

Research Article

Growth Factors and Condition Indices of Some Air-breathing and Catfishes From Hakaluki Haor, Bangladesh

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The present study investigated the morphometric traits and growth factors of seven fish species from Hakaluki Haor, Bangladesh. The standard empirical length–weight relationship parameters and condition indices were evaluated. The parameters “a” and “b” varied across species, indicating different growth patterns, with the coefficient of determination (r^2) values ranging from 0.74 to 0.91. *Channa punctatus* had a mean length of 15.52 cm and a weight of 63.50 g, while *Channa striata* showed a mean length of 34.96 cm and a weight of 354.88 g. *A. testudineus* had a mean length of 12.04 cm and a weight of 38.04 g, and *Heteropneustes fossilis* had a mean length of 12.11 cm and a weight of 15.97 g. *Mystus cavasius* had a mean length of 17.24 cm and a weight of 34.28 g, in contrast, *Mystus tengara* had a mean length of 10.07 cm and a weight of 10.57 g. While *Mystus vittatus* had a mean length of 11.64 cm and a weight of 17.42 g. Fulton’s condition factor, allometric growth, and relative condition factor were calculated for each species, with 95% confidence limits provided. *C. punctatus* had a Fulton’s condition factor of 1.86 ± 0.77 , while *C. striata* had 0.82 ± 0.08 . *A. testudineus* showed a higher condition factor of 2.12 ± 0.29 . The allometric growth parameter ranged from -0.008 ± 0.001 in *A. testudineus* to 1.33 ± 0.02 in *M. vittatus*. Relative condition factors varied, with *C. punctatus* at 0.013 ± 0.006 and *M. vittatus* at -0.71 ± 0.01 . Species-specific growth patterns and health conditions are key information for sustainable fishery practices. These findings highlight significant variations in growth patterns and health status among the species, providing valuable insights to support effective management, habitat protection, and conservation of fisheries resources.

Keywords: catfish; condition indices; Hakaluki Haor; length–weight parameters; snakehead fish

1. Introduction

Bangladesh is home to several species of snakehead fish, each with unique characteristics and diverse habitat specifications [1, 2]. The spotted snakehead (*Channa punctata*), locally known as “Taki,” is common in freshwater bodies. The striped snakehead (*Channa striata*), called “Shol,” is another prevalent species. The country represents various species of catfish, including silurid catfish and stringing catfish [3]. These species are native and crucial to both ecological balance and the economy [4, 5]. Bangladesh’s diverse water bodies, such as

rivers, ponds, and floodplains, provide ideal habitats due to their warm, nutrient-rich waters [6, 7]. Silurid catfishes are highly valued for their taste and nutritional benefits, making them a popular choice among consumers. The aquaculture of catfish has seen substantial growth, driven by high market demand and the species’ adaptability to intensive farming practices [3]. However, challenges such as water pollution, habitat destruction, and overfishing pose threats to catfish populations [8, 9]. These species are vital sources of affordable animal protein for rural and urban communities, contributing to food security [4].

Air-breathing fishes, also known as “bimodal breathers,” possess unique structures, including air-breathing organs [10], labyrinth organs, and modified gills, allowing them to extract oxygen from air and water [11–13]. These unique characteristics help them survive in habitats with fluctuating oxygen levels and protect themselves from predators by returning to the depths [11, 13, 14]. In Bangladesh, a widespread belief suggests that consuming air-breathing fish can increase blood levels or enhance overall health. However, there is no scientific evidence to support these claims, highlighting the need for accurate information to guide healthy dietary choices. In addition, these fish are highly valued for their high protein, low fat, and easy digestibility, making them a recommended diet option for convalescing and children [1, 2, 14]. During the past decade, the production and cultivation of these fish have increased significantly, making them a significant source of protein for human consumption worldwide due to the excellent taste of their meat [15–17]. Due to their high commercial value, air-breathing fish species are increasingly cultivated in Southeast Asia [17, 18], which is crucial for developing countries’ socio-economic growth by creating jobs and boosting the economy. They support the livelihoods of thousands of small-scale fishers and traders, especially in wetland regions [10]. Their adaptability to low-oxygen environments makes them an ideal catch in small ponds and seasonal water bodies, enhancing rural fish production [11, 13].

