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ARTICLE

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LENGTH-WEIGHT RELATIONSHIP AND RELATIVE CONDITION FACTOR OF *TENUALOSA ILISHA* (HAMILTON, 1822) FROM FARAKKA, IN RIVER GANGA, WEST BENGAL, INDIA

POONAM MAJUMDER[1], BASANTA KUMAR DAS[1*], SOURAV NANDY[1], ARCHISMAN RAY[1], ARGHYA KUNUI[1], SUSMITA JANA[1] AND SANTHANA KUMAR V.[1]

This study analyzed the length-weight relationship (LWR) and relative condition factor (Kn) of Tenualosa ilisha from 2021 to 2023 in the downstream of the Farakka Barrage, based on 1,500 samples (15-30 cm, 6-36.3 g). The regression coefficient (b) ranged from 2.6 to 3.1, with R^2 values of 0.82-0.96 and Kn between 1.008-1.038. These results denote the species' well-being, ecology, and demographic patterns, aiding in the effective management and conservation of Hilsa populations.

Keywords: *Hilsa, Length-weight relationship, Condition factor*

Introduction

The Indian shad, *Tenualosa ilisha* (Hamilton, 1822) belongs to the sub-family Alosinae, under the family Dorsomatidae and is primarily anadromous. It is distributed in the Persian Gulf, Red Sea, Arabian Sea, Vietnam Sea, China Sea, and Bay of Bengal[1]. It usually migrates from marine to estuarine and then freshwater habitats for breeding and feeding[2]. India accounts for 2.41% of global Hilsa production, contributing 0.14 lakh tonnes to the country's total fish production[3], with 14% of the catch from the Hooghly River[4]. Hilsa accounts for 12.5% of the fish caught in West Bengal[5]. Since 2001, Hilsa production has declined from 80,000 tonnes to 20,000 tonnes within 10 years[6]. Catches of Hilsa from the Hooghly River are declining rapidly year after year. This decline in Hilsa catch may result from over-fishing, industrial pollution and the construction of dams and barrages which in turn impacts the spawning and feeding migration[7]. Length-weight relationship (LWR) is an important tool in fish biology, physiology, ecology, fisheries assessment, and conservation[8]. Additionally, LWR can stimulate the ecosystem and construct an ecosystem model, which has a secondary effect on management and conservation[9]. Several studies has been conducted on the LWR and relative condition factor (Kn) of Hilsa in India[10-13] and on Season-wise LWR and Kn at Narmada estuary[14]. However, the season-wise relative condition factor of *T. ilisha* at downstream of Farakka Barrage, West Bengal is limited. In the present study, length-weight relationships and relative condition factor of *T. ilisha* were estimated to know the status of the Hilsa fishery in Hooghly River, West Bengal, India, which could be helpful for the management of fishery. Study of length-weight relationship generally used for the conversion of growth-in-length equations to growth-in-weight equations for use in stock assessment models to estimate the stock assessment, fish population dynamics, growth and biomass from a limited sample size as indicators of fish condition[14,15]. Therefore, the aim of our study was to assess the length-weight relationship and Kn of Hilsa at different years and seasons.

1 ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata, West Bengal - 700120
e-mail: majumderpoonam99@gmail.com

