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ORIGINAL RESEARCH ARTICLE

First record of important biological parameters of Badis badis: A small indigenous species in Bangladesh

Md. Rabiul Awal[1*], Subrina Nasrin[2], Md. Ashikur Rahman[1,3] and Md. Nahiduzzaman[1]

[1]Bangladesh Fisheries Research Institute, Freshwater Station, Mymensingh - 2201, BANGLADESH
[2]Department of Aquaculture, Bangladesh Agricultural University, BANGLADESH
[3]Chung-Ang University, South KOREA
[*]Corresponding author's E-mail: rahimel933@gmail.com

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ABSTRACT

A total of 286 *Badis badis* were collected from the Sutiyahali Reservoir in Mymensingh from January to December 2022, and their sex ratios, first sexual maturity, length-weight relationships and condition factors were evaluated. The weight and length of *B. badis* varied from 0.81 to 1.01g (0.89±0.30) and 4.08 to 4.60cm (4.36±0.31), respectively. Logistic curves depicting a sex ratio and 50% maturity (L_{50}) estimated at 4.5cm for females and 4.05cm for males, as well as males reaching first sexual maturity with a shorter length than females. Regression coefficients in every month differ significantly (*p<0.05*), according to the regression equations. Each month, the values of the exponent b were less than 3 (b<3), with the highest value of b recorded in August (2.80) and the lowest value recorded in January (2.33). This led to a monthly negative allometric growth being seen. A strong positive relationship is evident from the coefficient of determination (r^2) values, which ranged from 0.92-0.98 with an average of 0.961. During the study, the average condition factor (K_n) value for *B. badis* was found to be 1.02±0.13, which is a positive indicator of the fish's physical well-being. The condition factor values varied between 0.84 to 1.39, making it abundantly clear that *B. badis* are in good health and the waterbody is an ideal habitat for their survival. Relative condition factor (K_r) values, which varied between studies and ranged from 0.78 to 1.01, also exhibited a noteworthy difference (*p<0.05*). For its long-term management, the above findings will be very helpful.

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INTRODUCTION

The blue perch, *Badis badis*, also referred to as the "Napit koi" in local dialect, is a small indigenous species (SIS) in Bangladesh, which is also popular as an ornamental fish. The aquarium fish *B. badis* is one of the most sought-after native ornamental fish for both the domestic and international markets (Dutta *et al*., 2020). This species is only sparsely distributed in Bangladesh, India, Myanmar, Pakistan, and Sri Lanka (Talwar and Jhingran, 1991). According to Talwar and Jhingran (1991), it is observed in freshwater areas like rivers, ponds, and ditches. It is also present throughout Bangladesh in beels, ditches, ponds, and swamps (Rahman, 1989 and 2005). This species, which is found at the bottom of aquariums and only consumes live, moving organisms, is known as a lurking predator as well as it is also a column feeder that consumes mosquito larvae (Talwar and Jhingran, 1991). This species is endangered because of the destruction of its habitats (IUCN Bangladesh, 2000). This species is threatened by habitat loss and over exploitation, which has caused it to become endangered (IUCN Bangladesh, 2000). Fishery biology and stock assessment place a high value on the length-weight relationship of fish as these factors offer a statistical correlation that can be used to calculate the mean weight of fish in a given length (Beyer, 1987). In Bangladesh, the population and health of this species have been tracked using conventional methods. These include the LWR, a tool for estimating weight from the length, and the transformation of advancement-in-length equations into improvement-in-weight equations (Mansor *et al.*, 2012). Fish growth seasonality can be detected using LWR (Sangun *et al.*, 2007). Important evidence showing how environmental factors can affect fish development as well as growth is provided by the change in LWR (Tagarao *et al.*, 2020). To evaluate an individual's health and spot potential discrepancies between various unit stocks of the similar species, one can use the relationship between length and weight (King, 2007). A helpful index for tracking fish feeding frequency, age, and growth rates is the condition factor, also known as the wellbeing of fish (Oni *et al.*, 1983). This parameter changes as an outcome of the impact of physiological factors and changes throughout the fish's development at various stages (Le Cren, 1951). Furthermore, it's essential to comprehend the variables that influence a population's spawning size by measuring the size at first sexual maturity (Hossain *et al.*, 2013; Elahi *et al.*, 2017). There is currently no data existing on the sexual maturity and sex ratio of *B. badis* in Bangladesh. The length and weight parameters of the *B. badis* population were the primary goals of this research in order to compare the population characteristics of this species with earlier findings. The population's condition factor was additionally identified as something that makes a significant contribution as substantially as possible to the expanding information source for the species. Therefore, for the first time in Bangladesh, this investigation is an attempt to compile information on sexual maturity, sex ratio, LWR and condition factor of *B. badis*, which will undoubtedly aid fishery researchers, planners, and policy makers in the protection and management of the ornamental fish in Bangladesh's natural environment.

