Research Article

First Report on Temporal Variation of Conditions of *Clupisoma garua* in the Ganges River Through Multiple Functions

Taiba Akter Laboni[1], Md. Akhtar Hossain[1,2], Mst. Shahinur Khatun[1,2], Md. Golam Sarwar[1,2], Nur-E-Farjana Ilah[1], Kamruzzaman[1,2], Tasnim Akter Akhi[1,2], Mst. Meherun Nesa[1,2] and Md. Yeamin Hossain[1*]

[1]Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh; [2]Institute of Natural Resources Research and Development, Rajshahi 6206, Bangladesh.

Abstract | The Garua bacha, scientifically known as *Clupisoma garua*, is a fish species of significant commercial and nutritional value. This research presents the initial exploration of condition factors, including Fulton's condition factor (K_F), allometric condition factor (K_A), relative condition factor (K_R) and relative weight (W_R) of *Clupisoma garua* in the Ganges River, northwestern region of Bangladesh using 12-months data. A total of 1200 individuals (630 male and 570 female) were taken from May 2017 to April 2018. Body weight (BW) and the total length (TL) were determined using a digital scale and measuring board, respectively, with an accuracy of 0.01 g and 0.01 cm. LFD showed TL for males ranged from 3.8 to 25.9 cm, while for females, it ranged from 3.9-26.3 cm. The report showed negative allometric growth of this species. K_F values of males were 0.511 to 1.713, while females ranged from 0.519 to 1.669. In contrast, K_A fluctuated from 0.034-0.004 for male and 0.032-0.004 for female individuals. Moreover, K_R ranged from 0.845-1.312 for male and 0.873-1.447 for female individuals. Yet, W_R for male sexes ranged from 39.89-131.18 and 83.67-129.28 for females. The K_F values of male and female *C. garua* exhibit a significant correlation with TL and BW relationships. The mean relative weight (W_R) which indicating an imbalanced condition between food supply and predators for this species. Male and female sexes of *C. garua* had form factors ($a_{3.0}$) of 0.0061 and 0.0063 respectively, indicating the fish was elongated. Consequently, this study will provide valuable insights for fisheries biologists and environmentalists to establish sustainable management practices for *C. garua* in the Ganges River and its adjacent environs.

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***Correspondence** | Md. Yeamin Hossain, Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh; **Email:** yeamin.fish@ru.ac.bd
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Introduction

The Garua Bachcha, scientifically referred to as *Clupisoma garua* belongs to the Schilbeidae family within the order Siluriformes (Ullah, 2022). The Garua Bachcha commonly known as the Ghaura or the Muribacha in the country of Bangladesh (Table 1). The geographic distribution of *C. garua* encompasses India, Bangladesh, Pakistan, Nepal and Burma (Bhuiyan, 1964; Day, 1878; Jayaram, 1981; Mishra, 1959; Talwar and Jhingran, 1991). This species is predominantly encountered in lacustrine environments, which may typically be found in bigger rivers and reservoirs, as well as in impoundments that are not moving. The majority of this species habitats are freshwater, where it lives as a bottom-dwelling species; however, brackish water abundance has also been reported. According to Verma and Serajuddin (2017), *C. garua* is commonly observed moving in cohesive groups referred to as shoals, traversing various waterways such as canals, Rivers, streams, lakes, reservoirs and swamplands. These water bodies encompass both freshwater and brackish water environments. According to Nikolsky (1963), *C. garua* is categorized as a euryphagous fish. According to Nath (1994), this species of fish is extremely carnivorous and predatory in its natural environment. All types of consumers eat this fish, but low-income individuals are the most likely to do so because of the fish's high nutritional value. *C. garua* contains approximately 18.40% protein, 5.2% fat and 74.2% water content, making it a valuable food source (Bhuiyan, 1964; Memon *et al*., 2010). Moreover, this species is recognized for its pleasant flavor (Siddik *et al*., 2016; Verma and Serajuddin, 2017). Although the IUCN Red List Status classifies the species as Least Concern (IUCN, 2022), Bangladesh considers it to be endangered and takes necessary conservation measures (IUCN, 2015).

Table 1: *Common names and country list of Clupisoma garua.*

Common name	Country	Language
Garua bachcha	Global	English
River catfish	Bangladesh	English
Ghaura/ Gang gaira	Bangladesh	Bengali
Sillimoni	Finland	Finnish
Neria	India	Assamese
Garua bachcha	India	English

The length-frequency distribution (LFD) is a fundamental biometric tool widely used in various ecological and fisheries studies. It is instrumental in calculating growth rates, determining growth performance indices, and assessing fish mortality rates (Neuman and Allen, 2001). Additionally, LFD is critical for evaluating river health by estimating residual biomass and identifying breeding seasons (Laboni *et al*., 2024b; Ranjan *et al*., 2005). It also supports comparative analyses of physical traits among different species and examines population dynamics of a single species across diverse aquatic ecosystems (Ilah *et al*., 2023).

Moreover, length-weight relationships (LWRs) are significant biometric indicators used to compare and analyze various biological conditions. They are particularly valuable as they enable the estimation of weight based on length measurements, which is especially useful when direct weight measurements in the field are impractical or time-consuming. The parameters obtained from LWRs play a critical role in fish biology, offering valuable insights into the status of fish stocks (Khatun *et al*., 2023; Laboni *et al*., 2024a). Additionally, LWRs serve as an essential tool for understanding population growth patterns and dynamics.

The condition factor is commonly calculated to assess the overall health, productivity, and physiological state of fish populations (Richter, 2007). It also offers valuable information about physiological condition, such as body shape, lipid content, and growth rates (Froese, 2006; Rypel and Richter, 2008). Among these metrics, the relative condition factor (K_R) remains a practical and widely used tool for biologists and fisheries managers to evaluate the health of fish stocks. Additionally, morphometric relationships, such as length-weight relationships (LWRs), along with relative condition factor (K_R), Fulton's condition factor (K_F), and allometric condition factor (K_A), are key biological parameters for studying condition or health status of fish populations. The relative weight (W_R) approach is frequently utilized to analyze fish populations within specific ecosystems, particularly in understanding their roles as either prey or predator (Rypel and Richter, 2008). Furthermore, variations in body shape among different fish species or populations can be identified using the form factor (Froese, 2006).

