Padma River, Northwestern Bangladesh. *Asian Fish. Sci.*, 23 (2010): 329-339.
- 31 Hossain, M. Y., Rahman, M. M., Fulanda, B., Jewel, M. A. S., Ahamed, F. and Ohtomi, J., Length-weight and length-length relationships of five threatened fish species from the Jamuna (Brahmaputra River tributary) River, northern Bangladesh. *J. Appl. Ichthyol.*, 28 (2012a): 275-277.
- 32 Hossain, M. Y., Rahman, M. M., Jewel, M. A. S., Ahmed, Z. F., Ahmed, F., Fulanda, B., Abdallah, E. M. and Ohtomi, J., Conditions- and form-factor of the five threatened fishes from the Jamuna (Brahmaputra River distributary) River, Northern Bangladesh. *Sains Malays.*, 41 (2012b): 671-678.
- 33 Hossain, M. Y., Sayed, S. R. M., Rahman, M. M., Ali, M. M., Hossen, M. A., Elgorban, A. M., Ahmed, Z. F. and Ohtomi, J., Length-weight relationships of the nine fishes from the Tetulia River, southern Bangladesh. *J. Appl. Ichthyol.*, 31(2015b): 967-969.
- 34 Froese, R., Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. *J. Appl. Ichthyol.*, 22 (2006): 241-253.
- 35 Sokal, R. R. and Rohlf, F. J., *Introduction to Biostatistics*. 2nd ed. New York: Freeman Publication, (1987).
- 36 Tesch, F. W., *Age and growth*. In: *Methods for assessment of fish production in fresh waters*. W. E. Ricker (Ed.). Blackwell Scientific Publications, Oxford, (1968): 93-123.
- 37 Fulton, T. W., *The rate of growth of fishes*. Twenty-second Annual Report, Part III. Fisheries Board of Scotland, Edinburgh, (1904): 141-241.
- 38 Le Cren, E. D., The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *J. Anim. Ecol.*, 20 (1951): 201-219.
- 39 Binohlan, C. and Froese, R., Empirical equations for estimating maximum length from length at first maturity. *J. Appl. Ichthyol.*, 25 (2009): 611-613.
- 40 Anderson, R. O. and Neumann, R. M., *Length, weight and associated structure indices*. In: *Fisheries techniques*, 2nd ed. Murphy B. R. and Willis, W. D. (Eds.), American Fisheries Society, Bethesda, MD, (1996): 447-482.
- 41 Hossain, M. Y., Khatun, M. M., Jasmine, S., Rahman, M. M., Jahan, S., Jewel, M. A. S. and Ohtomi, J., Life-history Traits of the Threatened Freshwater Fish *Cirrhinus reba* (Hamilton 1822) (Cypriniformes: Cyprinidae) in the Ganges River, Northwestern Bangladesh. *Sains Malays.*, 42 (2013b): 1219-1229.
- 42 Hossain, M. Y., Jewel, M. A. S., Rahman, M. M., Haque, A. B. M. M., Elbaghdady, H. M. and Ohtomi, J., Life-history Traits of the Freshwater Garfish *Xenentodon cancila* (Hamilton 1822) (Belontiidae) in the Ganges River, Northwestern Bangladesh. *Sains Malays.*, 42 (2013c): 1207-1218.
- 43 Hossain, M. Y., Islam, R., Hossen, M. A., Rahman, O., Hossain, M. A., Islam, M. A. and Alam, M. J., Threatened Fishes of the World: *Mystus gulio* (Hamilton, 1822) (Siluriformes: Bagridae). *Croatian J. Fish.*, 73 (2015c): 43-45.
- 44 Hossain, M. Y., Hossain, M. A., Islam, R., Hossen, M. A., Rahman, O. and Rahman, M. M., Threatened Fishes of the World: *Pethia ticto* (Hamilton, 1822) (Cypriniformes: Cyprinidae). *Croatian J. Fish.*, 73 (2015d): 37-39.
- 45 Sani, R., Gupta, B. K., Sarkar, U. K., Pandey, A., Dubey, V. K. and Lakra, W. S., Length-weight relationships of 14 Indian freshwater fish species from the Betwa (Yamuna River tributary) and Gomti (Ganga River tributary) rivers. *J. Appl. Ichthyol.*, 26 (2010): 456-459.
- 46 Nabi, M. R., Kader, M. A. and Hakim, M. A., Length-weight relationship and condition factor in the fish *Polynemus*

- paradiseus* from the Bay of Bengal. *The Chittagong Univ. J. Sci.*, 23 (1999): 87- 91.
- 47 Carlander, K. D., *Handbook of Freshwater Fishery Biology* vol.1. Ames, IA: The Iowa State University Press, (1969).
- 48 Beginal T. B., *Methods for Assessment for Fish Production in Freshwater (3rd edition)*, Blackwell Scientific Publication, London, Md, (1978).
- 49 Hossain, M. Y., Rahman, M. M., Miranda, R., Leunda, P. M., Oscoz, J., Jewel, M. A. S., Naif, A. and Ohtomi, J., Size at first sexual maturity, fecundity, length–weight and length–length relationships of *Puntius sophore* (Cyprinidae) in Bangladeshi waters. *J. Appl. Ichthyol.*, 28 (2012c): 818-822.