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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Length-weight relationships and condition factors of *Mystus vittatus* (Hamilton, 1822) in natural and culture habitat

Mystus vittatus (Hamilton, 1822)'un doğal ve kültür ortamındaki boy-ağırlık ilişkisi ve kondisyon faktörü

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Abstract: The Asian catfish *Mystus vittatus* is very popular food and ornamental fish in India. Length- weight relationships and condition factors of this fish are crucial component in fishery managements. The objective of this study is to investigate the relationships between the length, weight, condition factor (K), relative condition factor (Kn) and modified condition factor of *Mystus vittatus* (Hamilton, 1822). The study is particularly focus on analysing the sex wise variations in growth patterns, productivity, stocks, and conservation in two different habitats, natural habitat and biofloc system. The findings show that the species did not strictly follow the predicted cube law and showed allometric growth patterns in both habitats. The "b" value varies from 2.72 to 3.12, the condition factor (K) ranges from 0.587-1.50, modified condition factor ranges 0.54-2.26 and relative condition factor (Kn) ranges from 0.71-1.65. Natural habitats had the highest mean values for the regression parameter (b), condition factor (K), and relative condition factor (Kn). For male, female, and combined sexes in two different habitats, the R^2 values show a statistically significant relationship between weight and length. The correlation analysis indicates some positive and negative significant relationships among sex, length, weight, condition factor, and relative condition factor. Therefore, there is significant relationship between condition factor, relative condition factor length, weight in two different habitats and it varies between male and female within same habitat. Thus, this finding will help to fishery managers for long term strategy development of *Mystus vittatus* in both natural as well as biofloc system.

Keywords: Length-weight relationship, condition factors, *Mystus vittatus*, natural growth, biofloc growth

Öz: Asya kedi balığı *Mystus vittatus* Hindistan'da çok popüler bir yiyecek ve süs balığıdır. Bu balığın boy-ağırlık ilişkileri ve kondisyon faktörleri balıkçılık yönetiminde önemli bir bileşendir. Bu çalışmanın amacı *Mystus vittatus*'un (Hamilton, 1822) boy, ağırlık, kondisyon faktörü (K), nispi kondisyon faktörü (Kn) ve modifiye kondisyon faktörü arasındaki ilişkileri araştırmaktır. Çalışma özellikle iki farklı habitatta (doğal habitat ve biyoyumak sistemi) büyüme kalıpları, üretkenlik, stoklar ve korumadaki cinsiyete dayalı farklılıkları analiz etmeyi odaklamaktadır. Bulgulara göre tür öngörülen küp yasasına tam olarak uymamış ve her iki habitatta da allometrik büyüme göstermiştir. "b" değeri 2,72 ile 3,12 arasında, kondisyon faktörü (K) 0,587-1,50 arasında, modifiye kondisyon faktörü (Kn) 0,54-2,26 arasında ve nispi kondisyon faktörü 0,71-1,65 arasında değişmektedir. Regresyon parametresi (b), kondisyon faktörü (K) ve nispi kondisyon faktörü (Kn) açısından en yüksek ortalama değerler doğal habitatlarda bulunmuştur. İki farklı habitattaki erkek, dişi ve tüm cinsiyetler için gözlenen R^2 değerleri, ağırlık ve boy arasında istatistiksel olarak anlamlı bir ilişki olduğunu göstermektedir. Korelasyon analizi cinsiyet, boy, ağırlık, kondisyon faktörü ve nispi kondisyon faktörü arasında bazı pozitif ve negatif anlamlı ilişkileri göstermiştir. Buna bağlı olarak, iki farklı habitatta kondisyon faktörü, nispi kondisyon faktörü, boy ve ağırlık arasında önemli bir ilişki bulunmuştur ve bu aynı habitatta erkek ve dişi arasında farklılık göstermektedir. Dolayısıyla bu bulgu, *Mystus vittatus*'un hem doğal hem de biyoyumak sisteminde uzun vadeli strateji geliştirilmesinde balıkçılık yöneticilerine yardımcı olacaktır.

