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Relationships between Body Size, Weight, Condition and Fecundity of the Threatened Fish *Puntius ticto* (Hamilton, 1822) in the Ganges River, Northwestern Bangladesh

(Hubungan antara Saiz Badan, Berat, Keadaan dan Tahap Kesuburan Spesies Ikan Terancam *Puntius Ticto* (Hamilton, 1822) di Sungai Gangga, Barat Laut Bangladesh)

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ABSTRACT

The ticto barb Puntius ticto *(Hamilton 1822) is a small, indigenous fish species of Bangladesh that is widely distributed in the natural waters of Asian countries. This study describes the relationships between body size, weight, condition (Fulton's, K_F; allometric, K_A, K_R; and relative weight, W_R) and fecundity of the threatened species* P. ticto *from the Ganges River, northwestern Bangladesh. A total of 24 mature female specimens were collected by the traditional fishing gears from March to August 2006. For each individual, total (TL), fork (FL), standard length (SL), and ovary length (OL) were measured by digital slide calipers, while body (BW) and ovary weight (OW) were taken by a digital balance. Total fecundity (F_T) of each female was calculated as the number of eggs found in each ovary, whereas relative fecundity (F_R) was the number of eggs per gram of fish weight. The results showed that TL of* P. ticto *varied from 9.10 to 10.80 cm, with calculated mean ± SD as 9.77±0.57 cm. Body weights extended from 14.00 to 24.00 g, with calculated mean ± SD as 17.83±3.39 g. The mean F_T was 2586±700 and ranged from 1611 to 4130. BW was more significantly correlated with total fecundity (r^2>0.633; p<0.001) than various other body metrics. The results also indicated significant correlation between length-weight (df=22, t-test≥8.86, p<0.001); F_T-K_F (r_s=0.473; p=0.019), F_T-K_A (r_s=0.502; p=0.012), and F_T-W_R (r_s=0.483; p=0.016), but insignificant correlations were found between F_T-GSI (r_s=0.309; p=0.141) and F_R-with various other body metrics. The knowledge of fecundity would be useful to impose adequate regulations for the conservation of this threatened species in the Ganges River and nearby areas of Bangladesh.*

Keywords: Bangladesh; fecundity; Ganges River; Puntius ticto

ABSTRAK

Puntius ticto *(Hamilton 1822) merupakan ticto berduri bersaiz kecil yang merupakan spesies ikan berasal dari Bangladesh yang banyak dijumpai di perairan semula jadi negara Asia. Kajian ini menerangkan hubungkait di antara saiz badan, berat, keadaan (Fulton, K_F; alometrik, K_A dan berat relatif, W_R) dan tahap kesuburan spesies ikan terancam* P. tincto *yang didapati di Sungai Gangga, barat laut Bangladesh. Sebanyak 24 spesimen ikan betina matang diperoleh secara penangkapan tradisional yang dilakukan di antara bulan Mac dan Ogos 2006. Pengukuran jumlah panjang (TL), cabangan (FL), panjang piawai (SL) dan panjang ovari ditentukan menggunakan kaliper gelangsar digital, manakala berat badan (BW) dan berat ovari (OW) diukur menggunakan penimbang digital. Jumlah kesuburan (FT) setiap ekor ikan betina dikira sebagai bilangan telur yang dijumpai di dalam setiap ovari, manakala kesuburan relatif (FR) adalah bersamaan dengan bilangan telur per gram berat ikan. Keputusan menunjukkan TL* P.ticto *berada di dalam julat 9.10 hingga 10.80 cm dan nilai purata ± SD adalah 9.77±0.57 cm. Julat berat badan adalah 14.00 hingga 24.00 g dengan nilai purata ± SD bersamaan 17.83±3.39 g. Purata FT adalah 2586±700 dengan julat 1611 hingga 4130. BW didapati mempunyai korelasi yang signifikan dengan jumlah kesuburan (r^2>0.633; p<0.001) berbanding metrik badan yang lain. Keputusan juga menunjukkan korelasi yang signifikan di antara panjang-berat (df=22, ujian-t≥8.86, p<0.001); F_T -K_F (r_s=0.473; p=0.019), F_T-K_A (r_s=0.502; p=0.012), dan F_T-W_R (r_s=0.483; p=0.016), tetapi hubungan di antara F_T-GSI (r_s=0.309; p=0.141) dan FR dengan metrik badan yang lain tidak menunjukkan korelasi yang signifikan. Pengetahuan tentang pembiakan adalah berguna untuk mengenakan peraturan bagi tujuan pemuliharaan spesies ikan yang terancam di Sungai Gangga dan kawasan sekitarnya di Bangladesh.*

Kata kunci: Bangladesh; kesuburan; Puntius ticto*; Sungai Gangga*

INTRODUCTION

The 'fecundity' of a fish is defined as the number of eggs that are likely to be laid during a spawning season (Bagenal 1957). The reproductive potential, i.e., fecundity is an important biological parameter that plays a significant role in evaluating the commercial potentials of fish stocks (Gómez-Márquez 2003). Successful fisheries management including practical aquaculture relies on having an accurate assessment of fecundity to understand the recovery ability of fish populations (Lagler 1956; Nikolskii 1969; Tracey et al. 2007). The fecundity and its relation to female size make it possible to estimate the potential of egg output (Chondar 1977) and the potential number of offspring in a season and reproductive capacity of fish stocks (Qasim & Qayyum 1963).