MATERIALS AND METHODS

Study area and period

During the months of January to December 2022, the study was conducted in the seasonal reservoir of Sutiyakhali, Mymensingh. Its flood area is about 3500 hectares and is located between latitude 24.72470325 and longitude 90.411994025 (Figure 1).

Collection of samples

The sampling period spanned twelve months, from January to December, and included the pre monsoon, monsoon, and post monsoon seasons. Small hand nets, drag nets, and occasionally traps were used by local fishermen to catch this fish species. The sample was collected in the first hours of the first week of the month and the samples were transported in polyethylene bags to the laboratory where total length (TL) and body weight (BW) measurements were taken and recorded.

Measurements of samples

Morphometric characteristics like the overall length, as well as the weight of the individual, were assessed right away after collection. The fish's overall length was measured using a measuring scale, from the tip of the anterior part of its mouth to its caudal fin, and was calculated to the closest centimeter. After being blot dried with a clean hand towel, the weight of the fish was determined. Weighing was done to the nearest gram (0.001g) using an electronic weighing balance.

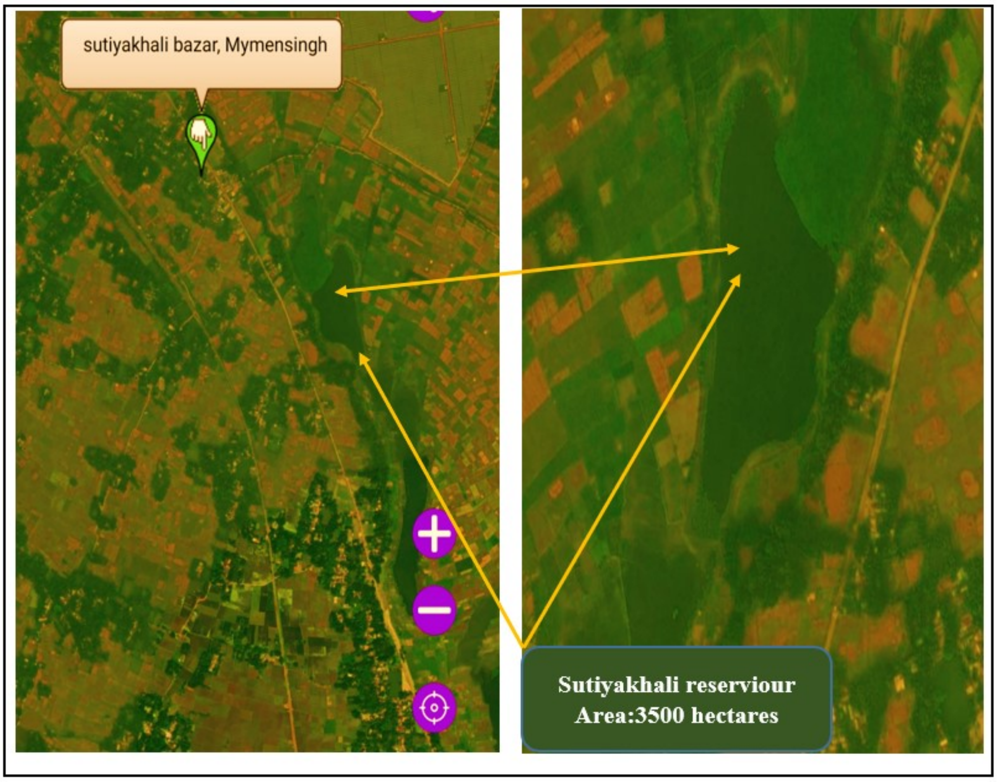

Figure 1. *Maps showing the study area (Source: Google earth).*

Parameters employed

Calculation of length-weight relationship

The subsequent equation was applied to measure monthly LWR of the fish (Panase and Mengumphan, 2015):