The author acknowledges a limited number of studies conducted on *C. garua*, with notable examples including research on the variation in the life history of this Schilbid catfish species in coastal waters (Siddik *et al*., 2016), the length weight relationship (Sani *et al*., 2016), the impact of gonadal weight on length weight relationship (Akter *et al*., 2019), modes of reproduction (Breder *et al*., 1966) and genetic characterization (Sarawat *et al*., 2013) (Table 2).

Table 2: *Available work on different aspects of Clupisoma garua world wide.*

Aspects	Habitat /Country	References
Length weight relationship	Gomti River, India	Sani *et al.* (2016)
Impact of Gonad weight on the length weight relationships	Old Brahmaputra River, Bangladesh	Akter *et al.* (2019)
Modes of reproduction	Neptune City, New Jersey	Breder *et al.* (1966)
Genetic characterization	Ganga, Gomti, Betwa, Gandak and Brahmaputra, India	Sarawat *et al.* (2014)
A Comprehensive Impression	Bangladesh	Ullah (2022)
Variation in the life-history traits of a Schilbid catfi sh	coastal waters of southern Bangladesh	Siddik *et al.* (2017)
Stock Structure	southern coastal zone of Bangladesh	Nahar *et al.* (2017)

There is an immediate need to manage and control of the numerous distinct stocks of *C. garua* in the investigated region since this species is crucial to small-scale inland capture fisheries. Consequently, the purpose of this research is to provide a comprehensive description of *C. garua* by examining its various functional aspects and condition factors, encompassing K_F, K_A, K_R and W_R based on twelve months of repeated sampling effort conducted in the Ganges River of Bangladesh.

Materials and Methods

Sampling and measurement

This research was conducted in the Nawabganj area of northern Bangladesh, which is located at a latitude of 24° 65' N and a longitude of 88° 06' E. (These coordinates may be found on a map) (Figure 1). From May 2017 to April 2018, monthly sampling were done on the individuals (*C. garua*) from a variety of locations in Rajshahi, in the Northwestern region of Bangladesh. These locations included Godagari, Shaheb Bazar, Jahajghat, Charghat and Yusufpur, as well as Bagha. The fish specimens were captured using traditional fishing equipment, including cast nets, Seine nets and gill nets. To preserve their freshness, after being immediately frozen with ice at the location, the specimens were transported to the laboratory where they were fixed in a solution of formalin containing 5% to ensure proper fixation. The necessary length measurements of each individual were taken using digital slide calipers with an accuracy of up to 0.01 cm, while their body weight was recorded using an electric balance with a precision of 0.01 g. These meticulous measurement techniques were employed to ensure accurate and precise data collection, enabling comprehensive analyses and investigations in the laboratory environment.

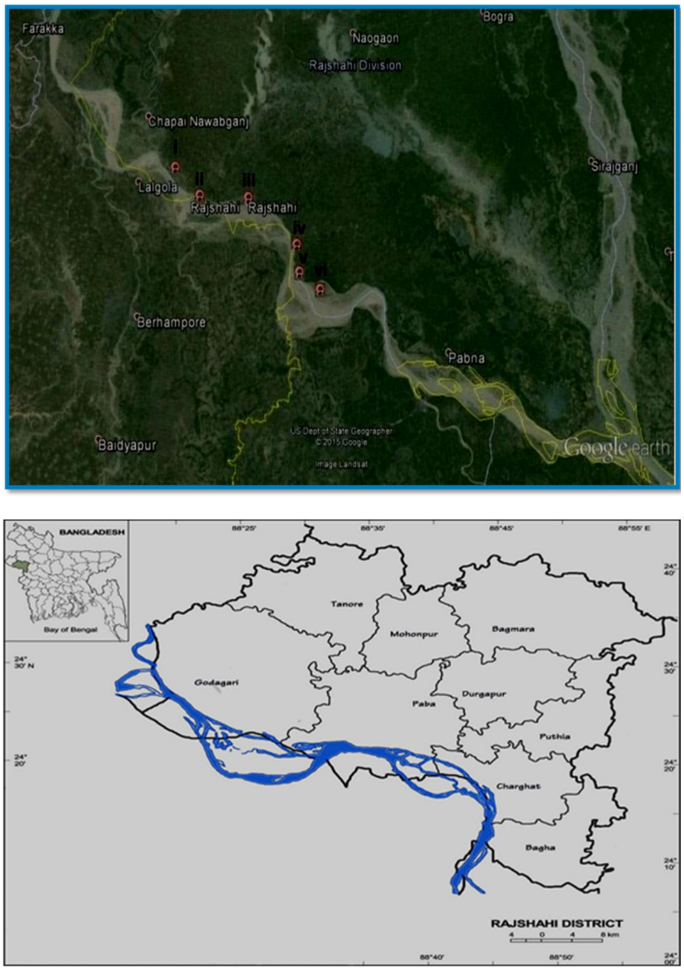

Figure 1: *Satellite view of study area, collected image is from in Google earth map and the following figure is general map view.*

Length–frequency distribution (LFD)

The estimation of fish age and growth necessitates the utilization of length-frequency distributions. To analyze the *C. garua* population, the length-frequency distributions (LFD) were utilized, whereby the total length (TL) was compared within 1.0 cm class intervals.

Length-weight relationships (LWR)

The length-weight relationship was determined using the following equation: BW = a*(TL)^b, where BW represents A total body weight measured in grams, and TL corresponds to A total length measured in centimeters. To calculate the parameters *a* and *b* in the linear regression analysis, natural logarithms were utilized: ln (BW)= ln (*a*) + *b* ln (BW) (TL). In accordance with Froese's Research (2006), the regression analysis was conducted after excluding severe outliers.

Condition factors

Various formulas were employed to assess the condition factor in different studies. Fulton's condition factor, based on the equation proposed by Fulton (1904), can be calculated as follows: K_F = 100 (W/L^3); while W represents the weight of the whole body in grams, and L represents the total length in centimeters. The scaling factor of 100 is applied to standardize K_F. To determine the relative condition factor (K_R), (Le Cren, 1951) equation is utilized: K_R = W/(a*L^b); where W denotes the body weight, L represents the total length and *a* and *b* are the parameters for length-weight relationships (LWR). Tesch's equation from 1968 is employed to obtain the allometric condition factor, K_A = W/L^b; where W is the weight of the body, L is the total length and *b* is the parameter for LWR. The relative weight (W_R) can be derived using Froese's formula: W_R is calculated as $W = (W/W_S) * 100$; where W represents the observed body weight of an individual and W_S is the prospective standard body weight for the similar species. W_S is calculated using the equation: $W_S = a * L^b$, where *a* and *b* are the parameters for TL and BW relations.