The small fish *Puntius ticto (*Hamilton 1822) (Cypriniformes: Cyprinidae) is a fresh- and brackish-water, subtropical species which is commonly known as "ticto" or "two-spot" barb. This fish is also known as *tit punti* in Bangladesh, *pothia* in India, *poti* in Nepal, and *thith pethiya* in Sri Lanka (Froese & Pauly 2011). The conservational status of this fish has been referred as vulnerable (IUCN Bangladesh 2000). It is a most popular aquarium fish among barb species in Bangladesh and other Asian countries (Froese & Pauly 2011). This fish is widely distributed through the Indian sub-continent, including Bangladesh, India, Nepal, Pakistan, Sri-Lanka, Myanmar, and Thailand (Talwar & Jhingran 1991). It also occurs in the upper Mekong, Salween, Irrawaddy, Meklong and upper Chao Phraya basins (Kottelat 2001). Ticto barb inhabits standing and running waters, usually in ponds and rivers with mostly muddy bottoms (Froese & Pauly 2011). Previously abundant in the rivers, creeks, canals, reservoirs, lakes, swampland (beels, haors, and baors) and ponds of Bangladesh (ICUN Bangladesh 2000), India, and Sri-Lanka (Froese & Pauly 2011), but the populations have seriously declined to the verge or extinction due to over exploitation and various ecological changes in its natural habitats (Mijkherjee et al. 2002).

To date there is no information on the fecundity of *P. ticto* from the Ganges River in Bangladesh, nevertheless a number of studies have been conducted on this minnow, including conservational status in Bangladesh (IUCN Bangladesh 2000); population traits in Maharashtra, Cauvery, Godavari, and Krishna rivers, India (Archarya & Iftekhar 2000; Chandrashekhariah et al. 2000); growth parameters in Dikshi beel of Pabna and Shapla beel of B. Baria District (Mustafa & de Graaf 2008), and length-weight and length-length relationships using combined sexes in the Padma River, Bangladesh (Hossain et al. 2009a; Hossain 2010a). The present study enhances our knowledge on the relationships between body size, weight, condition, and fecundity of female *P. ticto* from the lower Ganges River of northwestern Bangladesh.

Materials and Methods

Sampling site

The lower Ganges (known as the Padma River in Bangladesh) entered Bangladesh from India through the Rajshahi district (24° 22' N; 88° 35' E). A large number of fish species, including some commercially important species, are fished by both small- and large scale fishermen throughout the year (Hossain et al. 2009b).

Sampling and laboratory analysis

The samples for *P. ticto* were collected during daytime from the fishermen's catch landed at Rajshahi city ((Jhaj ghat, Binodpur), Rajshahi, Bangladesh from March to August 2006. The fish was caught by means of the traditional fishing gears *jhaki jal* (cast net), *tar jal* (square lift net), and *dughair* (conical trap) (Kibria & Ahmed 2005). The samples were immediately preserved with ice and fixed with 5% formalin solution upon arrival in the laboratory. All specimens were sexed by gonad observation under a binocular microscope to identify the mature females for this study.

For each individual, morphometrics were assessed. Total length (TL), fork length (FL), and standard lengths (SL) were measured to the nearest 0.01 cm using digital slide calipers (Mitutoyo, CD-15PS). Whole body weight (BW) was taken on a digital balance (Shimadzu, EB-430DW) with 0.01 g accuracy. The whole ovary was removed from each female fish. Each ovary length (OL) and weight (OW) was measured to the nearest 0.01 cm and to the nearest 0.001 g, respectively. The gonadosomatic index (GSI) was estimated by the equation, GSI (%) = (OW/BW) × 100.

Estimation of fecundity

For the estimation of fecundity, the ovaries of mature females were weighed; three sub-samples were taken from the front, mid-and-rear-sections of each ovary and weighed. Then the total number of eggs in each ovary sub sample was proportionally estimated using the equation, F_1 = (gonad weight x number of eggs in the sub-sample) / sub-sample weight (Yelden & Avsar 2000). Later, by taking the mean number of three sub-sample fecundities (F_1, F_2, F_3), the total (absolute) fecundity for each female fish was estimated $F_T = (F_1 + F_2 + F_3) /3$. In addition, individual fecundity was divided by the weight of the fish to estimate relative fecundity (F_R) in two ways: number of eggs per gram body weight and per cm of the body length measurements.

The relationship between fecundity and female size was determined in two ways. The first was by relating total fecundity (F_T) or relative fecundity (F_R) data to TL, FL, SL, and OL using an allometric model: F_T or $F_R = m \times SL^n$ that is equivalaent to $ln\ F_T$ or $ln\ F_R = ln\ m + n \times ln\ L$ using simple-linear regression analyses based on natural-logarithmic transformations. The second was by relating F_T or F_R to BW, OW, and BW-OW using linear-regression analyses, F_T or $F_R = m + n \times W$ that is equivalaent to $ln\ F_T$ or $F_R = ln\ m + n \times ln\ W$. According to Somers (1991), an isometric relation is found by values for n that are near 3. Thus, n value of <2.90 and >3.10 were taken as indication of a negative and positive allometric relation, respectively (Somerton 1980). The coefficients of determination (r^2) for all of these regression equations were also calculated to describe the proportion of the variation accounted for the independent variable (King 1995). Even if the r^2 indicates a relationship between variables, the correlation may not be significant if sample size is small ($n < 30$). In this case, a one-tailed t-test, $t = r\sqrt{(n-2)}/(\sqrt{(1-r^2)})$ for independent means might be applied to express correlation between two variables.