Anahtar kelimeler: Boy-ağırlık ilişkisi, kondisyon faktörü, *Mystus vittatus*, doğal gelişim, biyoyumak gelişim

INTRODUCTION

The high protein content of indigenous fish makes it a crucial dietary component. Regrettably, there is a significant decline in fish stocks globally, This decline may be attributed primarily due to two different factors: the over exploitation of the fish species and the degradation of the ecosystem, which includes pollution as a contributing factor (Zhou et al., 2010; Coll et al., 2010; Chanda, 2017). Fisheries management include the consideration of economic, social, and biological aspects that impact fish populations. Its objective is to develop a strategy that meets the nutritional needs of societies while avoiding the overexploitation of fish stocks (FAO, 2003). A crucial instrument for inquiry and management is the utilization of biometric studies, which provide data on fish species to estimate their biomass (Zargar et al., 2012). When conducting biometric research, it is crucial to assess the growth features of fish, such as weight and length (Morato et al., 2001).

Furthermore, it is essential to assess the species' well-being, which can be affected by a variety of biological and environmental conditions. The length weight relationship (LWR) information also provide details on the fish's growth pattern, habitat conditions, life history, overall health, fatness and condition, as well as its physical traits, several studies have emphasized that (Schneider et al., 2000, Froese, 2006). In fishery studies, length-weight relationships and condition factors are most significant (Jin et al., 2015). The length-weight relationship is valuable for evaluating morphometric parameters, comprehending fish health, and assessing the composition of fish landing and overall growth potentiality of fish (Gupta and Tripathi, 2017). On the other hand, the condition factor is used to assess the state of the individual fish (Le Cren, 1951; Froese, 2006). Based on the premise the parameter is predicated that larger fish of a specific length exhibit better physiological condition. In addition, it can be utilized to determine the development and feeding rate of fish, as well as the condition of the aquatic environment in which they thrive (Fagade, 1979). The LWRs of fish species vary based on their inherent body form and physiological parameters, such as maturity and spawning (Schneider et al., 2000). The dynamics of this association may fluctuate during different seasons or even over a span of days (De Giosa et al., 2014). According to Flura et al. (2015), there is a contention that b can vary over distinct time periods, reflecting factors such as stomach fullness, overall hunger, and phases of gonad development. Furthermore, the growth process might vary within the same species inhabiting different areas, as it is influenced by a multitude of biotic and abiotic factors. The relative condition factor (Kn) is calculated by using the methods of LWRs (Le Cren, 1951), is another significant biometric instrument. Calculating the deviation of an organism's weight from the average weight in a specific sample is known as Kn measurement. It is used to evaluate if a specific water condition is suitable for fish growth (Yılmaz et al., 2012; Mensah, 2015). A fish species is considered to have a high level of overall fitness when its Kn values are approximately greater than 1 or equal to 1. *Mystus vittatus* is an important food as well as ornamental fish species in the present study area and market acceptance is very high (Paul and Chanda, 2017; Chakraborty et al., 2019; Sit et al., 2021) population size of the species is gradually facing threats to extinction locally and need immediate action for proper conservation policy and procedure as well as market availably of fish species. Biofloc is an advance fish culture technology in respect to fishery production and supply as well as minimizing environmental pollution due to aquaculture. The measurement of length weight relationship in relation is crucial for proper culture and production in relation to the natural habitat as well as cultural medium. Various researchers (Paul and Chanda, 2017; Chakraborty et al., 2019; Sit et al., 2020; Jana et al., 2022a; Jana et al., 2022b; Sit et al., 2022; Sahil et al., 2023; Sit et al., 2023, Jana et al., 2024) have also studied some aspects of various indigenous fish species in West Bengal, but none of these observed the length-weight relationship in natural and cultural environment of *M. vitatus*. Therefore, the main aim of the present work is to determine the relationship between length and weight of *M. vittatus* both male, female and combined sex wise in natural and biofloc culture system and a comparison between natural and biofloc system has been done to achieve the goal.

MATERIAL AND METHODS

Study area

For this study a total of 331 fish were sampled from various freshwater habitats and biofloc culture system during the March, 2022 - February, 2023. The Natural habitat was located in the southeastern region of West Bengal, namely in the Paschim Medinipur district (Figure 1). The fishes that were captured by using a cast net, gill net, hand net from rivers, pond and canals are shown here as natural habitats. Then they were transported to the laboratory for morphometric analysis. The identification of fish was done based on the classification system established by Talwar and Jhingran (1991).

