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Original article

Population Parameters of *Macrospinosa cuja* (Hamilton 1822) in a wetland ecosystem (Northwestern Bangladesh)

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ABSTRACT

Macrospinosa cuja (Hamilton 1822) is a widely recognized and popular fish species globally for human consumption. This research offers valuable findings about biological parameters, including population structure, growth patterns, sexual maturity, form factor, and mortality of *M. cuja* by examining a sample of 123 individuals. These biological parameters are required for the formulation of sustainable management policies. From June 2021 to May 2022, these individuals were captured from the Babu Mondoler *beel*, a wetland ecosystem in Northwestern Bangladesh, using various traditional fishing tools and traps. Biometric information was gathered for every individual, helping to create an in-depth comprehension of this specimens. The documented findings indicated an extensive range of total length (TL), ranging from 5.9 to 12.3 cm. The body weight (BW) ranged from 1.81 and 15.01 g. The computed allometric coefficient (b) revealed that the allometric growth of combined sexes was negative (b <2.94). The size at sexual maturity (L_m) was measured at 7.0 cm TL. In this study, from the calculation of condition factors, W_R (100.58 ± 8.0287) was best for the well-being of *M. cuja* in the wetland ecosystem. The form factor ($a_{3.0}$) was estimated at 0.0079. The natural mortality rate M_w and the exploitation rate (E) were 1.30 year^{-1} and 0.29, respectively. These results provide valuable understandings of the population parameters, growth patterns, mortality, and the form factor of *M. cuja*, potentially serving a structure for future sustainable utilization strategies.

Introduction

The Sciaenidae family, also known as drums or croakers, comprises a variety of small to large, excellent food fish species (Roul et al. 2022). Berg (1958) stated that drums or croakers are broadly spread throughout the Atlantic, the Indian, and the Pacific oceans. According to Nelson (1994), the family comprises approximately 68 genera and approximately 293 known species. *Macrospinosa cuja* (Hamilton 1822) (Actinopterygii: Perciformes) which is known as Bola cuja, holds much importance as a fish species within the Sciaenidae family. The distribution of *M. cuja* spans Bangladesh, India (Talwar and Jhingram 1991), China (CAFS 2007), Vietnam (Ngyuen et al. 1995) and Thailand (Monkolprasit et al. 1997) and it shows partial anadromy. In Bangladesh, *M. cuja* is locally known as "Bola" and "Kuizzapoa". It can be found in a diverse range of habitats, including marine and estuarine waters, river mouths, areas adjacent to tidal rivers, and mangrove

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canals (Hasan et al. 2020). Additionally, *M. cuja* is known to occasionally inhabit freshwater sections of intertidal rivers, further displaying its adaptability to various environments (Rahman 2005; Nabi 2015). The hightest known length of this species is 152 cm (Hamilton 1822). Hasan et al. (2020) reported that its air bladder has been recognized as a premium trade item in recent years and usually attains maturity when its weight reaches 3 kg.

Rahman and Morshed (2007) found that this species feeds on minuscule fish, crabs, and small invertebrates. According to the evaluation by the IUCN of 2022, *M. cuja* is classified as having the status of "Data Deficient" (DD) (IUCN 2022). This species is considered "Near Threatened" in Bangladesh. (Pramanik et al. 2017). The information on threats is limited for this species; however, overfishing may be a threat because of its large size and the high value of its swim bladder. In this situation, population parameters offer potential information and can be viewed as significant signals of the health and the longevity of stocks, as well as their vulnerability to fishing operations (Froese and Binohlan 2000; Camargo et al. 2015).