Estimation of length-weight relationships

The length-weight relationship (LWR) was calculated using the expression: $W= aL^b$, where the W is the BW or gonad free body weight (BW-GW) in g and L is the TL, FL, or SL in cm. Parameters a and b were estimated by linear regression analysis based on natural logarithms: $ln(W) = ln(a) + b\ ln(L)$. Additionally, 95% confidence limits of b and the coefficient of determination r^2 were estimated. To confirm whether b values obtained in the linear regressions were significantly different ($\alpha = 0.05$) from the isometric value of 3.0, this equation according to Sokal & Rohlf (1981) was applied: $t_s = (b-3) / s_b$, where t_s is the two-tailed t-test value, b the slope, and s_b the standard error of the slope (b). The comparison between t_s and the respective critical table values allowed me to determine whether b values were in the isometric (b=3) or allometric range (negative allometric as b<3 or positive allometric as b>3) (Tesch 1971; Somers 1991).

Estimation of condition factors

Fulton's condition factor (K_F) and allometric condition factor (K_A) were calculated using the equations given by Htun-Han (1978) as $K_F = 100\times(W/L^3)$, and Ricker (1975) as $K_A = W/L^b$, respectively, where W is the body weight (BW) in g; L is the total length (TL) in cm, b is the parameters of the TL-BW relationship. According to Froese (2006), the factor 100 is used to bring K_F close to unity. In addition, relative weight (W_R) was calculated by the equation given by Rypel and Richter (2008) as $W_R = (W / W_S) \times 100$, where W is the weight of a particular individual and W_S is the predicted standard weight for the same individual as calculated by $W_S = a\ L^b$ (a and b values obtained from the relationships between TL and BW).

Statistical analyses

Statistical analyses were performed using Microsoft® Excel-add-in-DDXL, GraphPad Prism 5 and VassarStats softwares. All data were checked for homogeneity of variance. Tests for normality of each group were (1) conducted by visual assessment of histograms and box plots and (2) confirmed with the Kolmogorov-Smirnov test and Shapiro-Wilk test. Where test for normality assumption was not met, then the non-parametric Wilcoxon signed rank test was used to compare the mean relative weight of this population with 100 (Anderson & Neumann, 1996), whereas Spearman rank test was used to check fecundity and condition-factors correlations. The LWRs between TL vs. BW and TL vs. BW-OW were compared by ANCOVA (analysis of covariance). All statistical analyses were considered significant at 5% (p<0.05).

Results

A total number of 24 mature female specimens were randomly selected for the estimation of fecundity during March to June 2006. Descriptive statistics on the length, weight, condition, GSI, and fecundity measurements are given in Table 1. The minimum and maximum observed TLs of all individuals captured was 9.10 and 10.80 cm, respectively, from the Padma River. The mean value of F_T was 2586±700 and ranged from 1611 to 4130. The ovary from the smallest mature female weighted 3.50 g and its F_T was 1611 eggs. The highest F_T was 4130 eggs with a TL and total weight 10.60 cm vs. 23.00 g, respectively. The F_R of the individuals ranged from 107 to 192 eggs per gram of female, with a mean of 144±24 eggs. The individual with 9.30 cm TL has the highest F_R values.

Relationships between length and total fecundity (F_T)

The relationships between F_T and lengths for *P. ticto* are shown in Figure 1 and Table 2. These positive correlations were expressed by the following regression equations:

(1) $ln\ F_T = 3.262\ ln\ TL + 0.327$ (n = 24; r^2=0.484; p<0.001);
(2) $ln\ F_T = 3.606\ ln\ FL - 0.130$ (n = 24; r^2=0.576; p<0.001);
(3) $ln\ F_T = 3.448\ ln\ SL + 0.697$ (n = 24; r^2=0.548; p<0.001); and
(4) $ln\ F_T = 2.353\ ln\ OL + 4.696$ (n = 24; r^2=0.434; p<0.001)

Analysis of regression showed that there was a significant relationship between the F_T and different parameters length. The number of eggs per female increased with increasing length, as example.

Relationships between weight and total fecundity (F_T)

The relationships between F_T and weights of female *P. ticto* in the Ganges River are shown in Figure 2 and Table 2. The estimated linear equations are as follows:

(4) $ln\ F_T = 1.153\ ln\ BW + 4.520$ (n = 24; r^2=0.633; p<0.001);
(5) $ln\ F_T = 0.918\ ln\ OW + 6.514$ (n = 24; r^2=0.616; p<0.001); and
(6) $ln\ F_T= 1.074\ ln\ (BW-OW) + 5.041$ (n = 24; r^2=0.548; p<0.001);

Analysis of regression showed that there was a significant relationship between the F_T and different weights. The results indicated that the number of eggs per female increased with increasing weight.

TABLE 1. Descriptive statistics on the length (cm), weight (g), condition factor, and fecundity measurements of *Puntius ticto* (Hamilton, 1822) in the Ganges River during March to August 2006

Measurements	Sample size	Minimum	Maximum	Mean ± SD	95% CL
Length					
TL	24	9.10	10.80	9.77 ± 0.57	9.73 – 10.21
FL	24	8.30	9.90	9.09 ± 0.52	8.87 – 9.31
SL	24	7.25	8.60	7.91 ± 0.46	7.72 – 8.10
OL	24	3.40	4.40	3.79 ± 0.29	3.67 – 3.91
Weight					
BW	24	14.00	24.00	17.83 ± 3.39	16.40 – 19.26
OW	24	3.10	6.50	4.27 ± 1.04	3.83 – 4.71
Condition factor					
K_F	24	1.55	2.17	1.78 ± 0.14	1.72 – 1.84
K_A	24	0.017	0.023	0.020 ± 0.01	0.019 – 0.021
W_R	24	87.54	121.82	100.10 ± 7.71	96.85 – 103.35
GSI	24	17.50	29.50	23.88 ± 2.85	21.04 – 103.35
Fecundity					
F_T	24	1611	4130	2586 ± 700	2290 - 2882
F_R	24	107	192	144 ± 24	134 - 154