$W = aL^b$

Where, W is the fish's weight in grams, L is its overall length in centimeters and is the scaling constant that was determined through testing, and b is the growth component. It is said to be allometric growth if b is not exactly 3 and is either positive (if b>3) or negative (if b<3). If b is exactly 3, the growth is referred to as isometric (Imam *et al.*, 2010). The letters "a" and "b" stand for the point where the regression streak crosses the y -axis and the slope of the regression streak, respectively. The coefficient of determination (r^2) was used as a gauge of how accurate the linear regression was, as indicated by the value of "b".

Calculation of condition factor

The condition factor, which is heavily influenced by both biotic and abiotic environmental factors, is a crucial index for assessing feeding density, age, and rates of growth as well as the condition of an ecosystem where fish reside. The following equation was cast-off to calculate monthly condition factor (K_n) for *B. badis* (Fulton, 1904):

$K_n = 100\times W / L^3$

Where, K stands for the condition factor of fish, W stands for fish weight, L stands for fish length. Furthermore, "b" is the exponent of LWR.

Calculation of relative condition factor

The Le Cren (1951) equation was used to determine the relative condition factor (K_R) for each individual.

$K_R = W/ (aL^b)$

Where, W is the weight, L is the overall length, a is intercept and b is slope from LWR equation.

Calculation of sex ratio

The estimated sex ratio was calculated using the collected fish. Each fish's stomach was split open and through the anus to the lower jaw using scissors to determine the sex. The formula below can be used to calculate the sex ratio by counting the total amount of male and female fish.

$$\text{Female fish} = \frac{\text{No. of female fishes}}{\text{Total no. of fish}} \times 100$$

$$\text{Male fish} = \frac{\text{No. of male fishes}}{\text{Total no. of fish}} \times 100$$

Chi-square test (χ^2) determined whether a difference was significant. The following formula was used to perform a chi-square (χ^2) assessment (Sokal and Rohlf, 1995):

$\chi^2 = \sum O\text{-}E)\ 2\ /E$

Where, O = observed value and E = expected value

First sexual maturity

A logistic diagram was used to estimate the overall lengths at 50% maturity and to show the relationship for both length and maturity in size groups. The gonads of this fish were categorized in accordance with the Pollard (1972) description in order to determine its size at 50% maturity (L_{50}). The data was split into a variety of size classes, and estimates of the proportion of mature samples in every class of size were additionally estimated. Male and female fishes were found to be 50% sexually mature in the current study, and this percentage was found to be at a mature phase.

Data analysis

The intercept (a) and slope (b) were calculated from the collected data using Microsoft Office Excel 2016 software. Applying version 25 of the statistical software for the social sciences (SPSS), basic expressive statistics were also applied to the data, including minimum, maximum, mean, sample variance, Duncan's multiple range test, and 95% probability. With the help of Graph Pad Prism 6.0 software, the simple linear regression graphs were processed.

RESULTS AND DISCUSSION

There were 286 *B. badis* samples examined in total, 123 (43.71%) of which were female, and 161 (51.2%) of which were male (Table 1). The proportion of female to male is 0.78:1. During the study, the length and weight of *B. badis* varied from 4.08 to 4.60 cm (4.36±0.31) and from 0.81 to 1.01 g (0.89±0.30), respectively (Table 3). According to estimated logistic curves showing the relationship between sex and 50% maturity, females reached 4.50 cm, while 50% mature males were found at 4.05 cm (Figure 1). According to the findings, males were shorter than females when they attained their first sexual maturity. During the study, the regression equations based on body weight and length were calculated. Fish grow allometrically, as evidenced by the growth coefficient (b) values from linear regression, which were less than 3 (b<3). The lowest b value of 2.25 and the highest b value of 2.80, respectively, were found in January and August, respectively, and were followed by values of 2.31, 2.48, 2.51, 2.58, 2.59, 2.63, 2.66, 2.71, 2.73, and 2.74 in June, October, March, July, February, March, September, November, December, and April (Table 2). Negative allometric growth was observed in each month, and the results of the current study were significant (p<0.05). The length of the fish was responsible for more than 92–98% of the weight's explanation, according to the coefficient of determination (r^2) values, which ranged from 0.92-0.98 with an average of 0.961 during the study months. The length-weight relation was represented graphically as a straight line throughout the entire month. It was determined that the slope was exceedingly significant (p<0.05).