Fish population parameters are important for scientific research, providing information on abundance, distribution, mortality, age structure, and growth pattern, aiding in informed strategies for the preservation and control of resources. (Rahman et al. 2021a, b). It is essential to comprehend fish population factors to manage ecosystems, maintain sustainable fisheries, and preserve biodiversity. In case of scientific research, there is a scarcity of available literature that specifically addresses the status of *M. cuja*, in a few words such as environment (Riede 2004), species diversity (Bhakta and Das 2021), natural diets (Rahman and Morshed 2007), biological parameters (Lal Mohan 1981) and morphology (Hamilton 1822). According to the authors' best knowledge, no prior study has explored population parameter analysis of *M. cuja* in the existing literature (Lal Mohan 1981; Riede 2004; Rahman and Morshed 2007; Bhakta and Das 2021). This research is a pioneering study assessing population parameters for *M. cuja*, highlighting the urgent need for effective management policies in this significant fishery. Therefore, the primary aim of the current research is to examine various population parameters of *M. cuja* such as Length-frequency Distributions (LFDs), length-weight and length-length relationships (LWRs and LLRs), Condition Factors (K_A, K_F, K_R, and W_R), form Factor ($a_{3.0}$), size at sexual maturity (L_m), and natural mortality (M_w). The study comprises a wide range of specimens, ranging from small to large sizes, recorded during a one-year timeframe. Furthermore, the condition of *M. cuja* was assessed with the use of multiple models to enhance the accuracy of the findings.

Materials and methods

Sampling site and fish measurement

This investigation was performed at Babu Mondoler *beel* (24°28'51.20"N, 88°14'45.38"E), a wetland environment linked to the downstream Ganges, situated in NW Bangladesh (Fig. 1). Between June 2021 and May 2022, a total of 123 specimens were gathered periodically from local fishermen using various types of native fishing tools like gill nets, cast nets, seine nets, and box traps. The collected organisms were immediately put into ice to maintain their condition and then transported to the laboratory for further examination. In the laboratory, all measurements for each individual were captured with precision. The TL and SL were measured using digital slide calipers, ensuring precision to the nearest 0.01 cm. Meanwhile, body weight was weighted using an electric balance accurate to 0.01 g. These precise measurements acquired during this investigation significantly strengthen the dependability and accuracy of the compiled data, guaranteeing its overall legitimacy and credibility.

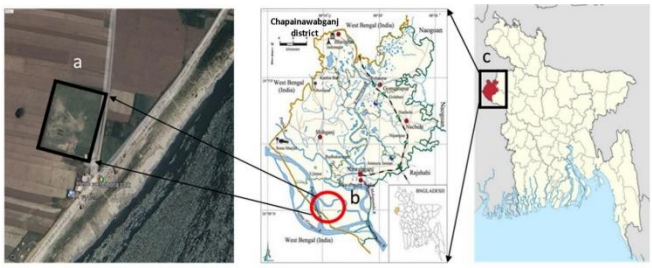

Fig. 1. Map of the study site, where the sampling point was marked by (a) rectangle, (b) oval shaped and location of waterbody in Map of Bangladesh also by (c) rectangle.

Population structure and Growth pattern

The population structure of *M. cuja* was examined using length frequency distribution with TL intervals of 1 cm. Researchers utilized LWRs to examine the growth pattern of the species, employing the formula

$W=a*L^b$, as outlined by Le Cren (1951). The parameters *a* and *b* were determined through the formula $ln(W) = ln(a) + b\ ln(L)$. The relationship between TL and SL, known as the LLR, was examined following the model described by Hossain et al. (2017), where the value of SL was deduced using the method, $SL=a+b*TL$.

Condition factors

The evaluation of the allometric condition factor (K_A) was carried out from the equation $K_A= W/L^b$ (Tesch 1968). Additionally, Fulton's condition factor (K_F) was computed using the formula $K_F = 100 * (W/L^3)$ (Fulton 1904). Moreover, the relative condition factor (K_R) was determined through the equation $K_R = W/(a * L^b)$(Le Cren 1951), where *W* stands for body weight (g), L signifies total length (cm), *a* and *b* denote the parameters of the LWR.

Prey-predator status

The prey-predator status of *M. cuja* was determined by calculating the relative weight (W_R) through the formula $W_R= (W/W_S)$ *100 (Froese 2006), where *W* stands for the weight of an individual, W_S signifies the standard weight for each particular organism, measured as $W_S = a*L^b$. The specific values of *a* and *b* have been derived from the LWRs.

Form factor

To analyze the form factor, the method $a_{3.0} = 10^{loga-s(b-3)}$ was used (Froese 2006), where the regression parameters for the LWR TL *vs* BW are represented by *a* and *b*, and '*s*' represents the gradient of the logarithm of '*a*' *vs.* '*b*'. A regression analysis of log '*a*' *vs.* '*b*' was conducted with an average slope (s) of -1.358, as the precise data of the LWR for this particular species was unavailable.