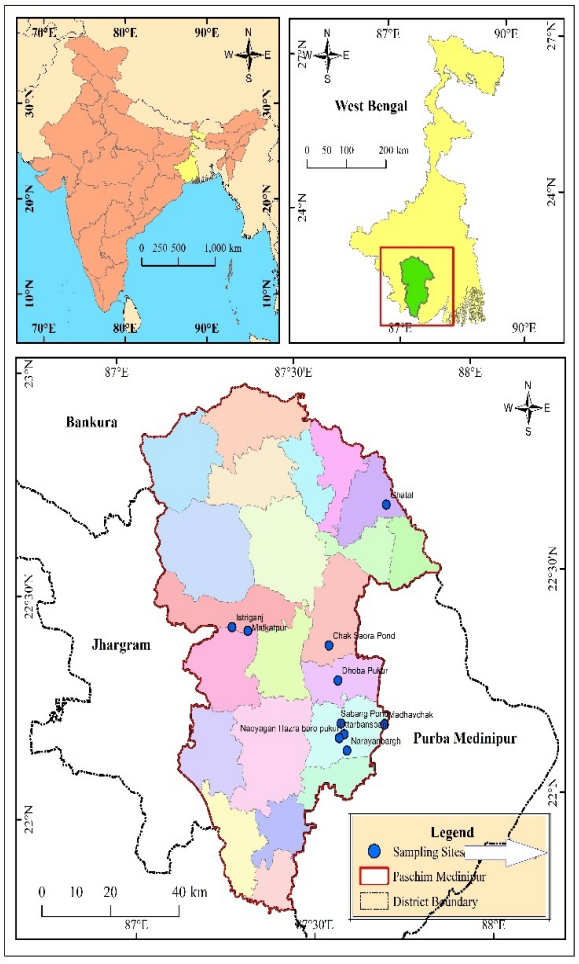

Figure 1. Study site

Length and weight measurements

The length measurements were done with an accuracy of 0.1 cm vernier calliper, measuring the total length (TL) from the

snout to the end of the caudal fin and standard length (SL) from the snout to base of the caudal fin. The weight measurement was done with an accuracy of 0.001 g by keroy11 balancer.

Length and weight relationship (LWR)

The Le Cren log transformation formula has been used to establish length-weight relationships (Le Cren, 1951) or known as Cubes Law (Kalita et al., 2017). The equation was used $W = aL^b$ to evaluate the correlation between the fish weight (g) and overall length (cm) of the fish. Applying linear regression to the equation after log transformation

$$\text{Log } (W) = \log (a) + b \log (L)$$

In the equation, 'a' indicates the coefficient of body shape and 'b' is the slope of the relationship or growth coefficient. The values of 'b' can be smaller or larger, indicating negative or positive allometric growth, or equal to 3, indicating isometric growth. The equation relates weight (W) in grams to total length (L) in centimeters. To determine LWR, fish were divided into male and female groups in two different habitats.

Fulton's condition factor (K)

The condition factor exhibits a negative correlation with length. Therefore, it is possible to compare the differences in the physiological condition of fish populations that live in various feeding or climatic situations. By using the following formula, the condition factor was calculated:

$K = 100 \times (W/L^3)$ (Fulton, 1904)

Here, W= Weight of the fish (g), L= Length of the fish (cm)

Relative condition factor (Kn)

The relative condition factor (Kn=W/w) is determined by dividing the observed fish weight (W) at a specific length by the expected fish weight (w) of the same length, which is calculated using Le Cren (1951) formula. This factor has been calculated for both male and female specimens of *Mystus vittatus* in two different habitats. The fish is considered to be in a state of good growth when the Kn value is equal to or more than 1. Conversely, if the "Kn" value is less than 1, the fish is in a state of poor growth relative to an average individual of the same length. It is important to mention that the stomachs of fish were not removed prior to being weighed.

Modified condition factor

$K = 100\ W/L^b$ (Ricker, 1975)

Where, W=fish weight in gram, L= fish length in centimeter and b is b value of length- weight relationships.

Data analysis

The data was analysed by using Microsoft Excel 2019. To study the data of LWRs, one-way ANOVA was applied to assess the statistical analysis identified up to the P value below 0.05. The t-test was applied to compare b value for each sex with the predictions made for isometric growth (b = 3) in order to determine whether the difference is statistically significant. When the value b is lower than 3 ($P < 0.05$) indicates negative allometric and when it is greater than 3, indicates positive allometric growth. Correlation was performed for establishing statistical relationships among habitat and sexes.