Form factor ($a_{3.0}$)

The formula presented by Froese (2006) was utilized to determine the form factor for *C. garua* as follows: $a_{3.0} = 10^{\log a - s\,(b-3)}$. In this equation, *a* and *b* represent LWRs parameters, while *s* denotes the slope of the regression line that compares the natural logarithm of *a* to *b*. However, due to insufficient data on LWRs for this particular species, it was not feasible to calculate the regression (S) of *ln a vs. b* accurately. Consequently, an average slope of -1.358 was employed as an approximation in this analysis to estimate the form factor. This approach was done so that the form factor could be calculated. This was done due to the necessity of having adequate evidence on LWRs in order to determine the regression (S) of *ln a vs. b.*

Statistical analysis

Graph Pad Prism 8.0 was used for statistical analysis. The relationships between condition factors with TL and BW was investigated through the utilization of the Spearman rank correlation test. In order to distinguish it from average relative weight (W_R), which is set at 100, a Wilcoxon sign-ranked test was conducted (Anderson and Neumann, 1996). Every single statistical test was run at a significance level of 5% (p < 0.05), which is the accepted standard. This approach ensured that the analysis remained independent and unbiased, allowing for a comprehensive examination of the relationship between the condition factors with the variables TL and BW.

Results

Length–frequency distribution

Fishers on the Ganges River in Northern Bangladesh supplied us with 1200 fish specimens that we randomly gathered on occasion. Table 3 provides a summary of the length and weight measurements for *C. garua*, along with their corresponding 95% confidence intervals (CI). The statistical data presented in this table offer valuable insights into the characteristics of the species. During the investigation, the TL ranged from around 3.8 to 25.9 centimeters for males, 3.9 to 26.3 centimeters for females, while the BW ranged from around 19.5 to 106.57 grams for males and 20.07 to 125.41 grams for females. In accordance with length frequency distribution, the TL size that ranged from 15.99 to 17.99 centimeters had a statistically top ranking for the male individual (Figure 2); whereas the TL size that ranged from 14.99 to 17.99 centimeters had a statistically top ranking for the female individual.

Table 3: *Descriptive statistics on the length (cm) and weight (g) measurement of C. garua.*

Measurement		*n*	Min	Max	Mean ± SD	95% CL
Male	TL	1200	3.8	25.9	11.39±3.81	10.41-12.37
					19.75±3.26	18.85-20.64
	BW		0.94	106.57	52.83±24.26	46.14-59.52
					25.65±21.11	20.25-31.06
Female	TL	1200	3.9	26.3	11.46±3.86	10.21-12.71
					21.10±3.44	20.09-22.11
	BW		0.99	125.41	66.37±29.50	57.71-75.03
					26.51±24.79	18.48-34.54

Length-weight relationships (LWRs)

Table 4 and Figure 3 present an important information regarding the sample size (n), regression parameters

Table 4: *Descriptive statistics and estimated parameters of the length-weight relationships ($BW = a \times TL^b$) of the Clupisoma garua (Hamilton, 1822) in the Ganges river, Northwestern Bangladesh.*

Month	Sex	N	Regression parameters		95% CL of a	95% CL of b	r^2	GT
			a	*b*				
May	M	53	0.0295	2.52	0.0221-0.0395	2.41-2.62	0.980	-A
	F	47	0.0189	2.66	0.0142-0.0251	2.56-2.76	0.985	-A
June	M	45	0.0060	3.03	0.0047-0.0078	2.94-3.11	0.991	I
	F	55	0.0147	2.72	0.0115-0.0189	2.64-2.80	0.980	-A
July	M	43	0.0084	2.91	0.0067-0.0104	2.84-2.98	0.992	-A
	F	57	0.0092	2.89	0.0068-0.0123	2.80-2.99	0.988	-A
August	M	45	0.0070	3.00	0.0051-0.0095	2.90-3.11	0.987	I
	F	55	0.0108	2.85	0.0082-0.0142	2.76-2.94	0.986	-A
September	M	56	0.0303	2.69	0.0271-0.0339	2.64-2.73	0.996	-A
	F	44	0.0203	2.83	0.0188-0.0220	2.80-2.87	0.998	-A
October	M	52	0.0100	2.84	0.0082-0.0122	2.76-2.91	0.990	-A
	F	48	0.0087	2.89	0.0069-0.0109	2.81-2.98	0.989	-A
November	M	56	0.0097	2.83	0.0081-0.0116	2.76-2.90	0.993	-A
	F	44	0.0088	2.87	0.0073-0.0106	2.80-2.93	0.994	-A
December	M	51	0.0050	3.07	0.0041-0.0059	3.01-3.14	0.995	I
	F	49	0.0044	3.12	0.0036-0.0053	3.05-3.19	0.993	+A
January	M	54	0.0098	2.82	0.0079-0.0122	2.74-2.90	0.989	-A
	F	46	0.0088	2.87	0.0069-0.0111	2.78-2.95	0.990	-A
February	M	52	0.0076	2.95	0.0056-0.0103	2.83-3.06	0.983	-A
	F	48	0.0135	2.72	0.0097-0.0188	2.76-2.84	0.979	-A
March	M	51	0.0278	2.51	0.0203-0.0380	2.40-2.62	0.977	-A
	F	49	0.0213	2.59	0.0154-0.0296	2.48-2.70	0.978	-A
April	M	52	0.0090	2.90	0.0074-0.0110	2.83-2.96	0.993	-A
	F	48	0.0217	2.59	0.0179-0.0265	2.52-2.66	0.992	-A

M, Male; F, Female; n, Sample Size; a, Intercept; b, Slope ; CL, 95% confidence limit; GT, growth type.

of length-weight relationships along with their 95% confidence limits (CL) and determination of coefficient. Also, these studies clarify the development pattern of *C. garua* (r^2). Estimated values of *b* were indicated that this species had an allometric growth pattern (TL vs. BW).