Bangladesh’s northeast area is mostly wetland basins with heavily flooded depressions called haors [19–21]. Among them, Hakaluki Haor is richly biodiverse [22–24], an ecologically critical area, and a protected proposed Ramsar site of international importance for wetland conservation [20, 24–26]. Haor are wetland ecosystems that have seasonal changes in their water level and therefore serve as diverse habitat platforms for aquatic and terrestrial flora and fauna [25–27]. The beels (water reservoirs) in Hakaluki Haor provide winter shelter for “mother fisheries” [19] and contribute significantly to the society, economy, and ecology of Bangladesh [22, 24]. During the early monsoon, the Haor fisheries produce millions of fries for downstream communities. The floodplains also offer important fishing resources in the area [26]. Haor fish is in high demand across the country due to their premium quality and savory taste [19].

There is very little previous research work on establishing growth factors and condition indices of air-breathing and catfishes in particularly from the Hakaluki Haor, Bangladesh. A lot of studies have been conducted focusing on species diversity, seasonal variations, and catch effort of fisheries resources in this world ecosystem [25, 26, 28]. However, gaps remain in understanding the growth factors, different condition indices of these fish, and correlating the length–weight parameters, which need to be explored comprehensively as a means to provide key information in sustainable management and conservation strategies for these species. Condition factors are measures of the relationship between the observed and theoretical mass of a fish, which can indicate the quality and suitability of its

environment [29]. Constructing an empirical relation between length and weight based on parameters will provide significant resources for stock management. Therefore, the current study aimed to evaluate the growth patterns of air-breathing fish and catfish species inhabiting the Hakaluki Haor, serving as a case study for floodplain water bodies.

2. Materials and Methods

2.1. Study Area and Sampling. The Hakaluki Haor is located in the northeastern part of Bangladesh, specifically in the Sylhet Division [24]. The approximate geographical coordinates of Hakaluki Haor are latitude (24°35′ N to 24°45′ N) and longitude (92° 00′ E and 92° 08′ E) [25] (Figure 1). The Kushiya River, which flows through it to the west-northwest, is the waterway via which the Hakaluki Haor receives its primary water supply [14, 30]. Geographically, it is in the regions of low-lying floodplains and is distinguished by a wetland ecology made up of seasonal floodplains and waterbodies [23]. Hakaluki Haor is a large wetland region that is dynamic and constantly changing due to seasonal variations in water levels and rainfall [4]. The hydrology and ecological dynamics of this significant environment are shaped by the interplay of seasonal fluctuations, human interventions, and natural processes that affect the flow of water in the Haor. The samples were collected in February 2022 from different locations in the Haor from the harvest of traditional fishermen. Following transportation of the sample to the Fish Biology and Genetics laboratory, the sample was rinsed with tap water, and additional moisture was removed using a paper towel. The lengths of each fish were estimated using a specially designed scale attached to a wooden frame, and recorded values in cm (two decimal places) units, while the weights were measured using an electric precision balance (Model no: EK600I, United Kingdom) in g (up to two decimal places) units.

2.2. Measurement Tools for Length–Weight Relationships (LWRs) and Condition Indices. The LWR was examined through the following equation: $W = aL^b$ [31], where W stands for the weight of the fish in grams (g) and L represents the total length of the fish in centimeters (cm). The variable “ a ” denotes the intercept, while the variable “ b ” indicates the weight at unit length (slope). The a and b parameters were established by using a log transformation of the length and weight of the respective fish. Fulton’s condition factor was measured by using $K = 100 W/L^b$ [32], where K represents the condition factor, W represents the weight of the fish in grams, L represents the total length of the fish in centimeters, and b specifies the weight in unit length (slope). The relative condition factor (K_n) was calculated using $K_n = W/W'$ [33], where K_n denotes the relative condition factor, W represents the weight of the fish in grams, and W' signifies the weight calculated using the formula $W' = aL^b$. Again, the allometric condition factor is calculated as $K_a = W/L^b$ [34], where W refers to weight in g, L to length in cm, and b is acquired from the LWR regression plots.