* Corresponding author: basantakumard@gmail.com

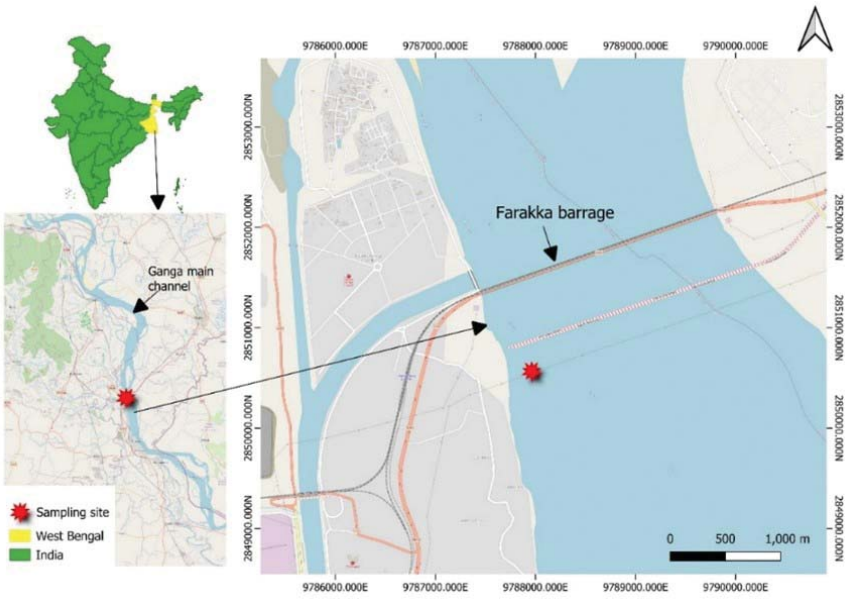

Fig. 1: Study area map showing the sampling site from 2021- 2023

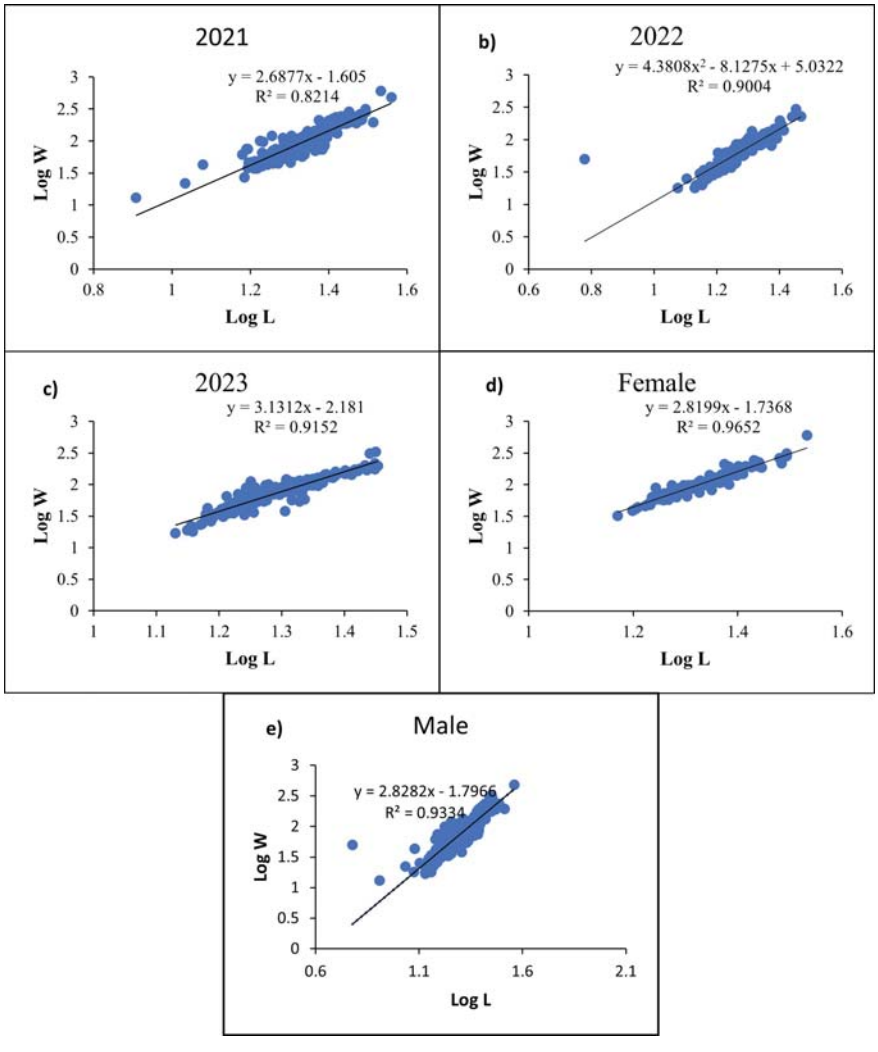

Fig. 2: Linearised length- weight relationship of *Tenualosa ilisha* for pooled samples in a) 2021, b) 2022, c) 2023, d) Female and e) Male

