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Biometric indices of near threatened reba carp, *Cirrhinus reba* from an oxbow lake in southwestern Bangladesh

SK INJAMAMUL ISLAM, MD. SAROWER-E- MAHFUJ*, IMRAN HOSHAN[1], MD. ASADUJJAMAN[2], MD. ABDUS SAMAD, MD. YEAMIN HOSSAIN[3]

Department. of Fisheries & Marine Bioscience, Jashore University of Science & Technology, Jashore-7408, Bangladesh
[1]Department of Fisheries Biology and Genetics, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh
[2]Department of Aquaculture, Khulna Agricultural University, Khulna-9100, Bangladesh
[3]Department of Fisheries, Rajshahi University, Rajshahi-6000, Bangladesh
* Corresponding author's Email: sa.mahfuz@gmail.com

Abstract: *Cirrhinus reba*, is a freshwater fish species which is distributed throughout the South Asian countries. The current study reports the detailed biometric indices of *C. reba* in the Bergobindapur oxbow lake (*Baor*) located in southwestern Bangladesh. The parameters assessed included length-frequency distributions (LFD), length-weight relationships (LWR), form factor ($a_{3.0}$) and length at first sexual maturity (L_m) and four types of condition indices (i.e. allometric, K_A; Fulton, K_F; Relative, K_R and Relative weight, W_R).Conventional fishing equipment such as cast nets and monofilament fixed gill nets were used to collect samples from July to August 2019. Digital slide calipers were used to assess total length (TL), standard length (SL), fork length (FL), and trunk length (TrL), and body weight (BW) was quantified with an electronic balance with 0.01 g precision. Total 157 specimens with lengths ranging from 12.24 to 24.82 cm and weights ranging from 22.00 to 100.27 g were studied. The computed 'b' demonstrated negative allometric growth (< 3.00) in pooled sexes for the LWR. In this investigation, the mean of W_R (100.36) did not differ significantly demonstrating that the environment was still in good shape. Furthermore, the size of *C. reba* at sexual maturity was estimated as 14.40 cm TL. The findings of this study would be worthwhile for the sustainable management of reba carp fisheries.
Keywords: *Cirrhinus reba,* Biometry, Length-Weight, Oxbow lake

Introduction

Biometric studies are classically described by investigators to manage and protect fisheries resources because they can deliver a precise representation of freshwater fish biomass in a specific ecosystem (Jisr *et al.* 2018). In profoundly exploited populations, the changes of phenotypic traits have been switched over time (Du *et al.* 2011, Hossen *et al.* 2019a, 2019b). Biometric indices such as size, age, growth rate, conditions are recognized as underlying variables that can be used to explain and forecast how various species respond to stressors such as exploitation, climate change, and so on (Hu *et al.* 2015; Hossain *et al.* 2016; Hasan *et al.* 2021). Fish biometric indices or phenotypic traits are also strongly linked to extinction risk and restoration possibilities (Hutchings *et al.* 2012). Studies on fish biometric indices can be used not only analyze the effects of exploitation, but also aid in the development of fisheries management plans for the conservation of commercially valuable threatened fish such as *Cirrhinus reba* (Hossain *et al.* 2012a, Hossain *et al.* 2016, Mahfuj *et al.* 2021). *Cirrhinus reba*, a member of the Cyprinidae family, is popularly known as Reba carp, raik bhagnabata, or tatkini, and is readily distinguishable by its scales, which are darkest at their bottom and top edges and appear bluish longitudinal lines above and for two or three rows below the lateral line. In Bangladesh and its neighboring countries, it is predominantly reported in the clean waters of rivers, canals,