TL, total length; FL, fork length; SL, standard length; OL, ovary length; BW, body weight; OW, ovary weight; K_F, Fulton's condition factor; K_A, allometric condition factor; W_R, relative weight; *GSI*, gonadosomatic index; F_T, total fecundity; F_R, relative fecundity; SD, standard deviation; CL, confidence limit of mean

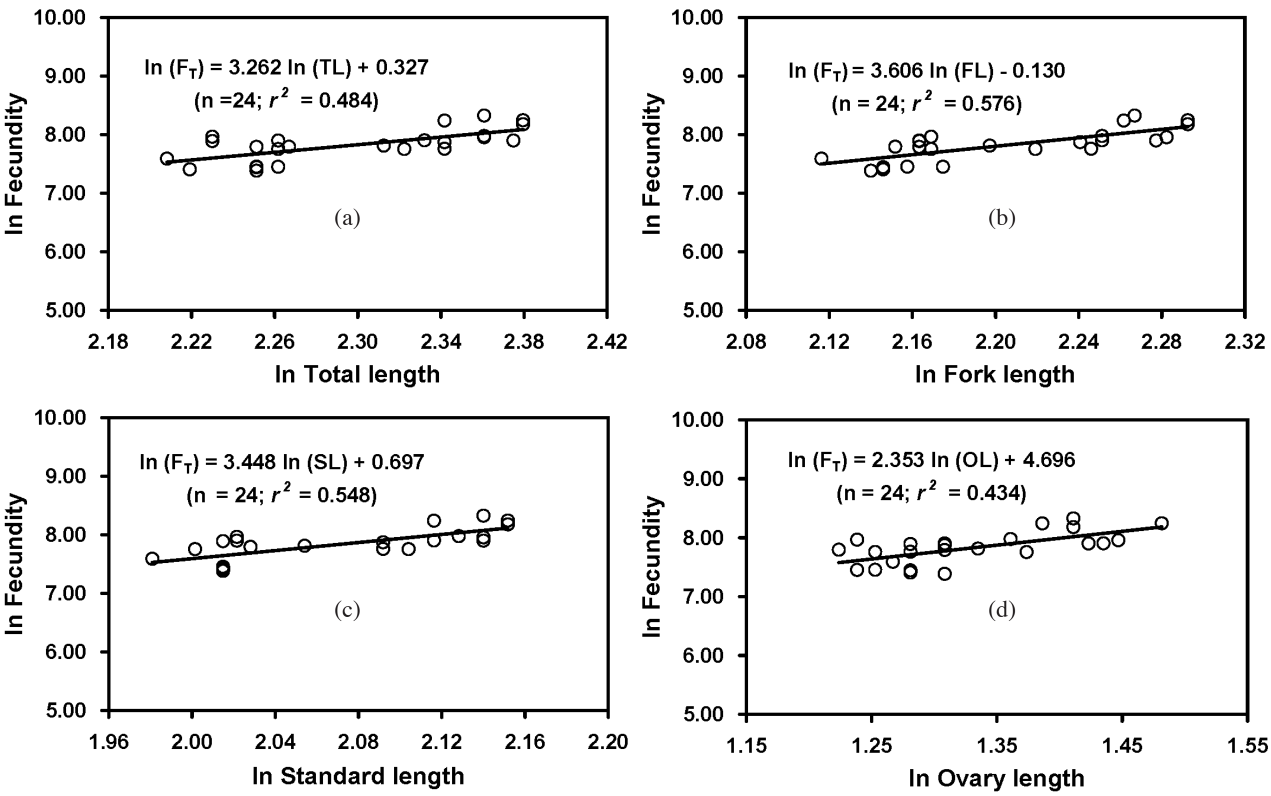

FIGURE 1. Relationships between length and total fecundity (a) ln (F_T) vs. ln (TL), (b) ln (F_T) vs. ln (FL), (c) ln (F_T) vs. ln (SL), and (d) ln (F_T) vs. In (OL) of *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh

TABLE 2. Descriptive statistics and estimated parameters of the fecundity-length and fecundity-weight relationships (sample size = 24) of female ticto barb *Puntius ticto* (Hamilton, 1822) from the Ganges River (*, significant; ns, not significant at 5%)