Materials and Methods

Study Area: The study was conducted downstream of Farakka barrage in West Bengal, India. Fresh specimens of *Tenualosa ilisha* were obtained during 2021, 2022 and 2023 from the downstream of Farakka barrage (22.403105º N & 88.139743 ºE) (Fig. 1).

Sampling and Data Analysis: A total number of 1500 specimen (male: 954 and female:546) of *Tenualosa ilisha* comprising mixed-size length groups were collected monthly from April 2021 to December 2023 from downstream of Farakka Barrage, West Bengal, India. The fish specimens were mainly caught by gill nets having mesh size (MS) of 40-60 mm and scoop nets with MS of 40-50 mm. The Total length (TL) was taken from the tip of the snout to the tip of the caudal fin in 'cm' using a meter scale, and weight was measured in 'g' by digital weighing balance, and the data was recorded for individual Hilsa with an accuracy of 0.1 cm and 0.01 gm respectively. The sex of each collected specimen was examined by investigating the reproductive organs after dissection of the samples. The data collected were grouped into different length classes (cm). The data were analysed using SPSS software.

Length-weight Relationship (LWR) and Relative Condition Factor (Kn): The length-weight relationship of Hilsa for each size class was established using the non-linear equation in the form of $W = aL^b$ given by LeCren, 1951 where 'a' is the intercept and 'b' is an exponent are the parameters of the regression equation. The intercept and slope were then calculated from the least-squares regression (ln BW = a + b ln TL) method for the length and weight log-log plot. The coefficient

of determination (R^2) was calculated following standard statistical procedure.

The relative condition factor (Kn) which makes up for the change in form or condition with an increase in length and is given by the formula, $Kn = W_0/W$, where W_0 is the observed body weight and W is the calculated weight for a given length. The mean value of Kn indicates the physiological wellness of the Hilsa- habitat type, having a mean value of $Kn \geq 1$ showing good health status, and $Kn \leq 1$ signifies poor health status. All the calculations were done using Microsoft Office Excel and IBM SPSS Statistics 22.0.

Results

Year wise length-weight relationship and relative condition factor of overall 1500 specimen of *T. ilisha* collected from downstream of Farakka barrage from 2021-2023 are presented in Table 1. Statistical parameters like sample size, length and weight of the specimen, regression parameters of a and b for length-weight relationship, correlation of determination (R^2), and relative condition factors are provided. Percentage frequency of female, male and pooled samples are provided in Figure 5, showing the Maximum percentage of female, male and pooled samples of Hilsa, respectively, belonging to the length class between 15- 30 cm. The minimum and maximum total length and weight were 8.1cm (13 g) and 36.3 cm (603 g) in 2021, 6 cm (18 g) and 29.5 cm (294 g) in 2022 and 13.5 cm (17 g) and 28.4 cm (328 g) respectively. The 'b' value recorded was 3.131 during 2023 and 2.688 and 2.791 during 2021 and 2022, respectively, which indicates that during the year 2023, growth was positively allometric (b>3) but shows negative allometric growth (b< 3) during 2021 and 2022 (Figure 2 a,b,c). The coefficient of determination (R^2) value recorded was 0.915 during 2023 and 0.821 and 0.839 in 2921 and 2022 respectively. The relative condition factors for the three consecutive years were found to be more than 1 (1.022 in 2021, 1.038 in 2022 and 1.088 in 2023), indicating that the fish inhabits in good condition.