Table 1. Calculation of sex ratio of *B. badis* during the study period.

Months	No.	Female		Male		Chi square (χ^2)	Sex ratio	*P* value
		N	%	N	%		F : M	
Jan	29	13	44.83	16	55.17	0.015	0.81:1	NS
Feb	25	11	44.00	14	56.00	0.001	0.79:1	NS
Mar	20	9	45.00	11	55.00	0.014	0.82:1	NS
Apr	21	9	42.86	12	57.14	0.006	0.75:1	NS
May	19	8	42.11	11	57.89	0.020	0.73:1	NS
Jun	24	10	41.67	14	58.33	0.041	0.71:1	NS
Jul	25	11	44.00	14	56.00	0.001	0.79:1	NS
Aug	25	10	40.00	15	60.00	0.139	0.67:1	NS
Sep	27	13	48.15	14	51.85	0.217	0.93:1	NS
Oct	21	9	42.86	12	57.14	0.006	0.75:1	NS
Nov	22	10	45.46	12	54.54	0.027	0.83:1	NS
Dec	28	12	42.86	16	57.14	0.008	0.75:1	NS
Total	286	125	43.71	161	56.29	0.04	0.78:1	-

Table 2. Regression equation of *B. badis* from length-weight relationship during the study.

Months	Regression equation	b	a	95% CI		R^2	*P*-values
				b (Slope)	a (Intercept)		
Jan	$Y=0.032*X^{2..258}$	2.258	0.032	2.09 to 2.58	0.025 to 0.041	0.941	<0.0001
Feb	$Y=0.019*X^{2.592}$	2.592	0.019	2.32 to 2.74	0.015 to 0.025	0.978	<0.0001
Mar	$Y=0.021*X^{2.513}$	2.513	0.021	2.07 to 2.74	0.019 to 0.030	0.961	<0.0001
Apr	$Y=0.015*X^{2.743}$	2.743	0.015	2.63 to 2.82	0.012 to 0.021	0.921	<0.0001
May	$Y=0.017*X^{2.630}$	2.630	0.017	2.49 to 2.76	0.014 to 0.022	0.951	<0.0001
Jun	$Y=0.028*X^{2.319}$	2.319	0.028	2.15 to 2.47	0.023 to 0.038	0.964	<0.0001
Jul	$Y=0.020*X^{2.583}$	2.583	0.020	2.43 to 2.74	0.016 to 0.027	0.970	<0.0001
Aug	$Y=0.013*X^{2.801}$	2.801	0.013	2.92 to 2.66	0.009 to 0.018	0.957	<0.0001
Sep	$Y=0.017*X^{2.661}$	2.661	0.017	2.56 to 2.77	0.013 to 0.023	0.974	<0.0001
Oct	$Y=0.022*X^{2.489}$	2.489	0.022	2.37 to 2.58	0.017 to 0.029	0.980	<0.0001
Nov	$Y=0.015*X^{2.711}$	2.711	0.015	2.60 to 2.81	0.012 to 0.020	0.963	<0.0001
Dec	$Y=0.014*X^{2.738}$	2.738	0.014	2.66 to 2.83	0.011 to 0.019	0.973	<0.0001

When predicting the weight of a given value of length, the sprinkled lines among the linear fit stand accurate to inside 95% of the sureness intervals. The condition factor values for both sexes varied between 0.84 to 1.39 with a mean value of 1.02±0.13 and showed significant discrepancies ($p<0.05$). The K_R value fluctuated over the duration of the study period and was calculated for each month. The mean K_R value was 0.88+0.28, with the highest value (1.01) occurring in August and the lowest value (0.78) in February. The relative condition factor changed significantly ($p<0.01$) throughout the study month.