Equation	Regression parameters		95% CL of *m*	95% CL of *n*	r^2	*p*
	m	*n*				
Total fecundity-length						
$F_T = m \times TL^n$	1.386	3.262	0.045 to 42.564	1.772 to 4.751	0.484 *	< 0.001
$F_T = m \times FL^n$	0.878	3.606	0.043 to 17.975	2.237 to 4.940	0.576 *	< 0.001
$F_T = m \times SL^n$	0.008	3.448	0.114 to 35.269	2.062 – 4.834	0.548 *	< 0.001
$F_T = m \times OL^n$	109.508	2.353	22.556 to 531.658	1.166 – 3.540	0.434 *	< 0.001
Relative fecundity-length						
$F_R = m \times TL^n$	70.527	0.306	3.819 to 1301.145	-0.962 to 1.574	0.011 ^{ns}	0.621
$F_R = m \times FL^n$	48.183	0.491	2.898 to 801.114	-0.783 to 1.765	0.028 ^{ns}	0.432
$F_R = m \times SL^n$	57.628	0.438	4.327 to 768.162	-0.815 to 1.690	0.023 ^{ns}	0.476
$F_R = m \times OL^n$	101.393	0.256	28.395 to 366.134	-0.709 to 1.220	0.013 ^{ns}	0.588
Total fecundity-weight						
$F_T = a + b \times BW$	91.836	1.153	30.114 to 280.059	0.765 to 1.542	0.633 *	< 0.001
$F_T = a + b \times OW$	174.519	0.918	424.962 to 1071.698	0.598 to 1.239	0.616 *	< 0.001
$F_T = a + b \times (BW\text{-}OW)$	154.625	1.074	50.457 to 474.376	0.642 to 1.505	0.548 *	< 0.001
Relative fecundity-weight						
$F_R = a + b \times BW$	91.836	0.153	30.114 to 280.059	-0.235 to 0.542	0.029 ^{ns}	0.422
$F_R = a + b \times OW$	102.617	0.230	66.420 to 158.539	0.071 to 0.532	0.010 ^{ns}	0.127
$F_R = a + b \times (BW\text{-}OW)$	111.832	0.093	40.366 to 310.137	-0.299 to 0.486	0.011 ^{ns}	0.627

F_T, total fecundity; F_R, relative fecundity; TL, total length; TL, total length; FL, fork length; SL, standard length; OL, ovary length; BW, body weight; OW, ovary weight; m, intercept; *n*, slope ; CL, confidence limit; r^2, coefficient of determination; *P*, probability value

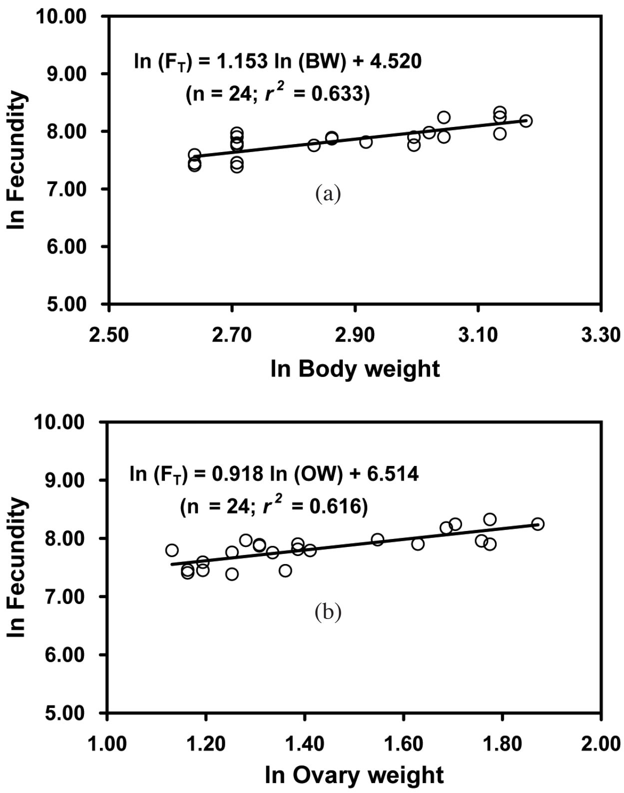

FIGURE 2. Relationships between weight and fecundity (a) ln F_T vs. ln BW and (b) ln F_T vs. ln OW of *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh

RELATIONSHIPS OF LENGTH OR WEIGHT WITH RELATIVE FECUNDITY (F_R)

The relationships of length or weight with F_R are shown in Table 2. These correlations were expressed by the following linear regression equations:

(7) $ln\ F_R = 0.306\ ln\ TL + 4.256$ (n = 24; r^2=0.011; p=0.622);

(8) $ln\ F_R = 0.491\ ln\ FL + 3.875$ (n = 24; r^2=0.028; p=0.432);

(9) $ln\ F_R = 0.438\ ln\ SL + 4.054$ (n = 24; r^2=0.023; p=0.476);

(10) $ln\ F_R = 0.256\ ln\ OL + 4.619$ (n = 24; r^2=0.013; p=0.588);

(11) $ln\ F_R = 0.153\ ln\ BW + 4.520$ (n = 24; r^2=0.029; p=0.422);

(12) $ln\ F_R = 0.230\ ln\ OW + 4.631$ (n = 24; r^2=0.010; p=0.422); and

(13) $ln\ F_R = 0.093\ ln\ (BW\text{-}OW) + 4.717$ (n = 24; r^2=0.011; p=0.627);

Analysis of regression showed that there was no significant relationship between F_R and various body metrics (length, weight, etc).

RELATIONSHIPS BETWEEN LENGTH AND WEIGHT

The sample size (n), regression parameters a and b of the LWR, 95% confidence intervals of a and b, the coefficient of determination (r^2), and growth type for female *P. ticto* in the Ganges River are given in Figure 3 and Table 3. All relationships were highly significant (P<0.001), with r^2 values being greater than 0.781. The relationships are as follows:

(14) $ln\ BW = 2.956\ ln\ TL - 3.928$ (n=24; r^2=0.835; p<0.001);

(15) $ln\ BW = 3.114\ ln\ FL - 4.005$ (n= 24; r^2=0.903; p<0.001);

(16) $ln\ BW = 3.010\ ln\ SL - 3.357$ (n=24; r^2=0.877; p<0.001); and

(17) $ln\ (BW\text{-}GW) = 2.855\ ln\ TL - 3.928$ (n=24; r^2=0.781; p<0.001)

The LWRs indicated negative isometric growth in mature female *P. ticto*. The calculated allometric coefficient b value 2.956 for TL, 3.114 for FL, 3.010 for SL and 2.855 for BW-OW vs. TL. Overall, the b value of LWRs for female *P. ticto* was close to 3 (b ~ 2.984), indicative of isometric growth. ANCOVA revealed significant differences between BW-TL and (BW-OW)-TL for the intercept (a) of the regression lines (F = 132.39; p<0.001), but no significant differences in slopes (F = 0.055; p=0.815).