The length-weight relationship and relative condition factor of 954 males of *T. ilisha* from 2021-2023 are shown in (Fig. 2 e) and the descriptive statistics are given in Table 2. The male has an average length and weight of 20 cm and 36.3 g, respectively. The minimum and maximum length and weight are 6 cm (13 g) and 36.3 cm (480 g), respectively. The 'b' value recorded was 2.83, which indicates negative allometric growth (b<3) during that period. The coefficient of determination (R^2) value recorded was 0.93, and the relative condition factor (Kn) value is 1.04, which indicates a good general condition of male population fish.

Length-weight relationship and relative condition factor of 546 females of *T. ilisha* from 2021-2023 are shown in (Fig.e 2 d) and the descriptive statistics are given in Table 2. The female has an average length and weight of 21.5 cm and 112.5 g, respectively. The minimum and maximum length and weight are 14.8 cm (32 g) and 34.1 cm (603 g), respectively. The 'b' value recorded was 2.82, which indicates negative allometric growth (b<3) during that period. The coefficient of determination (R^2) value recorded was 0.96 and the relative condition factor (Kn) value is 1.01, which indicates good general condition of the female population fish.

The total value of R^2 ranged from 0.821- 0.915 for both male and female sexes (comprising both sexes), 0.93

Table 1 Descriptive statistics and length-weight distribution of *T. ilisha* from 2021- 2023 of Farakka, West Bengal, India

Year	n	TL (cm)		BW (gm)		Regression parameters		R^2	Kn value	95 % CL
		Min	Max	Min	Max	a	b			
2021	450	8.1	36.3	13	603	0.025	2.688	0.821	1.022	2.5-2.8
2022	500	6	29.5	18	294	0.018	2.791	0.839	1.038	2.6- 2.8
2023	550	13.5	28.4	17	328	0.007	3.131	0.915	1.008	3.05- 3.2

Table 2 Descriptive statistics and length-weight distribution of male and female population *T. ilisha* from 2021-2023 of Farakka, West Bengal, India

Sex	n	TL (cm)		BW (g)		Regression parameters		R^2	Kn value	95 % CL
		Min	Max	Min	Max	a	b			
Male	954	6	36.3	13	480	0.02	2.83	0.93	1.04	2.67- 2.96
Female	546	14.8	34.1	32	603	0.018	2.82	0.96	1.01	2.76- 2.88

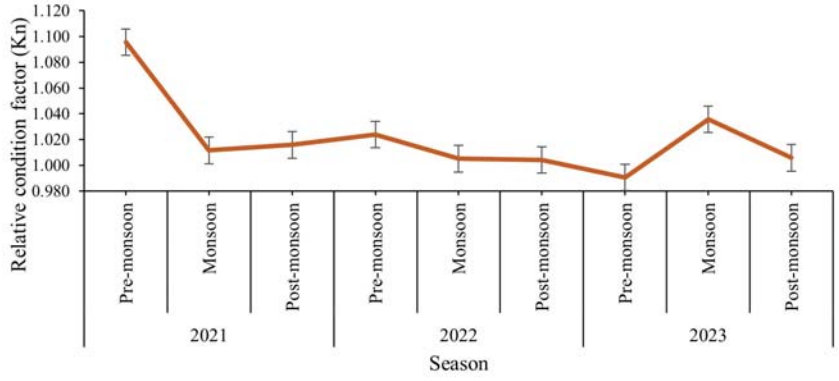

Fig. 3: Seasonal variations in mean Kn value of *T. ilisha* in Farakka, West Bengal