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streams, and other flood plains (Rahman 1989, Hossain 2001). *C. reba* is an omnivorous column feeder that feeds on plankton, detritus, insect larvae, mud, vegetables, and crustacean fauna in the wild, with size ranges of 15–28 cm (Lashari *et al.* 2010). The oily flesh and flavor of this fish, as well as the fact that it is high in protein, minerals and fatty acids, make it a popular choice among consumers (Afroz and Begum 2014). Females produce 200,000 to 250,000 eggs per kg of body weight during the spawning season of *C. reba*, which spawns from April to August (Hussain and Mazid 2001). This fish possessed a high potential for freshwater aquaculture but has yet to be exploited in Bangladesh. The natural population of the species has plummeted over the last two decades as a result of extensive harvesting, habitat degradation, and numerous changes of climatic condition to their habitat (Chowdhury 2015). However, effective control of this species in Bangladesh appears to be critical and necessary actions are highly prerequisite to conserve this species to maintain food security. Moreover, commercial aquaculture productions of this species are most likely to be regulated through wild populations in hatcheries. As a result, unique wild stocks of *C. reba* must be identified in order to establish viable hatchery stocks through artificial breeding technology, which is a critical step for mass sustainable aquaculture, seed production, and management (Sarkar *et al.* 2004). Since many environmental and biological influences are much more size-dependent than age-dependent. Consequently, length-weight parameters have been utilized routinely to assess weight from length in light of the fact that immediate weight estimations can be tedious in the field of fish biology (Andrade and Camos 2002, Sinovčić *et al.* 2004). LWR in fish populations were mainly used to evaluate whether somatic growth was isometric or allometric as well as provide information about the status of the fish (Le Cren *et al.* 1951). Furthermore, morphometric relationships such as length-weight relationships (LWRs), allometric condition factor (K_A), relative condition factor (K_R), and Fulton condition factor (K_F) are biologically important factors for fishes that can be used to determine the state of stocks and the wellbeing of fish populations (Bagenal and Tesch 1978). Since past two decades, relative weight (W_R) has been one of the most prominent indicators for ascertaining fish condition in the United States (Rypel and Richter 2008). Besides this, form factor ($a_{3.0}$) is being used to ascertain whether a population's or species physical appearance differs markedly from that of others (Froese 2006). Nonetheless, limited researches have been conducted on the LFD, LWRs, condition, form factor and size at first sexual maturity of *C. reba* populations inhabiting oxbow lakes in southern-western region of Bangladesh, except Hossain *et al.* (2013) and Jewel *et al.* (2019). In this study, we focused on biometric indices (i.e. LFD, LWR, K_A, K_R, K_F and W_R form factor and size at first sexual maturity of the wild *C. reba* from Bergobindopur *Baor* (oxbow lake) in southwestern Bangladesh. The findings of the study could lead to important recommendations for local fisheries management.

Materials and Methods

***Fish Sampling*:** A total of 157 wild *C. reba* specimens were collected by the local fishers from the Bergobindapur oxbow lake (*Baor*) in Southwestern part of Bangladesh (Fig. 1) during July and August 2019. Fishers were found using conventional fishing gears such as cast net (mesh size, 1 cm) and monofilament fixed gill net (mesh size, 1.2 cm) to harvest the fish. The specimens were then transferred to the lab and kept in 10% formalin until the assessment is conducted. The following morphometric lengths were measured such as total length (TL),

standard length (SL), fork length (FL), trunk length (TrL) and body weight (BW) of each specimen were weighed with a digital slide calipers and an electronic balance, respectively.

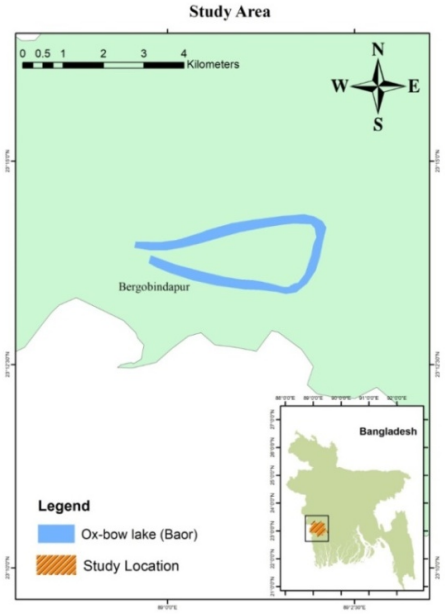

Fig. 1. Map showing the collection sites of *C. reba* from Bergobindapur oxbow lake.