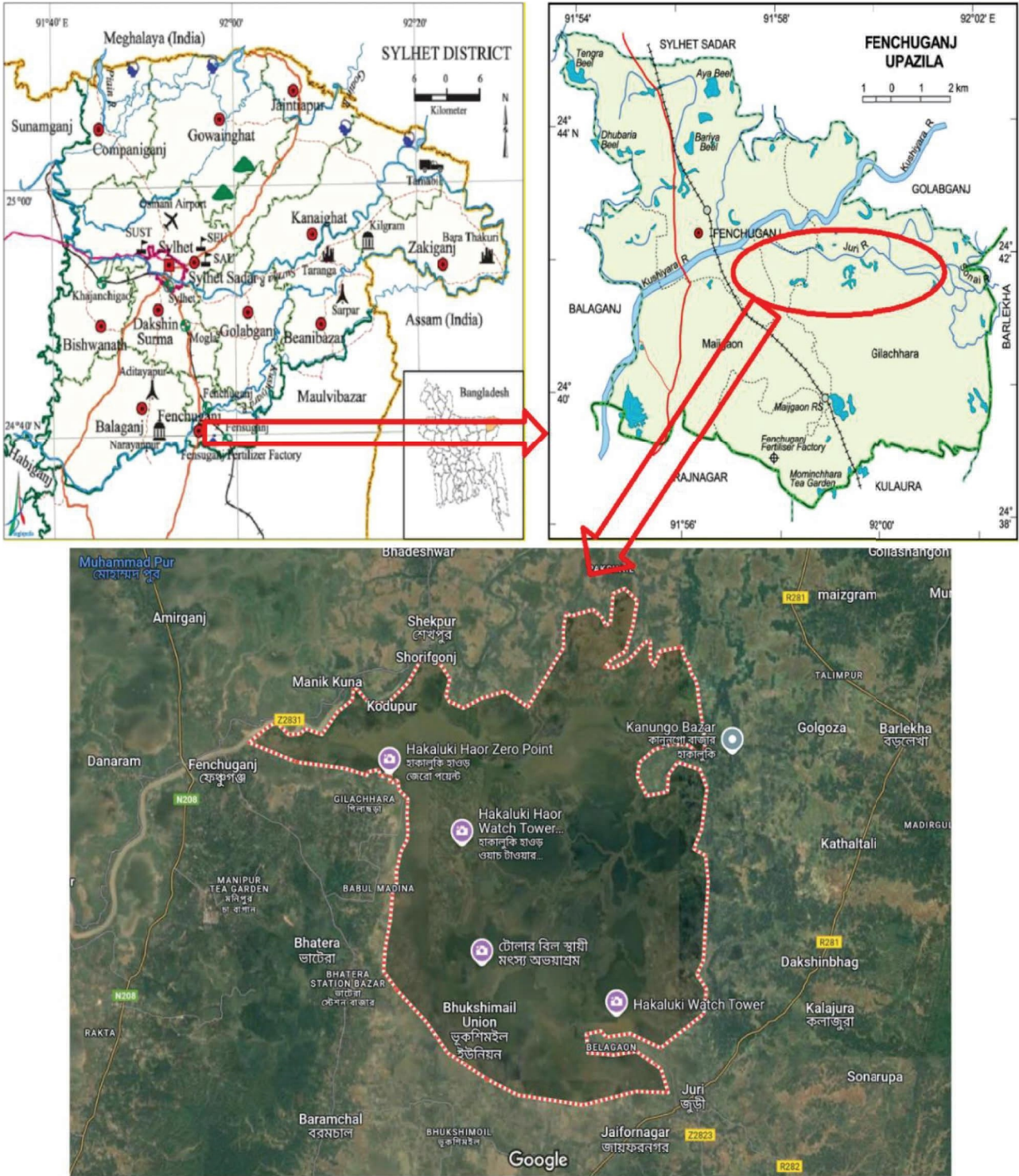


FIGURE 1: Location of Hakaluki Haor in Sylhet, Bangladesh.

2.3. *Statistical Analysis.* Data were statistically analyzed using an Office 365 Excel spreadsheet in IBM SPSS V26. The *t*-test was adopted to validate the regression values. Graphs were constructed in Office 365 Excel tools by using SPSS-analyzed data.