Size at first sexual maturity (L_m)

The maximal length-based model yielded the L_m expressed as: $log\ (L_m) = -0.1189 + 0.9157 * log(L_{max})$ (Binohlan and Froese 2009). The maximum reported length (TL) of *M. cuja* in the present investigation indicated L_{max}.

Mortality and exploitation rate estimation

The natural mortality (M_w) was ascertained utilizing the empirical formula $M = -ln\frac{[0.01]}{t_{max}}$ (Pauly 1980) with t_{max} denoting the life span of the species, and an estimate of the exploitation rate was made by using the equation: $E = F/(F + M)$ (Gulland 1983).

Statistical analysis

We conducted statistical analysis on the data using computer programs, specifically GraphPad Prism 8, Microsoft Excel 2019, and Past 4.03. The analyses were carried out with a significance level set at 5%. The Wilcoxon sign rank test was employed to compare the mean relative weight (W_R) to 100. Additionally, the Spearman rank test was utilized to identify correlations between body measurements such as TL and BW with condition factors (K_A, K_F, K_R, and W_R) (Anderson and Neumann 1996).

Results

Population structure and Growth pattern

Table 1 consists of 123 specimens of *M. cuja*, with data on their length and weight, showing a comprehensive study of these variables associated with

Table 1. Descriptive statistics on length (cm) and weight (g) measurements with their 95% confidence interval of *Macrospinosa cuja* in the Babu Mondoler *beel*, Chapainawabganj, Bangladesh

Measurement	Min	Max	Mean ± SD	95% CL
Total length	5.9	12.3	9.82 ± 1.21	9.603 - 10.036
Standard length	4.9	10.4	8.07 ± 1.11	7.877 - 8.276
Body weight	1.81	15.01	8.22 ± 2.78	7.727 - 8.720

95% confidence limits (CL). From the LFD study, the smallest specimen was found to be 5.9 cm in TL while the largest was 12.3 cm in TL (Fig. 2). BW variations were between 1.81 and 15.01 g. Additionally, based on LWRs calculations, the regression analysis revealed that the coefficients *a* and *b* were 0.0095 and 2.94, respectively, which accounted for a substantial association ($p < 0.005$; $r^2 = 0.951$) as shown in Table 2.

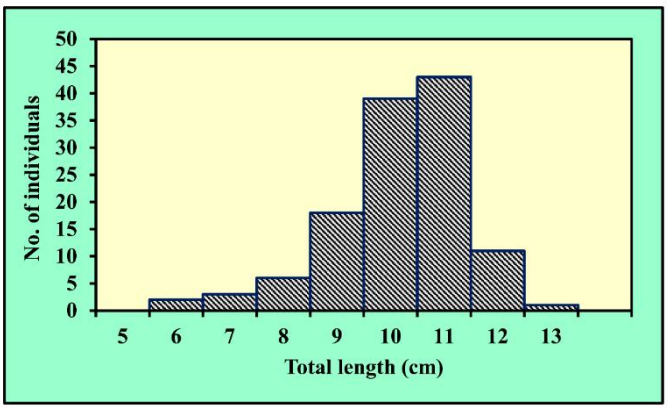

Fig. 2 Length frequency distribution of *Macrospinosa cuja* in the Babu Mondoler *beel*, Chapainawabganj, Bangladesh

Table 2. Descriptive statistics of length-weight and length-length relationships (LWR & LLR) of *Macrospinosa cuja* in the Babu Mondoler *beel*, Chapainawabganj, Bangladesh

Formula	*n*	Regression variables		95 % CL of *a*	95 % CL of *b*	r^2
		a	*b*			
$BW = a \times TL^b$		0.0095	2.94	0.0074 - 0.0121	2.83 - 3.04	0.951
$BW = a \times SL^b$	123	0.0334	2.61	0.0268 - 0.0414	2.51 - 2.71	0.934
$SL = a + b \times TL$		0.6683	0.89	0.3353 - 0.7833	0.84 - 0.93	0.933

n, sample size; TL, total length; BW, body weight; SL, standard length; *a*, intercept; *b*, slope; CL, confidence limit for mean values; r^2, coefficient of determination

The results explained a strong correlation between TL and BW, showing a significant relationship between these two variables, which was further sustained by the visual representation in Fig. 3. Moreover, Table 2 and Fig. 4 showed the LLR for TL *vs.* SL, indicating negative allometric growth and the high significance of the LLRs (p<0.0001) and contained a correlation coefficient (r^2<0.933).