***Length frequency distributions (LFDs)*:** Individuals of *C. reba* were prepared based on the total length (TL) recorded from various size groups and the total length (TL) composition was computed. On the basis of the TL of all individuals, length frequency analysis was performed using multiple length frequency data sets. The LFD data were constructed for combined sex using 1 cm intervals of TL. Histograms with a normal curve and confidence limits were used to conduct length-frequency distribution methods for combined sex.

***Length-weight relationships (LWRs)*:** The LWR was estimated by the formula: $W = aL^b$, where 'W' is the total body weight (g), 'L' is the total length (cm), and 'a' and 'b' are the regression parameters. The LWR parameters 'a' and 'b' were considered using natural logarithms and linear regression analysis: ln (W) = ln (a) + b ln (L). Moreover, the statistical significance level of r^2 (coefficient of determination) and the 95% confidence limits of the parameters 'a' and 'b' were also calculated. The r^2 value of coefficient ranges from 0 to 1, and it defines how much of the variation in one of the associated variables can be elucidated by variation in another (King 2007).

***Condition factors*:** The equation for calculating Fulton condition factor (K_F) (Fulton 1904) was $K_F = 100\ (W/L^3)$, where 'W' is the total body weight (g) and 'L' is the total length (cm). To bring the K_F closer to unit, a scaling factor of 100 was used. Additionally, to determine each individual's relative condition factor (K_R) was calculated using Le Cren (1951) equation: $K_R = W/(aL^b)$, where W is the body weight, L is the total length, and 'a' and 'b' are the LWR parameters. Additionally, the allometric condition factor (K_A) was also measured using the

equation proposed by Tesch (1968): W/L^b, where 'W' is the total body weight (g) and 'L' is the total length (cm) and 'b' is the LWR parameter.

***Relative Weight (W_R)*:** Relative weight was calculated as, $W_R = (W/W_S) \times 100$ given by Froese (2006), where 'W' is the body weight of a particular fish individual and W_S is the expected standard weight for that same individual as calculated by $W_S = aL^b$, where, 'a' and 'b' values were acquired from the interactions between TL and BW.

***Form factor and size at first sexual maturity*:** The form factor of *C. reba* was calculated following Froese (2006) 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' versus 'b'. Binohlan and Froese (2009) used the empirical equation for combined sex to calculate the size of first sexual maturity.

***Statistical analysis*:** Statistical Package for the Social Sciences (SPSS) software version 16.0 was used to conduct statistical analyses. Visual inspection of histograms and box plots was used to check for normality in each group, and the Shapiro-Wilk's test was used to confirm the normality assumption was met. The Spearman rank test was used to correlate body weight with condition factors. At 5% ($p < 0.05$), all statistical analyses were considered significant.

Results

***Descriptive statistics and length frequency distributions (LFD)*:** The TL and BW ranged from 122.4-248.2 mm and 22.00-100.27 g, respectively (Table I). In LFD analysis, the 150.0-159.9 mm and 160.0-169.9 mm TL size groups were statistically prominent, accounting for 81.00 % of the total population (Fig. 2).

Table I. Length-based descriptive statistics of *C. reba*

Measurements	Minimum	Maximum	Mean ± SD	95 % CI
Total length (TL)	12.24	24.82	15.56 ± 2.05	15.23-15.88
Fork Length (FL)	10.86	21.80	13.72 ± 1.80	13.44-14.00
Standard Length (SL)	9.88	20.99	12.67 ± 1.76	12.39-12.95
Body Weight (BW)	22.00	100.27	34.99 ± 12.30	33.05-36.93

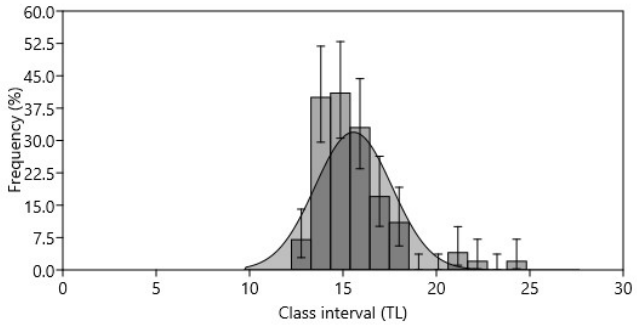

Fig. 2. Length frequency distribution of *C. reba* in Bergobindapur oxbow lake. Confidence limits are represented by vertical bars.