3. Results

The different parameters of the LWR are documented in Table 1. For *C. punctatus*, the average length is 15.52 ± 4.17 cm, and the weight is 63.50 ± 44.43 g. *C. striata*

TABLE 1: Descriptive statistics and a , b , and r^2 parameters for length–weight relationship.

Species	N	a	b	r^2	Length (cm)	Weight (g)	95% Confidence limit			
							Length (cm)		Weight (g)	
							Lower	Upper	Lower	Upper
<i>C. punctatus</i>	61	0.61	1.97	0.78	15.52 ± 4.17	63.50 ± 44.43	14.45	16.58	52.12	74.88
<i>C. striata</i>	60	1.25	2.45	0.74	34.96 ± 2.25	354.88 ± 58.79	34.38	35.54	339.69	370.07
<i>A. testudineus</i>	37	-1.34	2.69	0.85	12.04 ± 1.35	38.04 ± 11.85	11.59	12.49	34.08	41.99
<i>H. fossilis</i>	45	0.19	2.92	0.80	12.11 ± 4.08	15.97 ± 6.44	10.88	13.33	14.03	17.90
<i>M. cavasius</i>		2.98	-2.16	0.83	17.24 ± 0.22	34.28 ± 1.55	16.76	17.72	30.91-	37.66
<i>M. tengara</i>	32	2.89	1.88	0.91	10.07 ± 0.17	10.57 ± 0.54	9.72	10.42	9.46-	11.67
<i>M. vittatus</i>		2.93	-1.89	0.81	11.64 ± 0.15	17.42 ± 0.75	11.34	11.94	15.89-	18.96

Note: N refers to the number of samples for each species; values are expressed as mean ± standard deviation.

shows a higher average length of 34.96 ± 2.25 cm and a weight of 354.88 ± 58.79 g. *A. testudineus* has an average length of 12.04 ± 1.35 cm and a weight of 38.04 ± 11.85 g. *H. fossilis* shows an average length of 12.11 ± 4.08 cm and weight of 15.97 ± 6.44 g, with confidence limits of 10.88–13.33 cm for length and 14.03–17.90 g for weight. *M. cavasius* has an average length of 17.24 ± 0.22 cm and a weight of 34.28 ± 1.55 g. *M. tengara* has an average length of 10.07 ± 0.17 cm and weight of 10.57 ± 0.54 g, with confidence limits of 9.72–10.42 cm for length and 9.46–11.67 g for weight. *M. vittatus* has an average length of 11.64 ± 0.15 cm and a weight of 17.42 ± 0.75 g, with confidence limits of 11.34–11.94 cm for length and 15.89–18.96 g for weight. The regression coefficients and r^2 values indicate the strength and nature of the relationship between length and weight for each species (Figure 2).

Table 2 provides a comprehensive overview of condition factors in seven fish species, focusing on Fulton's condition factor, allometric condition factor, and relative condition factor. *C. punctatus* has Fulton's condition factor of 1.86 ± 0.77 , indicating the fish's overall health and robustness. The allometric condition factor is -0.006 ± 0.003 and the relative condition factor is 0.013 ± 0.006 . *C. striata* shows a lower Fulton's condition factor of 0.82 ± 0.08 , suggesting a leaner body condition compared to *C. punctatus*. The allometric condition factor is -0.002 ± 0.000 and the relative condition factor is 0.005 ± 0.000 . The confidence limits for Fulton's condition factor are between 0.81 and 0.85, for the allometric factor between -0.003 and -0.002 , and for the relative factor consistently at 0.005.

A. testudineus has a higher Fulton's condition factor of 2.12 ± 0.29 , indicating a robust body condition. The allometric condition factor is -0.008 ± 0.001 and the relative condition factor is 0.015 ± 0.002 . *H. fossilis* presents Fulton's condition factor of 1.62 ± 1.82 , showing significant variability. The allometric condition factor is -0.006 ± 0.007 and the relative condition factor is 0.012 ± 0.015 . *M. cavasius* has a Fulton's condition factor of 0.67 ± 0.02 , an allometric condition factor of 0.70 ± 0.02 , and a relative condition factor of -0.33 ± 0.01 . *M. tengara* shows a Fulton's condition factor of 1.01 ± 0.01 , an allometric condition factor of 1.30 ± 0.02 , and a relative condition factor of -0.66 ± 0.01 . The confidence limits for Fulton's condition factor range from 0.98 to 1.04, for the allometric factor from 1.26 to 1.34, and for the relative factor from -0.68 to -0.64 . *M. vittatus*