This is the first set of data for *B. badis* in Bangladesh regarding the sex ratio and first sexual maturity. According to this study, both sexes of *B. badis* have significantly different first sexual maturities. The maximum length for first sexual maturity was, however, a little bit longer for females (4.50 cm) than for males (4.05 cm). The research also noted the relationship between weight and length and the condition factor of *B. badis*. The longest possible overall length for *B. badis*, according to this study, was 4.60 cm. Ranganadi River in Assam, India, had a total length of 5.23 cm, which is almost the same as our findings (Kaushik *et al.*, 2015). In India, *B badis* were found to be between 1.65-5.93 cm in total length and weighing between 0.05-2.52 g (Dutta *et al.*, 2020). *B badis* have a total length that varies from 1.6 to 5.95 cm (Dutta, 2021). In this study, the parameter b of the length-weight relationships of *B badis* showed negative allometric growth and was significantly different from 3 ($p<0.05$). *B. badis* has a 'b' value of 2.96 (b<3), meaning that small specimens in the sample have precisely the same shape and physical characteristics as large specimens (Kaushik *et al.*, 2015). When combined with different size groups, *B badis* exhibits positive allometric growth with a b value greater than 3 (Dutta, 2021). Similar to our findings, *Trichogaster fasciata*, an ornamental fish, also has a b value that is less than 3 and exhibits negative allometric growth (Singh *et al.*, 2021). *Esomus danricus*'s 'b' value, which indicates negative allometric growth, also showed a similar trend across all seasons (Sanjay *et al.*, 2015). The estimated b values for *A. testudineus* showed an isometric growth pattern (b=3.00) (Khatun *et al.*, 2019). Parallel consequences were reported by (Alam *et al.*, 2014) for the mola carplet (*A. mola*), who reported a value of 2.86 for 'b'. The seasonal variations in the water temperature as well as the maturity stage may be to blame for the differences in the b-values (Weatherley and Gill, 1987). There are a number of variables that may affect the variation in the exponential value (b), including seasonal variation, the condition of the fish's body when it was collected, sex, gonadal development, and the nutritional state of the fishes' environment (Le Cren, 1951). In addition to the different sampling sites, this study did not account for age, sex, or other variables such as habitat, stomach fullness, preservation techniques, etc. The condition factor was employed for assessing the health or

Table 3. The condition factor and relative condition factor of *B. badis* throughout the study period.

Months	Mean Length (cm)	Mean weight (g)	Condition factor (K_n)			Relative condition factor (K_R)		
			Min.	Max.	Mean	Min.	Max.	Mean
Jan	4.53±0.45	0.98±0.28	0.89	1.39	1.05±0.13	0.36	1.57	0.97±0.34
Feb	4.08±0.39	0.81±0.23	0.94	1.24	1.03±0.17	0.43	1.32	0.78±0.30
Mar	4.59±0.55	1.01±0.39	0.86	1.20	0.86±0.14	0.47	1.49	1.00±0.35
Apr	4.29±0.38	0.84±0.26	0.84	1.19	1.03±0.10	0.39	1.32	0.82±0.26
May	4.32±0.42	0.85±0.28	0.88	1.17	1.02±0.09	0.46	1.32	0.84±0.29
Jun	4.57±0.46	0.97±0.32	0.89	1.39	1.04±0.14	0.39	1.57	0.97±0.32
Jul	4.27±0.41	0.86±0.28	0.94	1.24	1.08±0.11	0.43	1. 34	0.81±0.25
Aug	4.60±0.44	0.99±0.37	0.88	1.17	0.99±0.15	0.51	1.58	1.01±0.34
Sep	4.24±0.35	0.82±0.25	0.91	1.16	1.03±0.17	0.33	1.32	0.81±0.23
Oct	4.21±0.41	0.83±0.28	0.90	1.26	1.05±0.09	0.42	1.36	0.79±0.21
Nov	4.32±0.31	0.84±0.26	0.92	1.16	1.02±0.15	0.34	1.29	0.85±0.29
Dec	4.37±0.34	0.85±0.29	0.87	1.22	0.98±0.12	0.44	1.49	0.87±0.30
Mean	4.36±0.31	0.89±0.30	-	-	1.02±0.13	-	-	0.88±0.28