Fulton's condition factor (K_F)

The lowest K_F standard for males was 0.511 in December when the highest possible standard was 1.713 in September (Table 5 and Figure 4). On the other side, the lowest possible K_F value for females was 0.519 in December, while the highest possible value was 1.669 in September. Significant differences in K_F (condition factor) were observed between male and female individuals during the research work.

Relative condition factor (K_R)

Relative condition factor for males ranged from a high of 1.312 in October to a low of 0.845 in December. As opposed to, the lowest K_R values for female sexes were 0.837 during the months of October and the highest K_R value was 1.447 in January (Table 6). Mann-Whitney U-test (non-parametric) revealed statistically variations in K_R between male and female sexes. These findings indicate notable variations in the condition of male and female individuals.

Relative weight (W_R)

The lowest and highest values of W_R for male sexes occurred in the months of June and October, respectively. These values were 39.89 and 131.18 (Table 7 and Figure 5). On the other end, the lowest and highest potential W_R for females during the month of October were 83.67 and 129.28 respectively. The results of the one-sample t-test demonstrated a significant deviation of the relative weight from 100 for both male and female individuals.

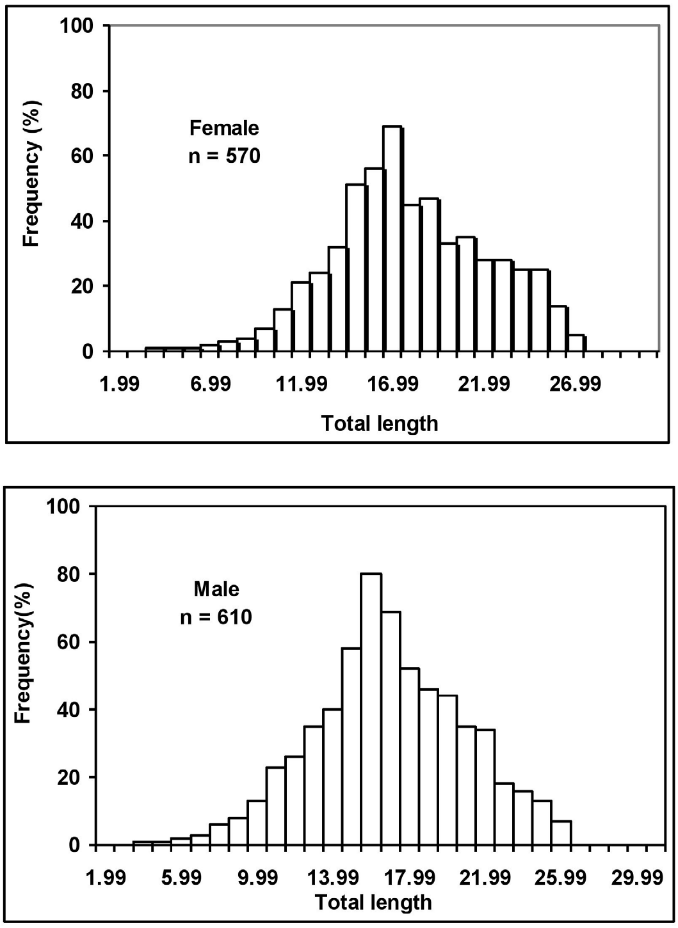

Figure 2: *Length frequency distributions of Clupisoma garua in the Ganges river, Northwestern Bangladesh.*

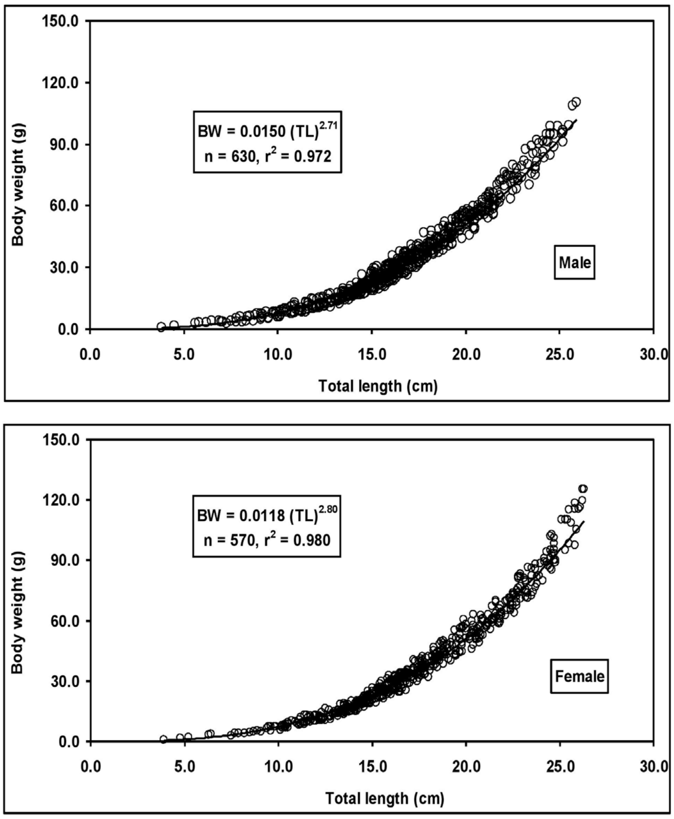

Figure 3: *Relationships between total length (TL) and body weight (BW) of Clupisoma garua in the Ganges river, Northwestern Bangladesh.*