has a Fulton's condition factor of 1.09 ± 0.02 , an allometric condition factor of 1.33 ± 0.02 , and a relative condition factor of -0.71 ± 0.01 . The confidence limits for Fulton's condition factor range from 1.05 to 1.13, for the allometric factor from 1.28 to 1.37, and for the relative factor from -0.73 to -0.68 .

4. Discussions

Length–weight parameters and condition indices provide vital information on fish growth and their habitat suitability [35–37]. All species in the current study exhibited a statistically significant correlation between LWR ($p < 0.001$). The value of the coefficient of determination (K_A) exceeding 0.74 implies that length can predict more than 74% of the variance in weight of fish species, which is a moderately good fit [38]. Several studies have confirmed that the anticipated range for b is 2.5–3.5 in fish [39–41]. This means that, except for *C. punctatus*, other species showed a share proportional relation in the current research. The value of b refers to the fact that length increased faster than weight [42]. Several studies on *C. punctatus* and *C. striata* indicated negative allometric growth ($b < 3$) with high correlation values ($r^2 = 0.99$), suggesting length increases more rapidly than weight [2]. *A. testudineus* and *H. fossilis* typically exhibit negative allometric growth, where weight increases at a slower rate compared to length [43, 44]. In *C. punctatus*, the b value is approximately 2.84, indicating negative allometric growth [45]. *C. striata* shows isometric growth with b values around 3.06–3.10 [46]. *A. testudineus* and *H. fossilis* exhibit negative allometric growth, with b values of 2.68 and 2.65, respectively [44]. *M. cavasius* has a b value of 2.65, indicating negative allometric growth. *M. tengara* and *M. vittatus* also show similar growth patterns, and b values reflect their adaptability to different environmental conditions [47, 48]. Some factors, such as season, location, species size, population, diet, maturity, sex, and overfishing, are responsible for the variation in b value [49, 50].

In assessing fish well-being and the health of fish populations in their habitat, different condition indices serve as reliable indicators and provide insight into environmental quality and growth fitness [51, 52]. The allometric condition factor (K_A) refers to the actual growth exponent, offering more insights into energy use and growth efficiency [53]. The K_A values lower than 1.00 indicate poor food availability or