CONDITION FACTORS

The K_F, K_A, and W_r values calculated for *P. ticto* is shown in Table 1. The calculated minimum and maximum K_F was 1.55 and 2.17 respectively, with a mean value of 1.78±0.14. In addition, the minimum and maximum W_R

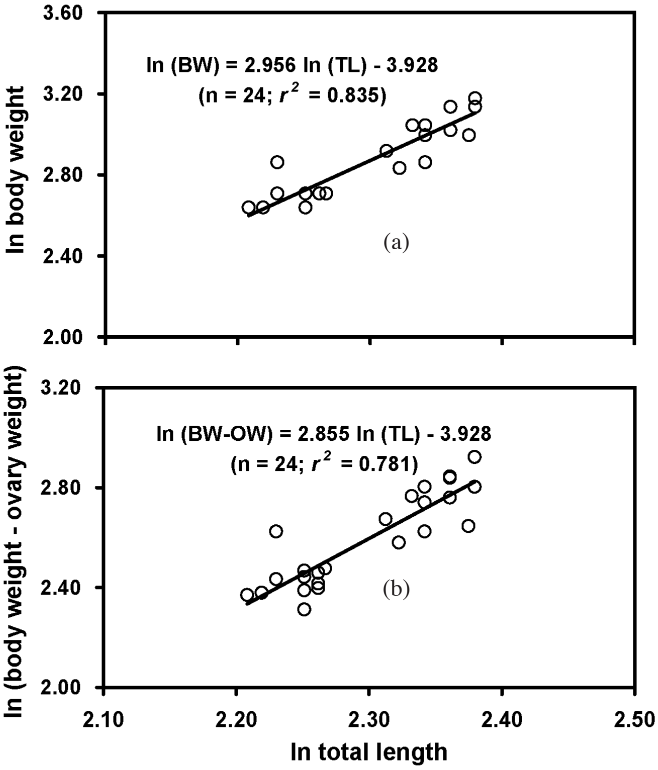

FIGURE 3. Relationships between weight and length (a) ln (BW) vs. ln (TL) and (b) ln (BW-OW) vs. ln (TL) of *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh

TABLE 3. Descriptive statistics and estimated parameters of the length-weight relationships (sample size = 24) of the female ticto barb *Puntius ticto* (Hamilton, 1822) from the Ganges River

Equation	Regression parameters		95% CL of a	95% CL of b	r^2	*Growth type
	a	*b*				
$BW = a \times TL^b$	0.0196	2.956	0.0052 to 0.0747	2.375 to 3.537	0.835	I
$BW = a \times FL^b$	0.0182	3.114	0.0067 to 0.0493	2.663 to 3.566	0.903	I
$BW = a \times SL^b$	0.0340	3.010	0.0067 to 0.0493	2.512 to 3.508	0.877	I
$BW\text{-}OW = a \times TL^b$	0.0197	2.855	0.0041 to 0.0879	2.186 to 3.524	0.781	-A

BW, body weight; TL, total length; FL, fork length; SL, standard length; OW, ovary weight; *a*, intercept; *b*, slope ; CL, confidence limit; r^2, coefficient of determination; I, isometric growth; -A, negative allometric growth; [* based on Sokal and Rohlf (1987): $t_s = (b\text{-}3) / s_b$, where t_s is the t-test value, *b* the slope, and s_b the standard error of the slope (*b*)].

TABLE 4. Analyses for fecundity-condition relationships of the ticto barb *Puntius ticto* (Hamilton 1822) from the Ganges River using the Spearman rank correlation test

Condition factors	Total fecundity (F_T)	Relative fecundity (R_F)
K_F	$N = 24$; $r_s = 0.473$; $p= 0.019$ *	$N = 24$; $r_s = 0.167$; $p= 0.435$ ^{ns}
K_A	$N = 24$; $r_s = 0.502$; $p= 0.012$ *	$N = 24$; $r_s = 0.213$; $p= 0.318$ ^{ns}
W_R	$N = 24$; $r_s = 0.483$; $p= 0.017$ *	$N = 24$; $r_s = 0.174$; $p= 0.416$ ^{ns}
GSI	$N = 24$; $r_s = 0.309$; $p= 0.141$ ^{ns}	$N = 24$; $r_s = 0.331$; $p= 0.114$ ^{ns}

N, sample size; K_F, Fulton's condition factor; K_A, allometric condition factor; W_R, relative weight; *GSI*, gonadosomatic index; r_s, Spearman's rank correlation coefficient, *p*, probability value.

was 87.54 and 121.82 respectively, with a mean value of 100.10±7.71, indicating the female *P. ticto* stock is in good condition in the Ganges River (Wilcoxon signed-rank test, *p*=0.830). In addition, the Kruskal-Wallis test revealed no significant differences in relative weight (W_r) among populations (*p*=0.375).