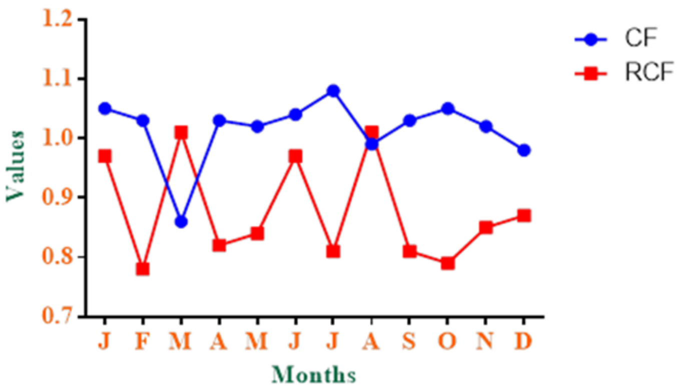

Figure 2. *Monthly variation in condition factor and relative condition factor during the study.*

well-being of fish under the assumption that bigger fish of a particular length are in greater shape (Mir *et al.*, 2012). In this study, the condition factor 'K_n' was found to vary by month, peaking in January and June at 1.39 and lowest in April at 0.84. Fish have a condition factor of 1.39, which indicates a healthy biological condition such as good growth and a good L-W relationship, as opposed to 0.84, which indicates a physiological condition that is not healthy and results in poor growth. *B. badis* was found to have a condition factor of 1.61, which denotes a healthy physiological state (Dutta, 2021), which is similar with our findings. A similar result of condition factor was observed in *Esomus danricus* (Sanjay *et al.*, 2015). In a wetland ecosystem (Gajner Beel, Pabna, Bangladesh), the predicted condition factor for *A. testudineus* fluctuated between 1.33-2.43 (Khatun *et al.*, 2019). The average condition factor values in female *A. mola* were found to be 1.14 in October and 1.40 in November, almost matching our findings (Mondal *et al.*, 2020). The spawning process, recovery afterward, gonadal development, as well as the general state of seasonal appetite, can all be considered causes of condition factor variation in fishes (Dewan and Doha, 1967). For *B. badis*, the study noticed that the relative condition factor ranges from 0.33 to 1.58. The relative condition factor was found to be lowest in September (0.33) and highest in August (1.58). It was crystal clear from the data that *B. badis*' growth pattern was suitable in August but, worst in September. Seasonal variations and the effects of the environment are both factors that affect the relative condition factor's values. A fish's physiological state in relation to its welfare is also reflected by the relative condition value. Fish sex ratios show how many males and females there are in a population. On the sex ratio of *B. badis*, no prior information had been found. The total sex ratio of *B. badis* in this study was M: F = 1:0.78. Although the sex ratio varied from month to month, males still outnumber females. According to the data table, August had the lowest percentage of females (40.00%) and September had the highest percentage (48.15%) of females. August noted the highest percentage of males (60.00%), while September noted the lowest percentage (51.85%). Male to female ratio was 1:0.61 in a study on the sex ratio of the *Botia Dario* in Rajshahi, which is similar to our findings (Hussain *et al.*, 2007). For Amblypharyngodon Mola, the highest sex ratio (M: F=1:2.05) was identified in May and the lowest (M: F=1:1.33) in February (Das *et al.*, 2018). Amblypharyngodon mola had a sex ratio of 1: 1.95 on average per year, indicating that females dominated males throughout the year (Gogoi and Goswami, 2014). In Taungthaman Lake, Mayanmar, the sex ratios (M: F) were 1:5 in A. atkinsonii, 1:6.3 in *P. sarana*, and 1:6 in P. chola (Aye and Khaing, 2017). In Sigi, Central Sulawesi, Indonesia, the overall sex ratio of Anabas testudineus was found to be 1:1 (Ndobe *et al.*, 2020). Changes in the sex ratio of fishes can be attributed to a variety of factors, including increasing water temperature and moderate water velocity, female fishes' vulnerability to predators and other natural hazards, and the brooder population's migration phase (Beevi and Ramachandran, 2005). The size at sexual maturity of *B. badis* was first evaluated in this study, both in Bangladesh and globally. The option of permitted imprisonment size at first maturity is widely castoff and is likewise a crucial tool in managing fisheries in open waters (Lucifora *et al.*, 1999). Analyzing plots of the proportion of mature females regarding length class, the resulting logistic equation provides information on the size of fish beginning at sexual maturity (King, 2007). Its accuracy for organisms with brief life cycles is addressed, despite some