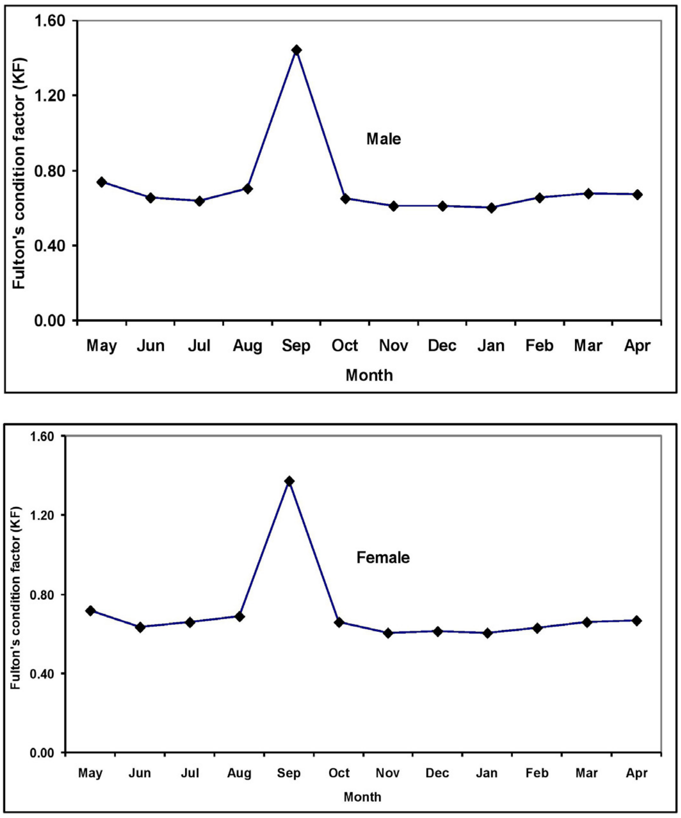

Figure 4: *Monthly variations of Fulton's condition factor for Clupisoma garua in the Ganges river, northwestern Bangladesh.*

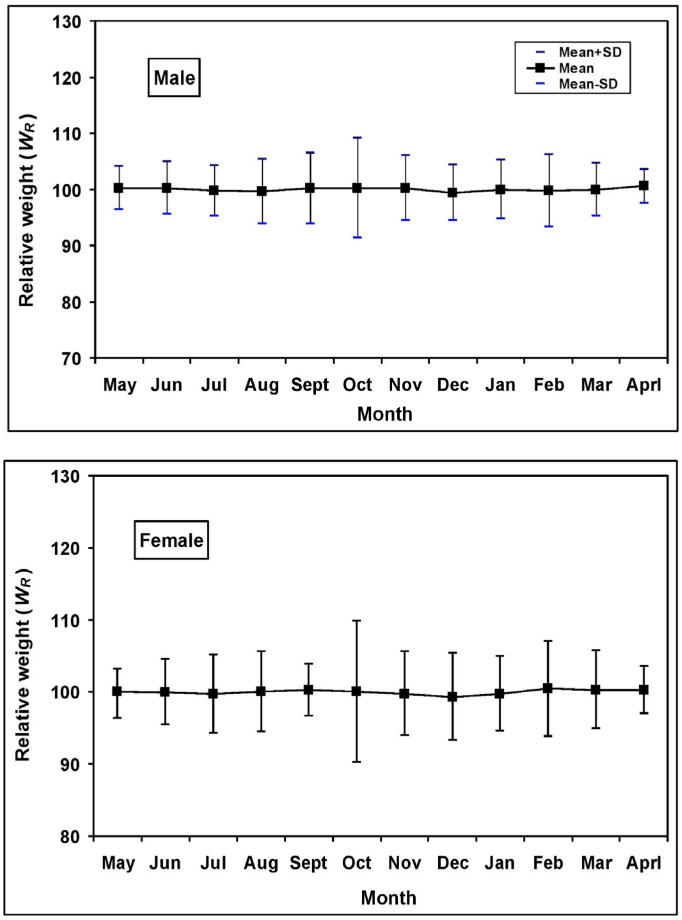

Figure 5: *Relationships between mean total length and relative weight of Clupisoma garua in the Ganges river, northwestern Bangladesh.*

Table 5: *Descriptive statistics on Fulton's condition factor (K_F) measurements and their 95% confidence limits of the Clupisoma garua (Hamilton, 1822) in the Ganges river, Northwestern Bangladesh.*

Month	Sex	n	Fulton's condition factor (K_F)			
			Min	Max	Mean ± SD	95% CL
May	M	53	0.665	0.860	0.7389±0.0483	0.7246-0.7512
	F	47	0.662	0.808	0.7173±0.0330	0.7076-0.7270
June	M	45	0.593	0.732	0.6576±0.0305	0.6489-0.6663
	F	55	0.576	0.713	0.6342±0.0411	0.6225-0.6459
July	M	43	0.596	0.706	0.6400±0.0300	0.6317-0.6483
	F	57	0.573	0.759	0.6607±0.0383	0.6494-0.6719
August	M	45	0.625	0.776	0.7055±0.0405	0.6929-0.7182
	F	55	0.611	0.772	0.6879±0.0421	0.6769-0.6990
September	M	56	1.080	1.713	1.4447±0.1754	1.3998-1.4896
	F	44	1.170	1.669	1.3716±0.0985	1.3397-1.4035
October	M	52	0.566	0.878	0.6500±0.0678	0.6422-0.6778
	F	48	0.570	0.870	0.6605±0.0705	0.6400-0.6809
November	M	56	0.537	0.718	0.6129±0.0440	0.6011-0.6247
	F	44	0.545	0.741	0.6049±0.0422	0.5921-0.6177
December	M	51	0.511	0.673	0.6102±0.0322	0.6008-0.6196
	F	49	0.519	0.696	0.6135±0.0411	0.6021-0.6250
January	M	54	0.551	0.715	0.6040±0.0378	0.5938-0.6142
	F	46	0.537	0.706	0.6032±0.0350	0.5927-0.6138
February	M	52	0.579	0.746	0.6543±0.0425	0.6425-0.6661
	F	48	0.549	0.736	0.6291±0.0506	0.6144-0.6438
March	M	51	0.583	0.771	0.6800±0.0524	0.6653-0.6948
	F	49	0.573	0.755	0.6584±0.0524	0.6434-0.6735
April	M	52	0.626	0.718	0.6724±0.0222	0.6663-0.6786
	F	48	0.576	0.765	0.6689±0.0443	0.6561-0.6818

M, Male; F, Female; Min, Minimum; Max, Maximum; SD, Standard Deviation.

Allometric condition factor (K_A)

Allometric condition factor (K_A) values ranged from high of 0.034 in September to low of 0.004 in December for male sexes (Table 8). The lowest K_A values for female was 0.032 in May to the highest value was 0.004 in December. Using a non-parametric Mann-Whitney U-test, we found that K_A differed significantly between male and female individuals (Table 9).

Form factor ($a_{3.0}$)

Table 10 presents the calculated form factors ($a_{3.0}$) for male and female fish in the Ganges River, located in northwestern Bangladesh. The form factor was determined to be 0.0061 for male individuals and 0.0063 for female individuals. These results provide important information regarding the body shape and proportions of the studied fish populations.