The correlations between fecundity and condition factors are presented in Table 4. F_T was strongly correlated with K_F ($r_s = 0.473$; *p*=0.019), K_A ($r_s = 0.502$; *p*=0.012), and W_R ($r_s = 0.483$; *p*=0.016), but surprisingly not with *GSI* ($r_s = 0.309$; *p*=0.141). Moreover, F_R also had no correlations with K_F ($r_s = 0.167$; *p*=0.435), K_A ($r_s = 0.213$; *p*=0.318), W_R ($r_s = 0.174$; *p*=0.416), and *GSI* ($r_s = 0.331$; *p*=0.114).

Discussion

Biological information of *P. ticto* from the Ganges River is inadequate. The data quality and methodology of earlier fecundity studies from this region is not well defined (Jhingran & Chondar 1977; Quddus et al. 1990; Verma 1967). In fisheries science, several numbers of methods have been applied to estimate fecundity (Arnold et al. 1997; Irwin & Bettoli 1991; Murdoch et al. 1990). The two most common methods still in use to count fish eggs involve digesting the ovaries in a mercury-based fixative (Gilsonõs fluid) and counting a sub sample of the eggs on the basis of certain volume (volumetric method) (Simpson 1951) or certain weight (gravimetric method) (Bagenal & Braum 1978). Nevertheless, a photographic technique has been recently developed by Şehriban and Gökçe (2005). However, to date, the most accurate way of estimating the number of eggs in the ovaries is to count them all. This should be done with egg-counting machines as the fecundity of most of the fishes is high, but this is unrealistic to do manually. Therefore, the present study applied the sub-sample method to estimate the fecundity for *P. ticto* in the Ganges River according to Yelden and Avsar (2000).

To estimate the fecundity of fishes, one needs to consider a variety of attributes including size at first sexual maturity (Hossain et al. 2010a; Lambert 2008), duration of spawning season, daily spawning behaviour, and spawning fraction (Murua et al. 2003), although these factors were not accounted for this study due to the limited number of female specimens with different ovarian-maturation stages, but other factors such as condition, gonadosomatic index, and ovary free weight were counted. In addition, Lambert, (2008) reported that fish fecundity varies with body length or weight, as it was found for *P. ticto*. To the best of the knowledge, there are no previous studies to consider the size at first sexual maturity for the estimation of fecundity from the region except by Hossan et al. (2008, 2010b) on another fish species. However, several studies on the fecundity of other fish species, including *Gudusia chapra* (Kabir et al. 1998; Narejo et al. 2000), *Mystus gulio* (Sarker et al. 2000), *Puntius gonionotus* (Bhuiyan et al. 2006), *Mystus bleekeri* (Musa & Bhuiyan 2007), *Mastacembelus pancalus* (Rahman & Miah 2009), and *Liza parsia* (Begum et al. 2010; Rehman et al. 2002) have been conducted in Bangladesh.

Moreover, a number of studies have been done without considering the accuracy of fecundity-length and fecundity-weight relationships. For example, Bahuguna & Khatri (2009) estimated F_T *vs. TL*, and F_T *vs. OL* relationships for *Noemacheilus montanus* in India using a simple linear-regression analysis ($Y = m + n \times X$) without log transformation of the data. Similarly, Begum et al (2010) examined the relationships between F_T *vs. TL* and F_T vs. gonad length for *Liza parsia* in Bangladesh. In contrast, more recently, İlhan et al. (2011) estimated the fecundity-weight relationship using power function ($Y = m \times X^n$) of the *Chondrostoma holmwoodii* in Turkey. However, the relationship between fecundity (F_T) and various morphometric variables (length, weight, etc.) are estimated by power ($F_T = m \times L^n$) or linear-regression functions ($F_T = m + n \times W$), where L, and W are the length and weigh of fishes. The parameters m and n of the models are usually estimated using simple linear regression after natural log (ln) or $\log_{10}$ transformation of the length or weight data and the corresponding fecundity estimates before back-transformation ($ln\ F_T = ln\ m + n \times ln\ L$ or $ln\ F_T = ln\ m + n \times ln\ W$) (Hossain et al. 2008, 2010b, Mustaquim & Rasheed 2010), all of which were accounted for in the present study.

According to Bhatt et al. (1977), fish fecundity is most accurately estimated by two morphometric variables taken together with less accuracy for length than weight variables (BW and OW). Moreover, gonad weight is more accurate for estimating fish fecundity than the two other variables (body length and weight) (Op. cit.). However, Bhatt et al. (1977) reported that it is not realistic to use gonad weight to estimate fecundity based on live specimens under field conditions. In the present study, mean F_T of the *P. ticto* (± 95%) was 2586±700 eggs per fish, positively correlated with TL ($r^2 = 0.484$), FL ($r^2 = 0.576$), SL ($r^2 = 0.548$), OL ($r^2 = 0.434$), BW ($r^2 = 0.633$), OW ($r^2 = 0.616$) and (BW-OW) ($r^2 = 0.548$). The r^2 was highest for F_T-*BW* relationship (equation no. vii), therefore, BW might be a better index of fecundity than other morphometrics, which is in accordance with earlier studies (Bhatt et al. 1977; Bahuguna & Khatri 2009). Moreover, several studies reported that F_T has a linear relationship with weight (BW, OW, etc.) (Bhatt et al. 1977; Bhargava 1971; Pantulu 1963; Qasim & Qayyum 1963). This suggests that the number of eggs in the ovaries increases in proportion to the body and gonad weight of the fish. In addition, positive relationships between F_T and length have been reported in a number of fishes in accordance with the present findings (Ikomi & Lambert 2008; Inyang & Ezenwaji 2004; Khan & Jhingran 1975; Sikoki 2003). But this study found no significant increase in F_R with length or weight (Table 2) making it a good, standardized fecundity variable to compare egg production by all individuals, regardless of their size or age. However, according to Oskarsson et al. (2002), Yoneda and Wright (2004) and Thorsen et al. (2006), F_R may vary over time within species, albeit the variation seems to be relatively modest. In addition, Kamler (2005) reported that F_R may also increase with size within species, but this would only aggravate the problem by affecting large species more than small species.