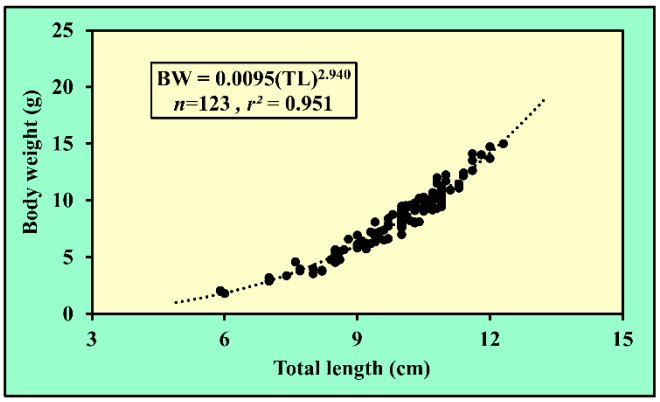

Fig. 3. Relationship between total length and body weight of *Macrospinosa cuja* in Babu Mondoler *beel*, Chapainawabganj, Bangladesh

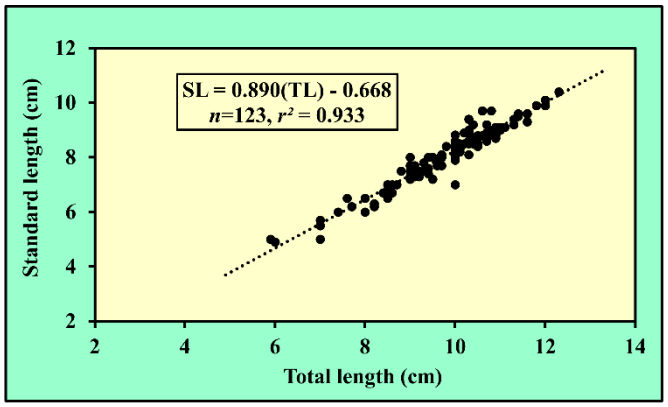

Fig. 4. Relationship between standard length and total length of *Macrospinosa cuja* in Babu Mondoler *beel*, Chapainawabganj, Bangladesh.

Condition factors

Table 3 contains all of the computed condition factors (K_A, K_F, K_R, and W_R). The outcomes of the Pearson rank correlation test from Table 4, outlined a robust connection between the condition factors (CF) and both the total length and body weight of *M. cuja*.

Table 3. Descriptive statistics on condition factors measurements and with their 95% CL of *Macrospinosa cuja* in Babu Mondoler *beel*, Chapainawabganj, Bangladesh.

Condition factors	Min	Max	Mean±SD	95% CL
K_A	0.7757	1.1834	0.9555 ± 0.0762	0.9419-0.9691
K_F	0.6837	1.0478	0.8336 ± 0.0671	0.8316-0.8456
K_R	0.8165	1.2457	1.0058 ± 0.0802	0.9915-1.0202
W_R	81.659	124.57	100.58 ± 8.0287	99.154-102.02

K_A, Allometric; K_F, Fulton's; K_R, Relative; W_R, Relative weight; CL, confidence limit

Table 4. Relationships of condition factor with total length (TL) and body weight (BW) of *Macrospinosa cuja* in the Babu Mondoler *beel*, Chapainawabganj, Bangladesh

Relationship	r_s values	95% CL of r_s	*p* value	Signif-icance
TL *vs.* K_A	-0.0005	0.1776 to 0.1765	0.9950	ns
TL *vs.* K_F	-0.1012	-0.2733 to 0.0773	0.2656	ns
TL *vs.* K_R	-0.0005	-0.1776 to 0.1766	0.9955	ns
TL *vs.* W_R	-0.0005	-0.1776 to 0.1766	0.9955	ns
BW *vs.* K_A	0.2244	0.0492 to 0.3861	0.0126	*
BW *vs.* K_F	0.1280	-0.0501 to 0.2984	0.1581	ns
BW *vs.* K_R	0.2244	0.0492 to 0.3861	0.0126	*
BW *vs.* W_R	0.2244	0.0492 to 0.3861	0.0126	*