***Length-weight relationships (LWRs) and length-length relationships (LLRs)*:** There were significant differences in BW versus TL (ANCOVA, F= 1931.94, df= 156, $p< 0.05$) and BW versus SL (ANOVA, F= 1331.36, df= 156, $p< 0.05$) and BW versus TL (ANOVA, F= 1931.94, df= 156, $p< 0.05$) (Table II) (Fig. 3). Table 3 shows the linear relationship between TL versus SL and TL versus FL of *C. reba*, as well as the assessed parameters of the length-length relationships (LLR) and the coefficient of determination (r^2). With correlation co-efficient determinations of 0.96937 and 0.9799 for TL versus SL and TL versus FL, respectively, the LLRs were highly significant ($p<0.05$) (Fig. 4).

Table II. Length-weight and length-length relationships parameter of the *C. reba* in Bergobindapur oxbow lake

Equation	Regression parameters		95% CI for a	95% CI of b	Coefficient of determination (r^2)	Growth type
	Intercept (a)	Slope (b)				
BW= a*TL^b	0.071	2.248	0.053-0.093	2.147-2.349	0.925	A-*
BW= a*SL^b	0.152	2.130	0.013-0.204	2.015-2.246	0.895	A-*
TL=+b*SL	-0.468	0.844	-0.210-(-0.596)	0.594-0.973	0.963	
TL=+b*FL	0.180	0.870	0.0959-0.225	0.066-0.969	0.979	

A-, negative allometry, * represents the significant level at $p < 0.05$.

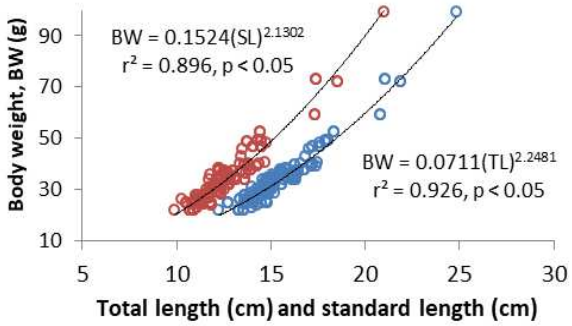

Fig. 3. Length-weight relationships (LWRs) of the *C. reba* in Bergobindapur oxbow lake.

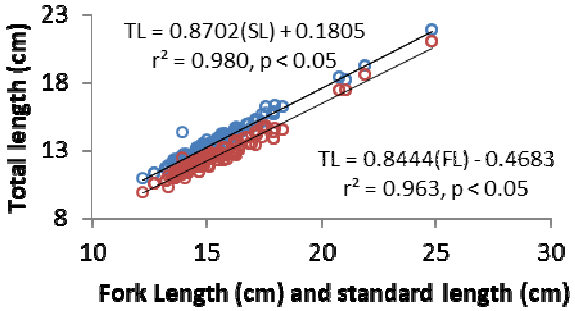

Fig. 4. Length-length relationships (linear) of the *C. reba* in Bergobindapur oxbow lake.

Table III, shows that the K_A, K_F, K_R and W_R ranged from 0.0581 to 0.0817 (mean±SD= 0.0713±0.0054), 0.6492 to 1.2002 (mean±SD= 0.9149±0.1075), 0.8176 to 1.1502 (mean± SD= 1.0035±0.0767) and 81.7654 to115.0221 (mean±SD= 100.3566±0.7.6713), respectively. Table IV, shows that K_F was strongly correlated with TL ($r = 0.664$, $p < 0.05$), FL ($r= 0.612$, $p<0.05$), SL ($r= 0.642$, $p<0.05$), and TrL ($r= 0.547$, $p<0.05$) using the Spearman rank test. In addition, there was also exceedingly correlation between K_F and BW ($r = 0.403$, $p<0.05$), K_A and BW ($r= 0.292$, $p< 0.05$), K_F and BW ($r= 0.403$, $p<0.05$) and W_R and BW ($r= 0.272$, $p<0.05$).