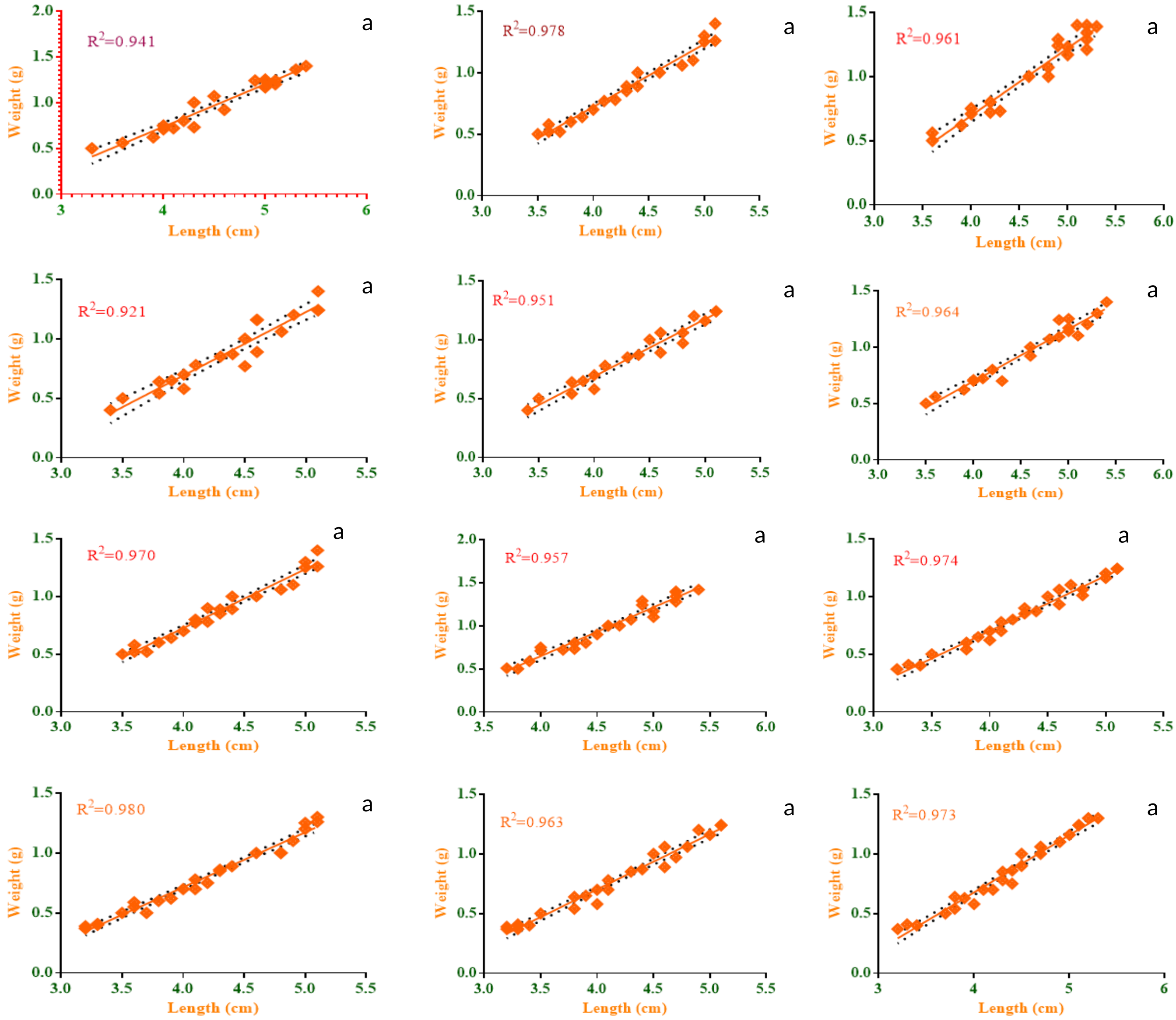

Figure 3. *Monthly affiliation between overall length and weight of B. badis during January-December 2022.*