RESULTS

The male and female individuals of *M. vittatus* in natural habitat system ranged in length from 4.1 to 16.0 cm and weight from 0.7 to 42.8 g (Table 1). Simultaneously, in biofloc culture system, length ranges from 6.1 to 13 cm and weight 1.8 to 24.6 g in the present study (Table 1). The 'b' values and 'R^2' values in the natural habitat vary from 2.93 to 3.12 and 0.965 to 0.978, respectively, whereas in the biofloc system it ranges from 2.72 to 2.85 and 0.870 to 0.892 (Table 2 and Figure 2).

Table 1. Length and weight values of *Mystus vittatus* individuals used in this study

Habitat	Sex	Total length (cm)				Total weight (g)			
		Min.	Max.	Average	SD	Min.	Max.	Average	SD
Natural Habitat	Male	4.3	12	7.798	±1.730	0.7	14.5	4.794	±3.086
	Female	4.1	16	8.268	±2.643	1	42.8	7.586	±8.959
	Combined	4.1	16	7.999	±2.171	1	42.8	5.987	±6.420
Biofloc culture	Male	6.4	11.5	9.385	±1.331	2.1	12.7	7.395	±2.788
	Female	6.1	13	9.978	±1.674	1.8	24.6	9.339	±4.283
	Combined	6.1	13	9.664	±1.527	1.8	24.6	8.310	±3.691

Table 2. Estimated parameters of length-weight relationships for *Mystus vittatus* from two different habitats

Habitat	Sex	a	b	R^2
Natural Habitat	Male	0.01011	2.934	0.965
	Female	0.00739	3.123	0.978
	Combined	0.00861	3.029	0.969
Biofloc culture	Male	0.01575	2.723	0.870
	Female	0.01201	2.858	0.892
	Combined	0.01297	2.817	0.889

In comparison to the natural habitat, the biofloc system exhibited the lowest 'b' value, while females show highest 'b' value in natural habitat. The condition factor (K) value ranges 0.699 to 1.50 in natural habitat and 0.587 to 1.260 in biofloc culture system in two sexes (Table 3). The relative (Kn) and modified condition factor ranges 0.739 to 1.65, 0.546 to 1.400 in natural system and from 0.696 to 1.44, 0.865 to 2.269 in biofloc culture system in two sexes (Table 3). Pearson correlation analysis revealed significant relationships between sex, length, condition factor, relative condition factor, and modified condition factor, in two habitats (Table 4). One-way ANOVA has represented statistical variations in length and weight values between two habitats and between the two sexes, at the significance level of $P < 0.05$ (Table 5).