Condition factors (K_A, Allometric; K_F, Fulton's; K_R, Relative); r_s, coefficient of spearman rank correlation test values; CL, confidence limit; ns, not significant; * significant; *p*, exhibitions the intensity of significance

Prey-predator status

The relative weight (W_R) of (100.58 ± 8.0287) for *M. cuja* in the Babu Mondoler *beel* wetland ecosystem did not exhibit a significant difference from 100 (p = 0.0078) (Table 3).

Form factor ($a_{3.0}$)

The form factor ($a_{3.0}$) of *M. cuja* in the Babu Mondoler *beel* wetland ecosystem was 0.0079, which indicates an elongated body with a terminal mouth.

Size at first sexual maturity (L_m)

The L_m was calculated as 7.00 cm TL, with 95% CL = 5.67-8.73 cm.

Mortality and exploitation rate

The mortality of *M. cuja* in the Babu Mondoler *beel* was determined using the slope of the length converted catch curve, where natural mortality rate (M_w) was measured to be 1.30 year^{-1} (Fig. 5). The overall mortality and fishing rates that were established were used to assess the exploitation rate in the following manner: E=0.29.

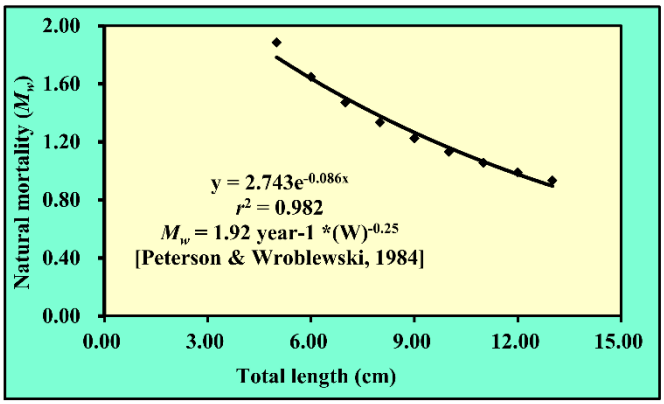

Fig. 5. Length converted catch curve of *Macrospinosa cuja* in Babu Mondoler *beel*, Chapainawabganj, Bangladesh

Discussion

There is very little information on *M. cuja* population parameters in literature from Bangladesh and other countries. An investigation was done by Lal Mohan (1981) on the important biological parameters of *M. cuja*. However, the focus of this study was on the population parameters of *M. cuja*, including its population structure, growth pattern, best condition factor, relative weight (W_R), form factor ($a_{3.0}$), size at first sexual maturity (L_m), mortality, and exploitation rates from the Babu Mondoler *beel*, NW Bangladesh. Using traditional fishing gears such as cast net, *moiya jal* etc., a variety of 123 specimens of *M. cuja* with various body sizes were obtained, advancing our understanding of the species. The maximum length of *M. cuja* was 12.3 cm in the current study, which was significantly less than the maximum length of 150 cm documented by Huda et al. (2003) in the Sundarbans, Bangladesh. The geographic condition and the accessibility of food might have contributed to this variation (Hossain and Ohtomi 2010). According to Hossain et al. (2017), Parvin et al. (2018) and Rahman et al. (2023), comprehensive information is required for precisely calculating population parameters, including L_∞, L_m, and K, which are necessary for planning and managing fisheries resources.