Discussion

There is very little information on the condition factor of *C. garua* that can be found in any of the existing literature from Bangladesh or anywhere else. As a result, the current study is the first attempt to define the temporal variation of conditions of *C. garua* originating from the Ganges River, northwestern in Bangladesh, including LFD, LWR, and $a_{3.0}$. During the twelve-month sampling period, we collected a total of 1200 specimens of different body sizes using locally available equipment. Out of these, 630 specimens were male, and 570 specimens were female.

In total, 1200 specimens of varying body sizes were sampled for doing this particular research. Nevertheless, it proved troublesome to collect fishes lower than 3.8 cm and larger than 26.3 cm in length. This may be because fishers did not use the appropriate

Table 6: *Descriptive statistics on Relative condition factor (K_R) measurements and their 95% confidence limits of the Clupisoma garua (Hamilton, 1822) in Ganges river, northwestern Bangladesh.*

Month	Sex	*n*	Relative condition factor (K_R)			
			Min	Max	Mean ± SD	95% CL
May	M	53	0.925	1.086	1.0022±0.0384	0.9917-1.0128
	F	47	0.946	1.081	1.0002±0.0317	0.9909-1.0095
June	M	45	0.908	1.123	1.003±0.0465	0.9893-1.0157
	F	55	0.899	1.081	1.000±0.0454	0.9867-1.0126
July	M	43	0.921	1.103	0.9982±0.0446	0.9859-1.0105
	F	57	0.870	1.138	0.9975±0.0544	0.9815-1.0103
August	M	45	0.870	1.082	0.9821±0.0564	0.9645-0.9996
	F	55	0.893	1.089	1.0007±0.0556	0.9861-1.0153
September	M	56	0.839	1.109	1.0021±0.0624	0.9851-1.0180
	F	44	0.901	1.116	1.0029±0.0362	0.9911-1.0146
October	M	52	0.848	1.312	1.0026±0.0887	0.9793-1.0259
	F	48	0.837	1.293	1.0006±0.0983	0.9721-1.0292
November	M	56	0.859	1.128	1.0022±0.0580	0.9867-1.0118
	F	44	0.871	1.201	0.9977±0.0580	0.9801-1.0154
December	M	51	0.845	1.104	0.9942±0.0500	0.9796-1.0087
	F	49	0.865	1.143	0.9933±0.0609	0.9764-1.0103
January	M	54	0.905	1.154	0.9995±0.0525	0.9853-1.0137
	F	46	0.891	1.447	0.9976±0.0514	0.9822-1.0131
February	M	52	0.872	1.130	0.9981±0.0640	0.9803-1.0160
	F	48	0.873	1.125	1.0044±0.0662	0.9851-1.0236
March	M	51	0.888	1.088	1.0000±0.0474	0.9867-1.0133
	F	49	0.856	1.109	1.0030±0.0541	0.9875-1.0185
April	M	52	0.947	1.0702	1.0057±0.0304	0.9972-1.0142
	F	48	0.922	1.0673	1.0026±0.0322	0.9933-1.0120

M, male; F, female; Min, minimum; Max, maximum; SD, standard deviation.

gear or because they skipped out the areas where larger fish are found (Hossain *et al*., 2016). According to Hossain and Ohtomi (2010), it is plausible that alterations in size could be attributed to fluctuations in environmental conditions, including water temperature and appearance of food. In the context of this research, the maximum total length (TL) observed for male *C. garua* was 25.9 cm, while for female it was 26.3 cm. Notably, these measurements are comparatively smaller than the highest documented TL values of 36.6 cm in the Betwa and Gomti Rivers in Karnataka and Uttar Pradesh, India (Sani *et al*., 2016), as well as 33 cm in the Gomti River in India (Kumar *et al*., 2014). Based on the results obtained from this investigation, the highest weight recorded for male specimens reached 106.57 g, while for female it reached 125.41 g. Nevertheless, it should be noted that the greatest body weight documented in coastal regions of Bangladesh was 128.80 g (Siddik *et al*., 2016). The assessment of the highest length of an individual holds paramount importance in the context of fisheries resource development and management (Hossain and Othomi, 2010).

Table 7: *Descriptive statistics on Relative Weight (W_R) measurements and their 95% confidence limits of the Clupisoma garua (Hamilton, 1822) in the Ganges river, Northwestern Bangladesh.*

Month	Sex	*n*	Relative weight (W_R)			
			Min	Max	Mean ± SD	95% CL
May	M	53	92.46	108.60	100.22±3.84	99.17-101.28
	F	47	94.63	108.06	100.02±3.17	99.09-100.95
June	M	45	39.89	49.22	44.15±2.05	43.57-44.74
	F	55	61.75	74.13	68.41±3.13	67.52-69.30
July	M	43	92.13	110.28	99.82±4.46	98.59-101.05
	F	57	86.99	116.81	99.75±5.44	98.15-101.34
August	M	45	88.23	109.69	99.64±5.72	97.85-101.42
	F	55	89.28	109.84	100.07±5.56	98.61-101.53
September	M	56	83.95	110.90	100.21±6.24	98.61-101.80
	F	44	90.13	111.64	100.29±3.62	99.11-101.46
October	M	52	84.85	131.18	100.26±8.87	97.93-102.59
	F	48	83.67	129.28	100.06±9.83	97.21-102.92
November	M	56	85.93	112.85	100.22±5.80	98.67-101.78
	F	44	87.12	120.09	99.77±5.80	98.01-101.54
December	M	51	84.55	110.40	99.42±5.00	97.96-100.87
	F	49	86.52	114.30	99.33±6.09	97.64-101.03
January	M	54	90.48	115.37	99.95±5.25	98.53-101.37
	F	46	89.08	114.70	99.76±5.14	98.22-101.31
February	M	52	87.23	112.99	99.81±6.40	98.03-101.60
	F	48	87.31	112.47	100.44±6.62	98.51-102.36
March	M	51	88.76	108.76	100.00±4.74	98.67-101.34
	F	49	85.56	110.86	100.30±5.41	98.75-101.85
April	M	52	94.69	107.02	100.57±3.04	99.72-101.42
	F	48	92.21	106.73	100.26±3.22	99.33-101.20

M, male; F, female; Min, minimum; Max, maximum; SD, standard deviation.