In this study, the fecundity of the *P. ticto* increased in proportion to the 3.262 power of TL, 3.606 power of FL, 3.448 power of SL, and 2.353 power of OL, which were within the model range (mode = 3.250-3.750 and range = 1.000-7.000) reported by Wootton (1979), who studied the energy costs of egg production and environmental determinants of fecundity in 62 fish species. In addition, the n values found in this study were 1.153 for F_T *vs. BW* and 0.918 for F_T *vs. OW*, which were approximately within the range reported by Wootton (1979).

The F_T of this species is comparable with the similar species from the Indian sub-continent (Froese & Pauly 2011). According to them, *P. ticto* lays a total of ~ 3000 eggs during the spawning season, which is similar to the present value of 2586 (see above). However, the small difference in fecundity estimates might be artificial (due to differences in techniques) or natural (due to differences in fecundity with geographic location or time). In addition, variation of fecundity between populations may result largely from environmental factors, of which temperature is considered the most probable selective factor (Jonsson & Jonsson 1999). Fecundity of fishes also varies across species, and within the same species because of differences in age, body length and gonadal weight (Lagler 1956).

For LWRs, all allometric coefficients (b) estimated during this study was within the expected range of 2.5-3.5 (Froese 2006), but they can vary between 2 and 4 (Bagenal & Tesch 1978). In general and despite the many variations in fish forms among species, b is close to 3, indicating that fish grow isometrically (Tesch 1971; Somers 1991). LWR with b values significantly different from 3.0 were often associated with narrow size ranges of the specimens examined; such LWR should be used only within the respective size range. Fish LWRs can be affected by several factors such as habitat, area, seasonal effect, degree of stomach fullness, gonad maturity, sex, health, preservation technique, and differences in the observed length ranges of the specimen caught (Tesch 1971), some of which the present study accounted for. However, the regression models showed a significant difference between body weight (BW) and ovary-free body weight (BW-OW) for mature female *P. ticto* in the Ganges River. The present results are comparable with earlier available studies (Hossain et al. 2009a), but no information on LWRs is available in Fishbase (Froese & Pauly 2011). Hossain et al. (2009a) recorded positive allometric growth for SL-BW relationship in *P. ticto* ($a = 0.035$; $b = 2.920$) from the Ganges River using unsexed samples. In a recent study, Hossain (2010a) recorded isometric growth (b = 3.093) for the TL-BW of unsexed relationship of *P. ticto* from the Padma (lower part of Ganges) River. These variations (b values) for *P. ticto* in the Ganges River might be attributed to differences in sampling, sample size, and length ranges. Nevertheless, growth increment (differences in age and stage of maturity), food, and environmental conditions such as temperature, salinity and seasonality can also affect the value of b within species (Weatherley & Gill 1987). However, the results presented in this paper, the b values were generally in agreement with results for other fish species in the same geographical area (Hossain et al. 2006a; 2006b; Hossain & Ahmed 2008; Hossain et al. 2009b; 2009c; Hossain 2010c; Hossain et al. 2012).

There is no published information on the condition factor of *P. ticto* are available (Hossain 2010c), preventing comparisons with the present results. However, condition factor based on the LWR is an indicator of the changes in food reserves, and is therefore an indicator of the general fish condition. In addition, values of W_R falling below 100 for an individual, size group, or population suggest problems such as low prey availability or high predatory density, whereas values above 100 indicate a prey surplus or low predatory density (Rypel & Richter 2008). Recently, a number studies have espoused the use of W_R for assisting in the management and conservation of nongame fishes, particularly those that are threatened or endangered (Bister et al. 2000; Didenko et al. 2004; Richter 2007). However, this study showed that the W_R of *P. ticto* was close to 100 in the Ganges, suggesting a of food availability relative to the presence of predators that may be indicative of good water quality. Nevertheless, this fish is categorized as vulnerable in Bangladesh (IUCN Bangladesh 2000), perhaps attributable to other factors besides water quality.

Spearman rank-correlation tests revealed that F_T was strongly correlated with K_F, K_A, and W_R, but not with GSI. However, failure to observe any meaningful relationship between F_T and condition indices could have potentially been caused by insufficient range of fish sizes (only 9.10-10.80 cm TL). In addition, correlation tests also showed no significant correlation between GSI and TL for females larger than 9.00 cm TL (r_s = 0.168; p = 0.431) in the Ganges River, suggesting body size as the threshold for sexual maturity (Hossain & Ohtomi 2008). GSI is also recommended as a good index for estimation of size at sexual maturity as well as spawning season for *P. ticto* (Op. cit.).

In conclusion, this study has provided some basic information on the size, weight, condition, and fecundity for *P. ticto* that will be helpful in similar studies. As no information on these biological aspects currently exists in FishBase, the present results may contribute to this invaluable database. Further, it would be useful for fishery biologists and managers to impose adequate regulations for sustainable fishery management in the Ganges River and nearby areas of Bangladesh.

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