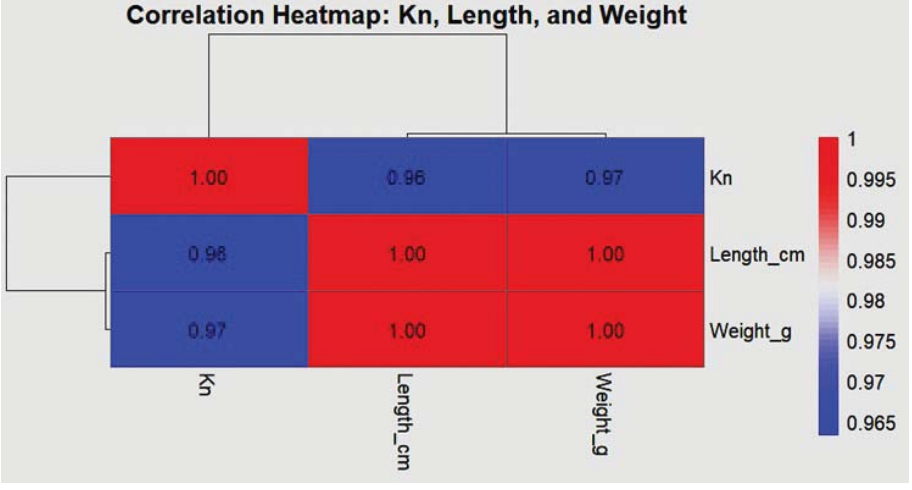

Fig. 4: Heatmap showing correlation between length, weight and condition factor (Kn)

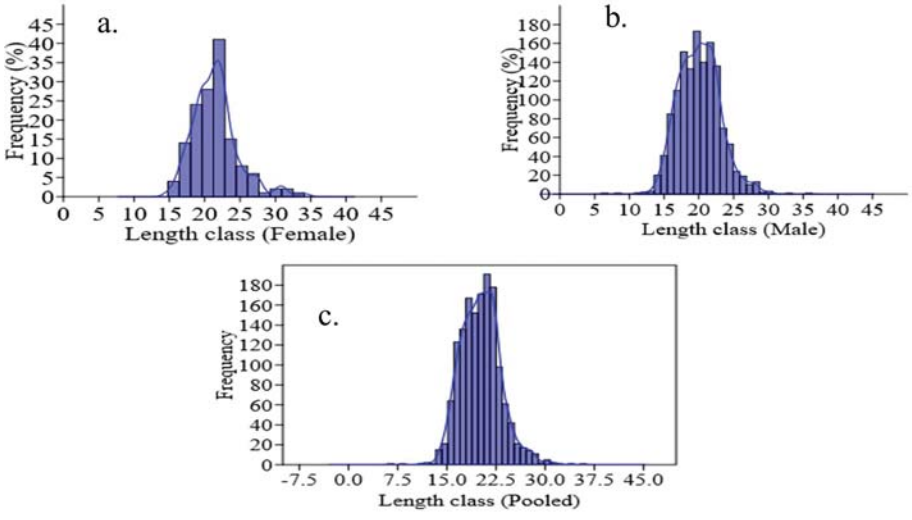

Fig. 5: Depicts the Percentage frequency of a. Female, b. male and c. pooled samples of *T. ilisha* in different length class (cm) from 2021-2023 in Farakka, West Bengal

in male samples and 0.96 in female ones. In 2023, a very high positive correlation was observed in pooled samples of Farakka. A high correlation ($R^2 > 0.9$) was observed in females in Farakka from 2021-2023.

The regression coefficient (b) ranged from 2.68 to 3.13 for pooled samples, 2.83 in males, and 2.82 in females. Prominent positive allometric development (b>3) was observed in total samples collected in 2023. Both male and female populations from Farakka in 2021-2023 showed negative allometric growth (b<3).

Seasonal Variation in Kn: The average relative condition factor Kn ranging from 1.022-1.008 in the pooled fish samples of Hilsa, 1.04 in males, and 1.01 in females in Farakka (Table. 2), which displays a healthy and suitable environment for growth dynamics of the Hilsa population in that region. There are variations in the Kn value in different seasons throughout the years (Fig. 3). The year 2021 and 2022 shows higher Kn values during pre-monsoon compared to the monsoon and post-monsoon season. However, in 2023, monsoon shows higher Kn values compared to pre-monsoon and post-monsoon.

The heatmap in Figure 4 shows the relationship between length, weight, and relative condition factor. Length and weight show a high positive correlation, suggesting larger fish tend to be heavier. Moreover, weight and Kn show a positive correlation (0.97), and length and Kn show a positive correlation (0.96), indicating healthier fish may weigh more.