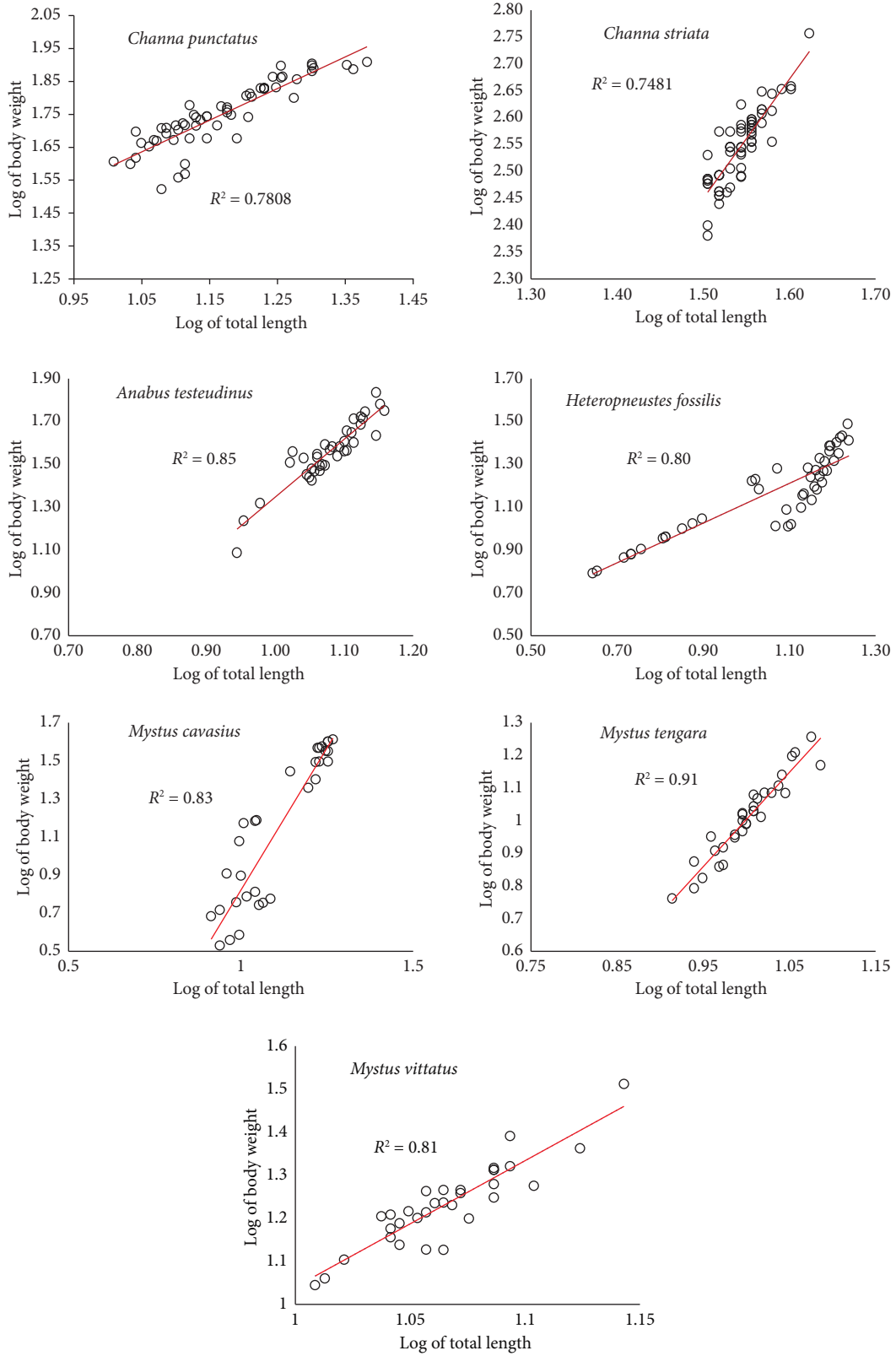


FIGURE 2: Length and weight regression curve for the studied species from Hakaluki Haor in Sylhet, Bangladesh.

high consumer density [54] and poor growth conditions, which may influence the species' life history. Due to the lower intensity of the food, based on the value of b and its

statistical significance, the growth type is identified as negative growth allometry, as indicated by $b > 3$ [29, 55]. The relative condition factor (K_n) compares a fish's actual weight

TABLE 2: Description of different condition factors in fish.

Species	N	Fulton's	Allometrics	Relative	95% Confidence limits					
					Fulton's		Allometrics		Relative	
					Lower	Upper	Lower	Upper	Lower	Upper
<i>C. punctatus</i>	61	1.86 ± 0.77	-0.006 ± 0.003	0.013 ± 0.006	1.67	2.06	-0.007	-0.006	0.011	0.014
<i>C. striata</i>	60	0.82 ± 0.08	-0.002 ± 0.000	0.005 ± 0.000	0.81	0.85	-0.003	-0.002	0.005	0.005
<i>A. testudineus</i>	37	2.12 ± 0.29	-0.008 ± 0.001	0.015 ± 0.002	2.03	2.23	-0.008	-0.007	0.014	0.015
<i>H. fossilis</i>	45	1.62 ± 1.82	-0.006 ± 0.007	0.012 ± 0.015	1.08	2.17	-0.008	-0.004	0.008	0.016
<i>M. cavasius</i>		0.67 ± 0.02	0.70 ± 0.02	-0.33 ± 0.01	0.62	0.71	0.66	0/75	-0.35	-0.30
<i>M. tengara</i>	32	1.01 ± 0.01	1.30 ± 0.02	-0.66 ± 0.01	0.98	1.04	1.26	1.34	-0.68	-0.64
<i>M. vittatus</i>		1.09 ± 0.02	1.33 ± 0.02	-0.71 ± 0.01	1.05	1.13	1.28	1.37	-0.73	-0.68