Table III. Condition factors of *C. reba* in Bergobindapur oxbow lake

Measurement	Minimum	Maximum	Mean ± SD	95 % confidence limits
Allometric condition factor (K_A)	0.058	0.081	0.0713 ± 0.005	0.070-0.072
Fulton's condition factor (K_F)	0.649	1.200	0.9149 ± 0.107	0.897-0.931
Relative condition factor (K_R)	0.817	1.150	1.0035 ± 0.076	0.991-1.015
Relative weight (W_R)	81.765	115.022	100.3566 ± 7.671	99.147-101.566

Table IV. Spearman correlations among lengths (TL, FL, SL, TrL) and condition factors (K_A, K_F, K_R and W_R) of *C. reba* in Bergobindapur oxbow lake

Characters	TL	FL	SL	TrL	BW	K_A	K_F	K_R	W_R
TL	1.000								
FL	0.974*	1.000							
SL	0.961*	0.970*	1.000						
TrL	0.868*	0.893*	0.889*	1.000					
BW	0.940*	0.943*	0.907*	0.849*	1.000				
K_A	-0.004	0.050	0.000	0.054	0.292*	1.000			
K_F	0.664*	0.612*	0.642*	0.547*	0.403*	0.698*	1.000		
K_R	-0.004	0.050	0.000	0.054	0.262*	1.000*	0.698*	1.000	
W_R	-0.004	0.050	0.000	0.064	0.272*	1.000*	0.688*	1.000*	1.000

Values represent Spearman correlation coefficient (two tailed)
* represents the significant level at $p< 0.05$.

The mean relative weight ranged from 90.00 to 114.00, with no significant difference at the one-sample t-test result where the benchmark value was 100 (t-value, 0.82 and p-value, 0.561 >0.05), indicating that the habitat for *C. reba* was still in good condition (Fig. 5). The results, however, revealed that the mean W_R varied over the course of their life history traits. Form factor ($a_{3.0}$) of unsexed of *C. reba* was calculated as 0.0119 and the size of sexual maturity was obtained as 14.40 cm.

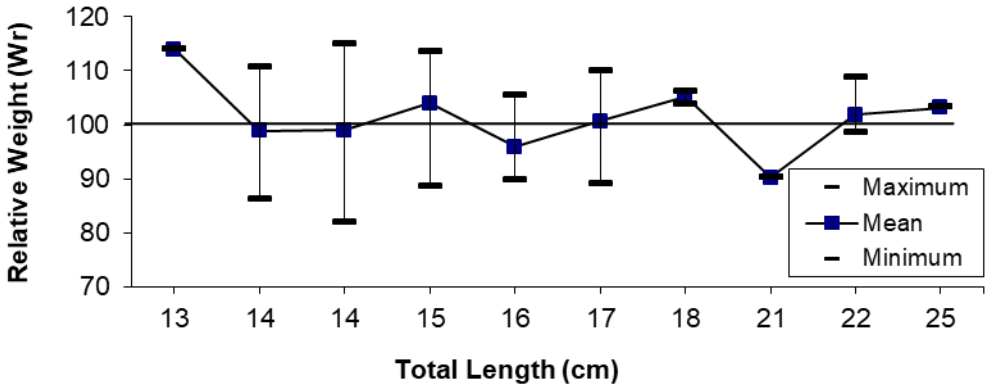

Fig. 5. The association between total length (TL) and relative weight (W_R) of *C. reba* in Bergobindapur oxbow lake.