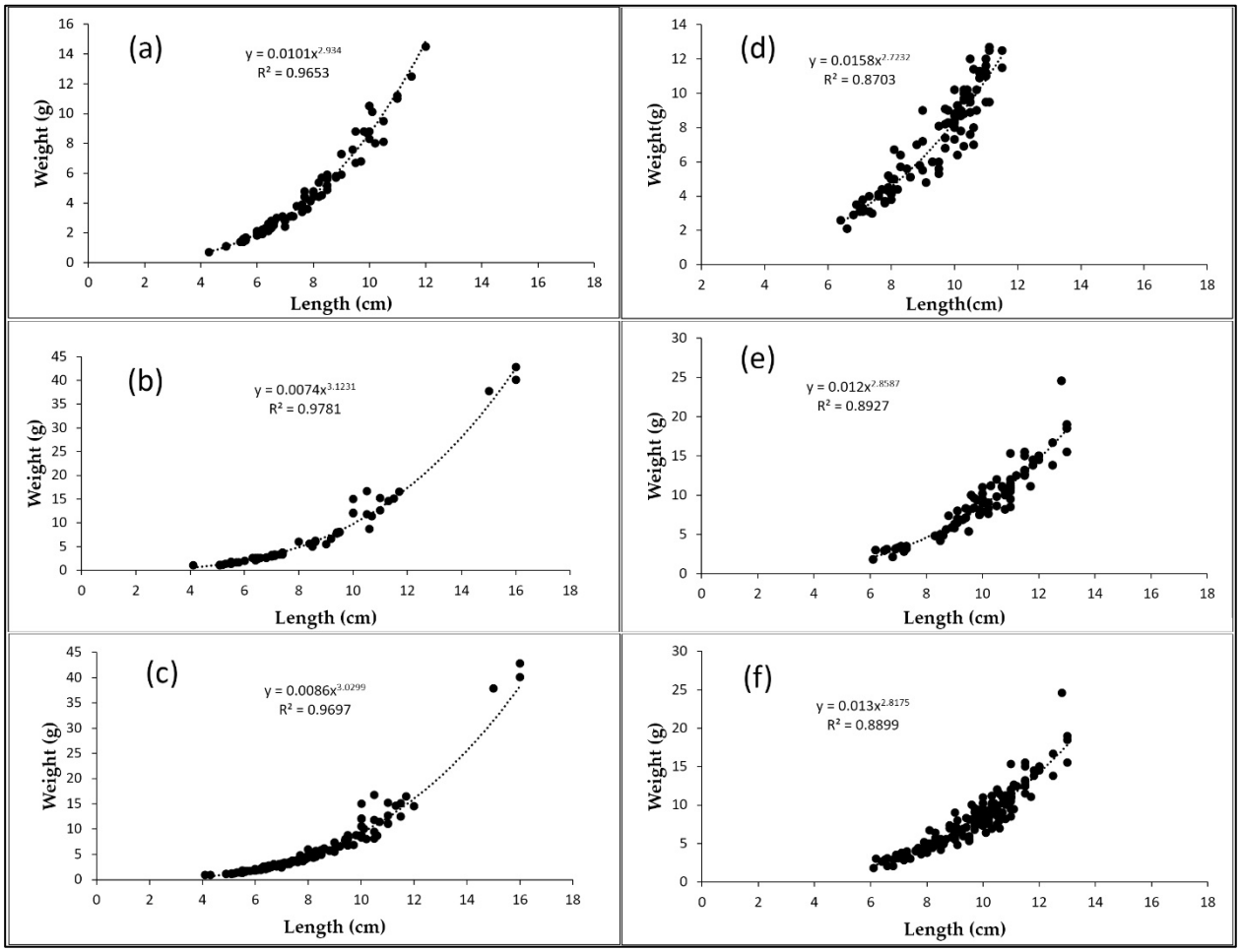

Figure 2. Length-weight relationship of *M. vittatus* in natural habitat (a-c) and culture system (d-f): a and d are male; b and e are female; c and f are combined sex

Table 3. Habitat wise condition factors of *M. vittatus*

Habitat	Sex	Condition factor (K) (Fulton,1904)				Modified condition factor (Ricker, 1975)				Relative condition factor (Kn) (Le Cren,1951)			
		Min.	Max.	Average	SD (±)	Min.	Max.	Average	SD (±)	Min.	Max.	Average	SD (±)
Natural Habitat	Male	0.699	1.051	0.888	0.082	0.795	1.222	1.015	0.094	0.786	1.20	1.004	0.093
	Female	0.730	1.50	0.963	0.154	0.546	1.219	0.746	0.117	0.739	1.65	1.010	0.158
	Combined	0.699	1.50	0.923	0.127	0.652	1.400	0.868	0.120	0.758	1.62	1.010	0.139
Biofloc culture	Male	0.587	1.260	0.858	0.123	1.130	2.269	1.591	0.218	0.717	1.44	1.01	0.138
	Female	0.629	1.258	0.878	0.124	0.865	1.682	1.213	0.168	0.720	1.39	1.01	0.140
	Combined	0.587	1.260	0.868	0.124	0.905	1.870	1.311	0.182	0.696	1.43	1.00	0.140

Table 4. Habitat wise (natural & biofloc) correlations among total length, total weight, fulton condition factor, modified condition factor and relative condition factor of male, female and combined sex of *M. vittatus*