Fulton (1904) showed that in LWRs, the b values should ideally remain between 2.5 and 3.5. According to Tesch (1971), the b >3 showed positive and b <3 showed negative allometric growth. In the Babu Mondoler *beel*, NW Bangladesh, the present investigation discovered that the b value for *M. cuja* was 2.94, ranging from 2.83 to 3.04 (95% CL of b), indicating negative allometric growth. Bhakta et al. (2019) reported that the b-value for *Otolithoides pama* in the estuarine system of Hooghly-Matlah, West Bengal, India, varied between 2.8072 and 2.9098. Purushottama et al. (2018) stated that the b value was 2.9 in the study LWRs of ten tropical finfish species from the northeastern Arabian Sea, India, showing similar growth patterns to this study. In contrast, the b value of *O. pama* was 3.17 in a previous study by Nath et al. (2004) on the Hooghly Estuarine System's biological flux, fisheries resources, and production potential, different from the negative allometric growth discovered in the current study. It is important to note that the data on *M. cuja* were gathered over a long period of time and did not relate to any distinct season. It is suggested that while comparing these statistics, one should regard them as typical yearly values as compared with seasonal changes. In this study, the LLR of *M. cuja* showed a high degree of correlation. The capacity for comparison, these results with other studies in the field is however constrained because there hasn't been a study that specifically addresses LLR.

To find out the physiological condition and current status of *M. cuja* in the Babu Mondoler *beel*, our attention was directed towards four condition factors (K_A, K_F and K_R) and prey-predator status (W_R). These variables were used as indicators to evaluate the

research area's ecological suitability and the general welfare of the species. The condition factors showed a highly significant relationship with BW when using Pearson rank correlation test. This suggested that these condition factors were accurate predictors of the weight and bodily condition of *M. cuja* in the investigation zone. Examining the correlation coefficients revealed that the relative condition factor had the highest value, indicating that it was more useful than other variables in predicting the health of *M. cuja* in the Babu Mondoler *beel*, Bangladesh. This showed that the K_R offered the most accurate measurement of this specimen's well-being in the research area. Additionally, our research discovered that the relative weight of *M. cuja* in the Babu Mondoler *beel* wetland ecosystem remained noticeably constant from 100 (p = 0.0078). This suggests that the habitat is balanced, with sufficient food and predators to sustain the species.

Scholars can evaluate and compare the differences in the structure of the body among various populations or species by examining the $a_{3.0}$, which can shed light on potential morphological and adaptive differences (Froese 2006; Rahman and Ohtomi 2021). *M. cuja* had a moderately elongated body form from the Babu Mondoler *beel*, a wetland ecosystem in NW Bangladesh, as it had the $a_{3.0}$ value of 0.0079. No previous references to the form factor ($a_{3.0}$) of this particular species were found in the existing literature. Therefore, this study served as a starting point for further research in this field by laying the foundation. The findings would lay the groundwork for additional research in this area and aid in understanding the species' form factor. According to the research done in the Babu Mondoler *beel*, the L_m of *M. cuja* measured 7.0 cm.

The natural mortality rate in our study was 1.30 years^{-1}. This calculation provided insightful information about the parameters of the *M. cuja* population in that particular area. The dearth of comprehensive literature on natural mortality makes it difficult to draw insightful conclusions from comparisons with another research pertaining to M_w of *M. cuja*. The E of *M. cuja* was calculated to be 0.29. The population of the species was looking under fishing because the exploitation rate is 29%. So, the fishing effort should be increased to develop the population stocks in our investigation area. Underfishing occurs when the exploitation rate is below the level that would maximize the sustainable yield from a fishery. In other words, it suggests that the fishing effort is not fully utilizing the available fish stock, potentially leading to missed economic opportunities (Sabbir et al. 2021).

Conclusion

This study has provided significant information about the population characteristics of *M. cuja* within a wetland ecosystem in NW Bangladesh. It has created a strong basis for future studies into this species and set the stage for future study. The findings suggest that the population in this wetland ecosystem is currently stable and sustainable. However, it is essential to maintain ongoing intensive conservation efforts to guarantee the prolong survival of this ecologically important species.

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Author contribution statement

Md. Mizanur Rahman: Conceptualization, Formal analysis and writing original draft. Tariq-Al-Kasif, Obaidur Rahman, Sohag Molla, Mst. Afia Sultana: collected and analyzed the data. Azhar Mahmud Azmi, Md. Sumon Hossain, Taiba Akter Laboni, Mst. Shahinur Khatun: analyzed the data and wrote the manuscript. Sadaf Tabassum and Dalia Khatun: reviewed and edited the manuscript.

Conflict of Interests

The authors state that there isn't any conflict of interest to the current paper's publication.

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