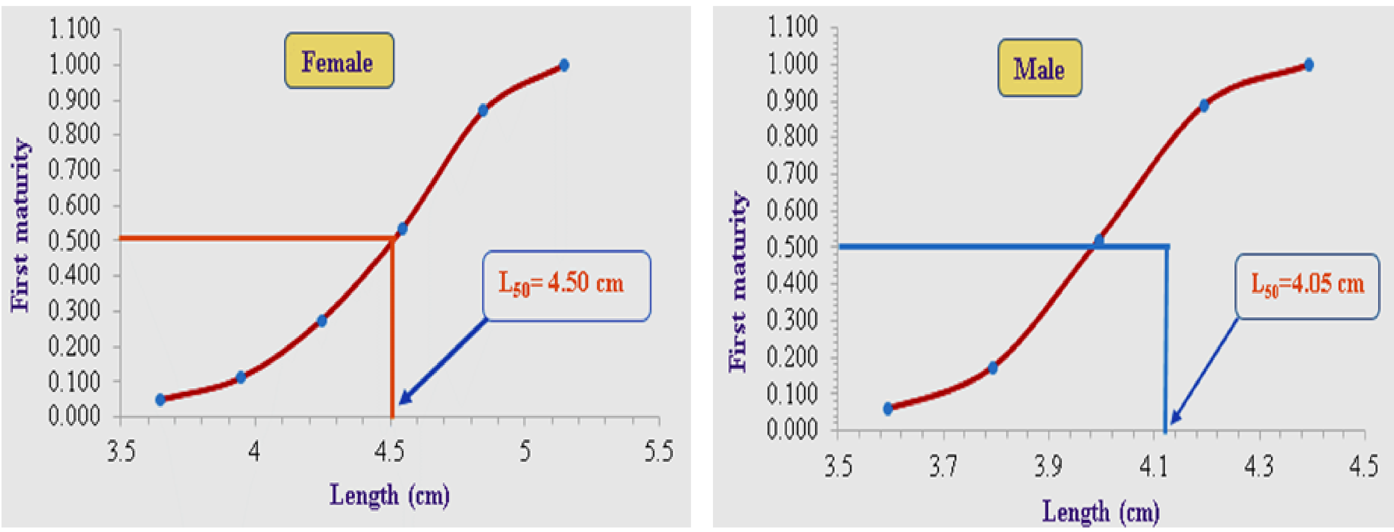

Figure 4. *The connection between the size groups of females (a) and males (b) and the proportion of maturity in each group's percentage composition of B. badis during January to December 2022.*

research (Hossain and Ohtomi, 2008; Hossain *et al*., 2013) reporting low preciseness in the determination of Lm of fishes through this logistic formula. A highly biased index of population reproduction, according to Garcia (1985), is the percentage of mature females. Male and female *B. badis* reached their first sexual maturity at 4.05 cm and 4.50 cm, respectively, in our study. In the Gajner Beel, Bangladesh, 8.41cm TL was found to be the length at first sexual maturity for *A. testudineus* (Khatun *et al*., 2019). The first sexual maturity of *A. testudineus* has been reported to be 9.26 cm in total length in Tetulia, Bangladesh, which is inconsistent with our findings (Hossain *et al*., 2015b). According to projections made in the Ganges River, which flows in northwest Bangladesh, both sexes of *E. danricus* were 3.98 cm long when they reached sexual maturity, which is very similar to our outcomes (Hossain *et al*., 2016). Fish growth and age at 50% maturity may be influenced by stock density, food quality, and water temperature (Tormosova, 1983). But depending on the sexes and their geographic distribution, different fish species reached sexual maturity at different sizes (Smida and Hadhri, 2014). The size of *B. badis* before reaching sexual maturity was examined in this study from Mymensingh, Bangladesh, is determined for the first time. There will be a list of factors affecting first sexual maturity and the sex ratio of *B. badis* in Bangladesh, further research is needed. As a result, this study provided the foundation for such research.

Conclusion

Key biological characteristics of *B. badis* are described at length and weight affiliations, condition factors, sex ratios, and ages at first sexual maturity. The results of this study can be used as a springboard for more in-depth planning and regulation for the sustainable protection of this species' remaining stocks in Bangladesh and its related environment by fisheries managers, fish biologists, and conservationists. Findings from this study provide invaluable information for the online Fish Base database and provide a foundation for future studies in Bangladesh and the surrounding regions.

Conflict of Interest

Authors have no conflicts of interest

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