		Total length	Total weight	Fulton cf	Modified cf	Relative cf
Natural habitat - Male	Total length	1				
	Total weight	0.96476347	1			
	Fulton cf	-0.15003376	0.003988	1		
	Modified cf	0.00598071	0.152644	0.987448	1	
	Relative cf	0.00598071	0.152644	0.987448	1	1
Natural habitat - Female	Total length	1				
	Total weight	0.926774	1			
	Fulton cf	0.263461	0.35827	1		
	Modified cf	0.026116	0.155714	0.968705	1	
	Relative cf	0.026116	0.155714	0.968705	1	1
Natural habitat - Combined	Total length	1				
	Total weight	0.898399	1			
	Fulton cf	0.114742	0.303436	1		
	Modified cf	0.056327	0.254315	0.998163	1	
	Relative cf	0.056327	0.254315	0.998163	1	1
Biofloc - Male	Total length	1				
	Total weight	0.9264	1			
	Fulton cf	-0.296	0.050241	1		
	Modified cf	-0.00682	0.335117	0.956307	1	
	Relative cf	-0.00682	0.335117	0.956307	1	1
Biofloc - Female	Total length	1				
	Total weight	0.925727483	1			
	Fulton cf	-0.187297354	0.121827	1		
	Modified cf	-0.005033676	0.296061	0.982452	1	
	Relative cf	-0.005033676	0.296061	0.982452	1	1
Biofloc - Combined	Total length	1				
	Total weight	0.92337102	1			
	Fulton cf	-0.2162123	0.107314	1		
	Modified cf	0.00055482	0.315375	0.975402	1	
	Relative cf	0.00055482	0.315375	0.975402	1	1

Table 5. Habitat wise (natural & biofloc) one-way ANOVA test among total length, total weight, fulton condition factor, modified condition factor and relative condition factor of male, female and combined sex of *M. vittatus*

Habitat	Sex		Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Natural habitat	Male	Intercept	5.20546239	0.096302846	54.05305	2.08126E-62	5.01365865	5.397266131
		Total weight	0.540839395	0.01691969	31.96509	8.06866E-46	0.507140912	0.574537877
	Female	Intercept	6.194242561	0.173018379	35.80106693	2.7921E-40	5.847645099	6.540840022
		Total weight	0.273486208	0.014812075	18.46373398	1.7523E-25	0.243814057	0.303158359
	Combine	Intercept	6.18032978	0.112407963	54.98125	8.16689E-94	5.958006412	6.40265314
		Total weight	0.30378871	0.012828999	23.67985	9.94219E-50	0.27841519	0.32916224
Biofloc culture	Male	Intercept	6.113763887	0.14418185	42.40314387	2.05445E-64	5.827602819	6.399924955
		Total weight	0.442340357	0.01825506	24.23110477	6.21747E-43	0.406109109	0.478571605
	Female	Intercept	6.597980203	0.163671951	40.31222298	1.25091E-57	6.272611132	6.923349274
		Total weight	0.361939095	0.015944636	22.69974071	4.45978E-38	0.330242208	0.393635982
	Combine	Intercept	6.48831769	0.106178694	61.10753	1.3E-124	6.27884093	6.69779444
		Total weight	0.38216512	0.011681994	32.71403	7.66E-79	0.35911806	0.40521217

DISCUSSION

Weight and length are positively correlated and hence, it is significant, according to the R^2 values, in both environments (Table 2 and Figure 2). Male in the natural habitat and female species in the biofloc system exhibit negatively allometric development or it is nearly isometric (≤3) in both environments; only the females and combined group in the natural habitat with the value of "b" show positive allometric growth. When fishes are insufficiently feeding or their environmental parameters and maturity is not favourable for their growth, then strongly negative allometric growth (< 2) is noticed, (Le Cren, 1951; Deka and Gohain, 2015). In Bangladesh, Hossain et al. (2006) documented that "b" value was 3.05, 2.96, and 3.13, for