Discussion

Variations in size class were found to be an expected phenomenon of *C. reba* in this study. When compared to other studies, the weight and total length of *C. reba* collected from Bergobindapur oxbow lake showed similar size variations (Narejo 2006, Muralidharan *et al.* 2011, Hossain *et al.* 2013, Jewel *et al.* 2019). In total, 157 wild fish specimens with various phenotypic lengths were sampled using conventional fishing gears during the study, but it was difficult to harvest *C. reba* smaller than 12.24 cm TL throughout the sampling period, which can be ascertained either to the nonappearance or lack of small sized fishes in their respective habitats or mesh sizes of the harvesting nets (Hossain *et al.* 2012b). However, the maximum length (TL) of *C. reba* recorded in this study was 24.82 cm, which is less than the extreme maximum recorded values of 32 cm TL in Baigul reservoir, India (Khan, 1986) and 30 cm TL in fish ponds in the district Jacobabad, Pakistan (Lashari *et al.* 2007). Moreover, Narejo (2006) reported the maximum total length of *C. reba* was 22.50 cm (TL) in Manchar Lake, Pakistan, and Muralidharan *et al.* (2011) reported the maximum length was 18.40 cm in Cauvery River, India, and Jewel et al. (2019) also described the maximum total length was 23.80 cm, all of which are lower than the maximum length found in this study. Furthermore, the maximum length observed in this study was 24.82 cm, which was considerably larger in total length than other Bangladeshi habitats previously studied. Furthermore, these disparities in total length may be influenced by the environmental conditions in the study areas. Likewise, the impacts of water temperature can be linked to biological productivity rates and food availability, as well as the composition of nekton and plankton, which together impact on fish growth (Weatherley and Gill 1987). Besides, the maximum body weight of *C. reba* found in this study was 100.27 g, which is lower than the 102.50 g found by Narejo (2006) in Manchar Lake, Pakistan, and the 147.00 g found by Muralidharan *et al.* (2011) in the Cauvery River, India. Distinctions in the maximum sizes of *C. reba* individuals recorded in different regions could be based on the absence of larger-sized specimens in fishing grounds populations, as well as natural mortality and evade during catching fish (Hossain *et al.* 2012b). Additionally, differences in fishing gear and target species selectivity may have a significant impact on the size dispersal of the individuals caught,

representing in extremely skewed estimates of many population characteristics, comprising the maximum length (Hossain *et al.* 2012a).

In this study, the calculated values of 'b' for LWRs were less than 3, indicating negative allometry. This could be due to the effects of the abiotic and biotic environmental parameters on fish growth patterns. Froese (2006) mentioned that seasonality in environmental parameters, biological conditions (i.e. gonad development sex, food availability and nutritive conditions) of the fish at the point of collection, can be influenced growth types. According to Tesch *et al.* (1971) habitat conditions, stomach fullness of individuals, preservation techniques may also affect the length-weight relationship in fishes. Differences in LWRs could also be caused by differences in behavior (active or passive swimmers) and water flow (Muchlisin *et al.* 2010).

During the study period, three types of condition factors have been used to evaluate the overall performance and wellbeing of *C. reba* in the Bergobindapur oxbow lake. The condition factor is a metric that measures how abiotic and biotic factors engage in the physiological state of fish (Lizama *et al.* 2010). Throughout the study period, the descriptive values of K_A and K_F were marginally lower than those found by Hossain *et al.* (2013). The mean W_R of the pooled sexes of *C. reba* in this study revealed no significant differences from the benchmark value 100 ($p = 0.561$). However, the outcomes of this study, it is perfect that the ecosystem of *C. reba* in the Bergobindapur oxbow lake is deteriorating day by day, and that juvenile stages of *C. reba* are particularly vulnerable. Hossain *et al.* (2013) demonstrated no significant associations in relative weight from the reference value of 100 for *C. reba* in their study, indicating that the habitat for *C. reba* was still in excellent condition. The vicissitudes of fluctuation in W_R, on the other hand, could be due to seasonal variations in natural food content. Moreover, the size of *C. reba* at sexual maturity was approximated to be 14.40 cm in this study. This information differs significantly from that of Hossain *et al.* (2013), who found 11.50 cm (TL) for males and 13.50 cm (TL) for females in their study (TL). Furthermore, the findings of this study will serve as the foundation for more detailed research into the specific factors that influence the size at first sexual maturity and spawning size in different populations of *C. reba* in oxbow lake ecosystems.

The growth pattern of *C. reba* in Bergobindapur oxbow lake was noticed to be negative allometry with the size variations of fish length and weight over time. The current study of the length-weight relationships and relative condition factor of the minor carp, *C. reba*, from Bergobindapur oxbow lake, shows that the growth rate is quite low. This study delivers significant baseline evidence on the LWRs, condition indices, form-factors, size at sexual maturity of *C. reba* from Southwestern Bangladesh. The findings of this study will be useful to fishery biologists, environmentalists, and managers in developing management plans and guidelines for long-term preservation of this species' remaining stocks in the oxbow lake ecosystem.

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