Discussion

The study of LWR is a very popular tool, and information on Hilsa, an economically viable fish species, is important for resource assessment and sustainability. The present study describes the growth pattern of Hilsa in different years

and sexes and its relative condition factor to provide insights into habitat suitability of Hilsa at Farakka, West Bengal. In current work, heterogeneity in the LWR was observed in the whole sample populations, male and female at Farakka in the period of 2021-23. The exponential value 'b' for LWR generally resides close to 3, indicating that the fish grows isometrically, which means no change in body shape, and other results pointing out towards allometric growth[16]. Negative allometric growth implies that the fish becomes slender as it increases in weight while positive allometric growth implies the fish becomes relatively stout or deeper-bodied as it increases in length[17]. Our findings showed negative allometric growth of 2.83 and 2.82, respectively, in males and females from Farakka (2021 to 2023). However, allometric growth shows negativity in case of total samples examined from Padma (Farakka, November, 1999) and as well as males from Padma (Farakka, November 2015)[12]. Previously reported negative allometric growth for small-sized Hilsa, which justifies our study that shows a negative allometric growth pattern of pooled samples where the maximum % share of the population is at a length range of 15 cm < TL< 25 cm[18]. The R^2 value (R^2> 0.9) of both the male and female population of Farakka (2021-23) are 0.93 and 0.96, respectively, which is the proper fit of the model of growth. Similar results were also reported[11], in which the value of 'b' is in the range of 2.81 to 2.91 and R^2 value 0.98 and [10] also depicted the value of 'b' has to be 2.57, 3.20 & 3.11 and R^2 to be 0.88; 0.95 and 0.93 in case of male, female and total samples (male & female), correspondingly from Hooghly River. Fish with 'b' value of 3 retain specific body shapes throughout their life span[16], therefore the negative allometric growth of Hilsa observed during that period may be due to the migration of Hilsa from the Bay of Bengal to the upstream in Farakka during the peak spawning period[12], which leads to the noticeable change in body shape.

Relative Condition Factor (Kn value): A season-wise relative condition factor (Kn) for pooled samples is represented in Fig. 6. A high mean Kn value was observed during pre-monsoon in the years 2021 and 2022 but showed a peak during the monsoon season in 2023. Relatively higher Kn value during monsoon in 2023 might be due to a higher Gonado-somatic index (GSI) and less during post and pre-monsoon, possibly due to less feeding intensity[13]. The relative condition factor can quantify the overall fitness of fish amongst habitats and seasons by providing information on its physiological factors like maturity and spawning and environmental factors like availability of food and feeding intensity [19,20]. Hilsa caught in the downstream of Farakka barrage during 1999, 2013 and 2015[12] identified different sites of Hooghly River viz. Farakka, Barrackpore, Balagarh, and Godakhali in West Bengal are suitable habitats for the Hilsa population, with the mean Kn being close to 1. Recently, studies conducted on the Narmada estuary, Gujrat showed a mean Kn value close to 1[14], which was observed in line with our Kn value from the pooled as well as male and female populations from the Farakka barrage. The high Kn value for Hilsa from Farakka indicates its habitat suitability[13]. The habitat quality of the Hooghly River is suitable for aquatic organisms, promoting the growth of Hilsa therein. The factor contributing to the habitat quality and health condition of Hilsa is the availability of food, where they mostly feed on phytoplankton[21]. Moreover, Hilsa migrates to distant locations in the river stretch for feeding and spawning, which utilises fat accumulated in the fish muscles, which in turn reduces the Kn[22].

The LWR and Kn are main components for knowing the status of the particular fish species in a specific habitat. This current work enlightens about the recent information on length-weight components for *T. ilisha* at downstream of Farakka Barrage, India. For a sustainable Hilsa fishery in the area, management techniques, including stock assessment, are required in light of this signal of overexploitation brought on by extensive fishing activities.

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