Stock condition can be evaluated using the growth parameter. The *b* value in the study was within the range of 2.5 to 3.5, which is consistent with the literature (Froese, 2006). According to Tesch (1971), when the b value is equal to 3, it indicates isometric growth. If the b value is greater than 3, positive allometric growth is observed, while b value is lower than 3 indicates negative allometric growth. Allometric coefficient *b* value of LWRs for *C. garua* was found to be 2.71, 2.80 and for male and female, indicating the negative allometric growth, while discussing the length-weight relationships of *C. garua*, it is worth noting that Sani *et al.* (2016) reported the *b* value of 3.10 for the similar individuals in the Gomti River in India. Conversely, Kumar *et al.* (2014) observed *b* value of 2.69 for the same individual in similar water body. Siddik *et al.* (2016) indicated that the *b* value for male in coastal water body of Bangladesh was 2.955, whereas for female it was 2.893. It is widely recognized that several variables impact the relationships of LWR in fish. These variables encompass the growth cycle, sex, season, rations (including quantity, quality and shaped), maturity stage, overall fish health and condition, conservation techniques and disparities in the noticed length ranges of captured individuals (Tesch, 1971; Hossain *et al.*, 2013a). Yet, it is noteworthy that none of these variables were accepted into account in the present investigation.

Table 8: *Descriptive statistics on Allometric condition factor (K_A) measurements and their 95% confidence limits of the Clupisoma garua (Hamilton, 1822) in the Ganges river, Northwestern Bangladesh.*

Month	Sex	*n*	Allometric condition factor (K_A)			
			Min	Max	Mean ± SD	95% CL
May	M	53	0.027	0.0320	0.0296±0.0011	0.0293-0.0299
	F	47	0.020	0.0320	0.0214±0.0007	0.0212-0.0216
June	M	45	0.006	0.007	0.0064±0.0003	0.0063-0.0065
	F	55	0.012	0.015	0.0135±0.0006	0.0134-0.0137
July	M	43	0.008	0.009	0.0084±0.0004	0.0083-0.0085
	F	57	0.008	0.010	0.0092±0.0005	0.0090-0.0093
August	M	45	0.006	0.008	0.0070±0.0004	0.0069-0.0071
	F	55	0.010	0.011	0.0108±0.0006	0.0107-0.0110
Sep-tember	M	56	0.025	0.034	0.0304±0.0019	0.0299-0.0308
	F	44	0.018	0.023	0.0204±0.0007	0.0201-0.0206
Octo-ber	M	52	0.008	0.013	0.0100±0.0009	0.0098-0.0103
	F	48	0.007	0.011	0.0087±0.0009	0.0084-0.0090
No-vember	M	56	0.008	0.011	0.0097±0.0006	0.0096-0.0099
	F	44	0.008	0.011	0.0088±0.0005	0.0086-0.0089
De-cember	M	51	0.004	0.006	0.0050±0.0003	0.0049-0.0050
	F	49	0.004	0.005	0.0044±0.0003	0.0043-0.0044
Janu-ary	M	54	0.009	0.011	0.0098±0.0005	0.0097-0.0099
	F	46	0.008	0.010	0.0088±0.0005	0.0086-0.0089
Febru-ary	M	52	0.007	0.009	0.0076±0.0005	0.0075-0.0077
	F	48	0.012	0.016	0.0136±0.0010	0.0133-0.0138
March	M	51	0.025	0.030	0.0278±0.0013	0.0274-0.0282
	F	49	0.018	0.024	0.0214±0.0012	0.0210-0.0217
April	M	52	0.009	0.010	0.0091±0.0003	0.0090-0.0091
	F	48	0.020	0.023	0.0218±0.0006	0.0216-0.0220

M, male; F, female; Min, minimum; Max, maximum; SD, standard deviation.

Table 9: *Relationships of condition factor with total length and body weight of Clupisoma garua in the Ganges river, northwestern Bangladesh.*

Relation-ships	Sex	r_s val-ues	95% CL of r_s	P values	Signif-icance
TL *vs.* K_A	M	0.2589	0.282-0.332	$P = 0.001$	*
TL *vs.* K_F		-0.232	-0.39 to -0.15	$P < 0.001$	***
TL *vs.* K_R		0.2798	0.2040-3523	$P = 0.003$	*
TL *vs.* W_R		0.2796	0.2037-0.35	$P = 0.003$	*
BW *vs.* K_A		0.3525	0.2800-4210	$P = 0.015$	ns
BW *vs.* K_F		-0.115	-1940 to-0.03	$P < 0.001$	***
BW *vs.* K_R		0.3875	0.3169-0.453	$P = 0.005$	*
BW *vs.* W_R		0.3872	0.3116-0.4535	$P = 0.001$	*
TL *vs.* K_A	F	0.1615	-0.24 to -0.07	$P = 0.001$	*
TL *vs.* K_F		-0.224	-0.30 to -0.14	$P < 0.001$	***
TL *vs.* K_R		0.2177	0.1357-0.296	$P = 0.003$	*
TL *vs.* W_R		0.2166	0.1345-0.2958	$P = 0.004$	*
BW *vs.* K_A		-0.161	-0.24 to -0.07	$P < 0.001$	***
BW *vs.* K_F		-0.124	-0.204 to -0.03	$P < 0.003$	***
BW *vs.* K_R		0.3166	0.2385-0.3907	$P = 0.035$	*ns*
BW *vs.* W_R		0.3156	0.2373-0.3897	$P = 0.001$	*

*ns, not significant; * significant; *** highly significant*

Table 10: *The calculated form factor, $a_{3.0}=10\log^{a-s(b-3)}$ for the C. garua of different habitats using available length-Weight relationship (LWR) parameters in the worldwide.*

Water body	Sex	Regression parameter		Form factor ($a_{3.0}$)	Reference
		a	*b*		
Gomti River, India	Unsexed	0.0056	3.10	0.0077	Sani *et al.* (2016)
Coastal waters of southern Bangladesh	Female	0.0101	2.89	0.006	Siddik *et al.* (2017)
	Male	0.0091	2.96	0.006	
Ganges River, Bangladesh	Female	0.0118	2.80	0.0063	Present study
	Male	0.0150	2.71	0.0061	

According to Froese (2006), provided a calculation of a value of $a_{3.0}$ is 0.01, suggesting that the body shape of the fish resembles an elongated cylinder. The fact that the $a_{3.0}$ value for male and female individuals in the Ganges River is 0.0061 and 0.0063, indicates that the *C. garua* species in the Ganges River has an elongated body shape. As opposed to, Siddik *et al.* (2016) indicated that the $a_{3.0}$ value for male and female individuals in coastal water body were 0.006 and 0.006 respectively. In accordance with findings of current research, this should be considered the first attempt to study *C. garua* in Ganges River, Bangladesh.