mixed sex, male, and female individuals of *M. vittatus*. In contrast, from Tamil Nadu, India, Victor et al. (2014) observed that "b" values of same species were 2.732, 2.405 and 2.873, respectively. The "b" value of the mixed sex of *M. vittatus* and had been documented as 2.88 by Srivastava et al., (2013) from India and as 3.27 by Hossain et al., (2009) from Bangladesh. Venkateshwarlu et al., (2007) obtained the "b" values for females and males of same species were 2.740 and 2.493, respectively. Krishna Rao (2007), Sani et al. (2010), Karna and Panda (2012) and Hossain et al. (2012) had documented on mixed sex of *M. cavasius* the "b" values was 2.83, 2.91, 3.009 and 3.21 accordingly. In *M. gulio* the same was measured by Begum et al. (2010) as 1.388 and 1.468 for male and female specimens whereas, Karna and Panda (2012) reported 3.032. Naeem et al., (2012) reported the same *M. bleekeri* was 2.62, 2.63 and 2.70. For *M. tengara* 'b' value was 2.071 and 0.74 to 1.39 was the Kn value (Kalita et al., 2017). The "b" values for *M. tengara* for the same variation ware 3.071, 3.119, and 2.941 (Gupta and Banerjee, 2013). Jana et al. (2022a) similarly reported a seasonal allometric growth trend in *M. tengara*, in their study the 'b' values range 2.00-3.29, the condition factor (K) ranges 0.33-1.49, and the Kn ranges 0.44- 1.77. This study also records quite similar results with the earlier researchers for *M. vittatus*, which ranges from 2.72 to 3.12. The "b" value changes mainly for the shape and fatness of the specimens, one or combination of above mention factors such as area or season, durations of sample collection, number of specimens examined etc., can create difference in "b" value (Moutopoulos and Stergiou, 2002). The parameter b, and a value, may vary according to seasonal change, or even diurnal, as well as habitat to habitat (Gonçalves et al., 1997 and Özaydin et al., 2007). According to Muchlisin et al., (2010) also suggested the same may be changed due to environmental parameters. So, at present, no data on the association between length, weight, 'K', and 'Kn' of *M. vittatus* have been investigated in sexual or habitat-related study. Hence, it is unfeasible to thoroughly compare the current outcome with prior data.

The study found that the 'K' values ranged 0.58 to 1.50, whereas 'Kn' values ranged 0.54 to 2.26 (Table 3). In female species of two habitat the highest average 'K' and 'Kn' values was observed. Kalita et al. (2017) founded the values 0.74-1.39, indicating lower 'Kn' results than the current study in different species. "Kn" values >1 for the majority of the fish indicated that they were in good health. The length of all specimens in biofloc culture system exhibited a significant negative correlation with 'K'. However, weights of the specimens show positive correlation with 'Kn' across all habitats (Table 4).

The relative condition component was shown to remain rather constant as the fish got larger or lighter, clearly shows good health of the fish. A reversal scenario was reported by Bhatta and Goswami (2014), wherein the medium-sized *Channa aurantimaculata* fish exhibited a high "Kn" value. Das et al. (2015) and Rahman et al. (2015), found the "Kn" value for *Heteropneustes fossilis* and *Anabas testudineus* in a gradient like the tendency for the same is in a degraded fashion as the size of the fish is increasing up to medium size and it is again highest in the larger fishes.

CONCLUSION

The length-weight relationship and the condition of fish are very useful parameters for understanding the general state, growth, survival, maturity, and reproduction of fish populations and also it is crucial to understand the suitability of the environment for fish, as well as playing an important role in fishery management, conservation and sustainability.

The present study represents the first data on the weight-length relationship and the condition of the *M. vittatus* species in two habitats viz. natural and culture habitat. The result of this study shows an allometric growth pattern where 'b' value ware < 3 in the Paschim Medinipur districts of West Bengal, India in both the natural and cultural habitat. The intended cube law may have been significantly deviated from by this species. In both ecosystems, the species' length and weight are significantly correlated. Significant relationships exist between weight, length, 'K', and 'Kn'; the same parameters also have habitat-dependent relationships. It was found that the 'K' and 'Kn' were in an optimal position for maintaining the health of the fish species. The obtained data could be valuable for guiding the design of future biometric studies for fish captured and culture in the study area.

Therefore, the present study certainly be helpful in assisting fishery personals in formulating significant methods for the sustainable maintenance of *M. vittatus* in natural as well as culture system also.

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AUTHORSHIP CONTRIBUTIONS

Angsuman Chanda & Basudev Mandal: Designing, monitoring, communication, reviewing; Purnachandra Das: Specimen collection, observation, data analysis, manuscript preparation; Arun Jana: Data analysis, manuscript preparation, reviewing; Godhuli Sit: Data analysis, manuscript preparation

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

ETHICAL APPROVAL

Ethical clearance from Institutional Animal Ethics Committee (IAEC), Approval no. 18/IAEC (05)/RNLKWC/2019, dated-27/07/2019

DATA AVAILABILITY

For questions regarding datasets, the corresponding author should be contacted.

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