Note: N refers to the number of samples for each species; values are expressed as mean ± standard deviation.

to its expected weight, helping detect nutrition status [56]. It is not necessarily realistic that $K_n = 1$ is indicated in good condition, as the shape of the fish correlates with relative condition factor values, and each species exhibits its independent shape pattern. Therefore, it is necessary to assess all the condition factors to explain the living conditions and growth dynamics as they are correlated [29]. The catfish species, including *M. cavasius*, *M. tengara*, and *M. vittatus*, display varied LWR parameters. *M. tengara* shows seasonal variations in its Fulton's condition factor and relative condition factor. Fulton's condition factor (K) is a simple index assuming isometric growth, useful for assessing fish health and crucial for understanding the species' adaptability to different environmental conditions and their overall health [57]. For *Channa punctatus* and *C. striata*, studies indicate isometric growth with K values ranging from 1.02 to 1.221 [14, 58]. *A. testudineus* and *H. fossilis* exhibit negative allometric growth, with K values reflecting their slower weight gain relative to length. The catfish species *M. cavasius*, *M. tengara*, and *M. vittatus* show diverse growth patterns. *M. tengara* demonstrates significant seasonal variations in K and relative condition factor, with values ranging from 0.33 to 1.49 and 0.44 to 1.77, respectively [48, 59]. The *M. cavasius* demonstrates positive allometric growth, with high correlation values ($r = 0.99$), indicating a strong relationship between length and weight [60, 61]. Current research showed that *A. testudineus* and *C. punctatus* have high K and K_A values, indicating robust growth and favorable environmental conditions. Conversely, *M. cavasius*, *M. tengara*, and *M. vittatus* exhibit negative K_A and low K values, suggesting poor condition or environmental stress. In addition, the K_n values for these species also followed a similar pattern, reinforcing the alignment of these findings. Together, all three different condition indices provide a comprehensive understanding of fish health and growth, supporting effective fisheries management, conservation strategies, and ecological assessments.

To enhance research on morphometric traits and growth factors of seven fish species in Hakaluki Haor, several key recommendations are proposed. Incorporating seasonal and temporal sampling would yield a more robust understanding of growth dynamics and condition indices under varying environmental conditions. Including water quality parameters such as temperature, dissolved oxygen, pH, and nutrient concentrations could reveal critical links

between habitat quality and fish health. Employing advanced statistical techniques, such as multivariate analysis or principal component analysis (PCA), may help identify the primary drivers of growth variation. In addition, integrating GIS-based habitat mapping would provide spatial insights into species distribution and environmental influences. These approaches aim to enhance the ecological relevance and support sustainable management of fish biodiversity in Hakaluki Haor.

5. Conclusions

This study reveals significant interspecific variation in morphometric traits and growth parameters among seven fish species from Hakaluki Haor, Bangladesh. The LWR coefficients and condition factors differed notably, reflecting species-specific growth dynamics. Particularly, *Channa punctatus* and *Channa striata* exhibited marked differences in size and condition indices, while *Anabas testudineus* demonstrated the highest condition factor, suggesting superior health status. These findings offer valuable insights into the biological performance and ecological adaptability of the species, providing a scientific basis for targeted fisheries management and conservation strategies. However, the study's scope is geographically limited and does not incorporate seasonal or long-term environmental variability, which may influence growth and condition metrics. To enhance the robustness and applicability of these findings, future research should include broader spatial coverage, larger sample sizes, and seasonal sampling. Such comprehensive approaches are essential for developing adaptive, species-specific management policies to ensure the sustainability of fish populations in Hakaluki Haor.

Data Availability Statement

Data will be made available based on reasonable requests to the corresponding authors.

Ethics Statement

The sample fish used in the current research were sourced from the catch of commercial and traditional fishermen; therefore, no institutional animal ethics approval is required for this purpose.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

A.C., N.B., U.A., and T.G.: investigation, methodology, writing—original draft preparation, analysis, data interpretation, writing, review, and editing; M.M.I. and M.A.H.: conceptualization, project administration, funding acquisition, analysis, data interpretation, validation, supervision, and review.

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