In the current study, various condition factor, namely K_F, K_R, K_A and W_R, were employed to evaluate the overall health and productivity of the *C. garua* population. To choose the most suitable condition factor, several condition factor were used. A fish population's condition factor provides information about its health within its natural ecology (Hossain *et al*., 2013b; Ilah *et al*., 2024). Moreover, it unveils diverse of bio-ecological relationships, such as the level of well-being, maturity and feeding behavior in relation to habitat suitability (Hossen *et al*., 2019).

In addition, the condition factor is a widely used biological indicator that indicates the entire health of a fish population. This index was developed for fish (Richter, 2007). A higher value of the condition factor indicates that the fish are in better condition, as supported by studies conducted by Hossain *et al*. (2017) and Maurya *et al*. (2018). Conversely, a lower value suggests that the environmental conditions are less favorable, as observed by Blackwell *et al*. (2000).

Furthermore, the condition factor serves as a widely employed biological metric, serving as an indicator of the overall health of a fish stock. The origins of this index can be attributed to Richter's (2007) regarding fish. When the condition factor exhibits a larger value, it suggests that the fish are in superior condition, as indicated by researches conducted by Hossain *et al*. (2017) and Maurya *et al*. (2018). Conversely, a lower value indicates the ambient situations are less friendly, as revealed by research conducted by Blackwell *et al*. (2000).

The Fulton's Condition Factor (K_F) is a widely used metric in fisheries science to assess the health, well-being, and nutritional status of fish populations. In this research, spearman rank correlation test discovered a strong and statistically significant association between the condition factor, specifically K_F and both total length (TL) and body weight (BW) for both male and female specimens. Throughout the study, it was observed that Fulton's condition factor (K_F) exhibited significantly higher values during the months spanning August to October. Yet, it was shown that the most favorable conditions were present throughout the September for both male and female individuals. K_F started rising after the month of May and kept doing so all the way through October. This may suggest that there are ample food reserves and a sustainable ecosystem state (Froese, 2006). According to the Le Cren (1951), the interplay among feeding habits, parasite diseases and physiological factors contributes to fluctuate the condition factor.

The relative weight (W_R) of an aquatic habitat influences the recruitment pattern of a fisheries community, as stated by Shulman and Ogden (1987). Values exceeding 100 imply an abundance of prey or a low consistency of predators, when standards below 100 signify a scarcity of prey or a high density of predators (Froese, 2006; Hossain *et al*., 2024). We found that average W_R for male and female individuals of *C. garua* were significantly different from 100, suggesting that ecosystem in the Ganges River is in an unbalanced state. Yet, in Bangladesh, this species of fish is listed as endangered (IUCN Bangladesh, 2015). Since the relative weight encompasses essential physiological aspects of life history trait, such as fat percentage and growth, it presents a reliable and convenient metric to evaluate health condition or well-being of fish populations. Additionally, it serves as a valuable tool to evaluate the population-level responses to ecosystem disturbances like climate change as revealed by research conducted by Rypel and Richter (2008). Furthermore, according to Offem *et al*. (2007), variations in food availability throughout different seasons can also affect these aspects.

In order to assess the health status of male and female participants within the resembling community, Froese (2006) suggested utilizing the relative condition factor (K_R) among these factors. In the current investigation, did not permit comparisons between populations unless those populations shared a fundamentally similar relationships between TL and BW. Additionally, the use of Fulton's condition factor, commonly referred to as K_F, may prove beneficial since it is independent on the parameters *a* and *b* of the length-weight relationship (LWR). In this study, we examined the overall health conditions and productivity of *C. garua* by employing multiple condition factor, including K_F, K_R and K_A.

Nevertheless, Siddik *et al*. (2016) documented that for the similar species in the coastal water body of southern Bangladesh, Fulton's condition factor was indicative of a decline in feeding conditions within the coastal water body. Furthermore, they found that W_R values were close to 100, suggesting a habitat characterized by a harmonious balance between supply of food and existence of predators (Anderson and Neumann, 1996). Yet, because it is first analysis of this species in the Ganges River, the results will serve as a baseline for comparison with subsequent studies.

Conclusions and Recommendations

This research provides fundamental data on the length-frequency distribution (LFD), length-weight relationships (LWRs), and form factor ($a_{3.0}$) of *C. garua*, while establishing a critical baseline for its condition factors (K_F, K_A, K_R, W_R) in the Ganges River, Bangladesh. The findings reveal that K_F values indicate most favorable conditions and high food reserves while W_R, K_R, and K_A provide additional insights into its physiological condition. Notably, the study highlights negative allometric growth and males and females exhibiting elongated body shapes. The mean relative weight (W_R) suggests an imbalance between food availability and predator pressure, underscoring the need for targeted conservation efforts. The findings equip fishery biologists, managers, and conservationists with essential tools to implement early management strategies and regulations, ensuring the sustainable conservation of *C. garua* populations in the Ganges River ecosystem. This research not only contributes to the scientific understanding of the species but also enhances the FishBase database, supporting global efforts in fisheries management and biodiversity conservation.

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Novelty Statement

This study provides the first comprehensive year-round assessment of *Clupisoma garua* in the Ganges River, revealing negative allometric growth, ecological imbalances, and an elongated body form, key insights for sustainable fisheries management and conservation.

Author's Contribution

Taiba Akter Laboni: Data analysis and manuscript writing.
Md. Akhtar Hossain: Data collection and writing
Mst. Shahinur Khatun: Data analysis.
Md. Golam Sarwar: Data collection and analysis.
Nur-E-Farjana Ilah: Data analysis
Kamruzzaman: Data collection and analysis.
Tasnim Akter Akhi: Data analysis.
Mst. Meherun Nesa: Manuscript writing.
Md. Yeamin Hossain: Data analysis and edited the whole manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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