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Temporal Variation of Growth Pattern and Physiological Status of Hilsa Shad, *Tenualosa ilisha* (Hamilton, 1822) in the Meghna River (Bangladesh)

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ABSTRACT

The current study was conducted on the temporal variation of the growth pattern and the physiological status of *Tenualosa ilisha* (Hamilton, 1822) from the Meghna River, Bangladesh for the period of July 2018 to June 2019. A sum of 1433 individuals were collected, where its body weight (BW), total length (TL), standard length (SL) and fork length (FL) were measured with 0.01 g and 0.01 cm accuracy. The growth pattern was estimated through length-weight relationship by the equation: $BW = a \times TL^b$, where BW was in g and TL in cm. The parameters *a* and *b* were estimated with linear regression analyses. Physiological status was determined using equation provided as follows: $\bar{a} = W/L^b$. If $\bar{a}$ was close to the *a* value (*a*, LWR parameter) then the fish was in an ideal condition, where $\bar{a} > a$ pointed to fatty fish and $\bar{a} < a$ to lean fish. The TL ranged from 15.3cm to 57.8 cm while the BW was from 37.17–2250 g. The overall growth pattern for *T. ilisha* was positive allometric (b = 3.135) in the Meghna River. The maximum fatty fish was found in the month of December (44%) while the minimum was in October. The highest percentage of lean fish was found in the monthof February (41%) and the lowest was in September (22%). The present findings would add some beneficial data for consumer preference, meanwhile further studies are recommended to achieve a sustainable management of hilsa fishery and other water bodies in the Meghna River.

INTRODUCTION

Tenualosa ilisha is locally known as ilish, ilsha or hilsa **(Shafi & Quddus, 1982)** in Bangladesh. This euryhaline species is found in marine, brackish and freshwater habitats occurring Bay of Bengal, Indian Ocean, Arabian Sea and Persian Gulf **(Amin *et al.*, 2005)** covering the country of Bangladesh, India, Sri Lanka, Iran, Iraq, Kuwait, Malaysia, Oman, Pakistan, Sumatra, Qatar, Saudi Arabia, Thailand, United Arab Emirates and Viet Nam **(Arai & Amalina, 2014; Freyhof, 2014)**. It is a commercially essential target species for large-scale fishers in Bangladesh and elsewhere in Asia. About 76% of the global hilsa production is supported from Bangladesh while Myanmar, India and other country (Including Thailand, Iran, Malaysia, Iraq, Kuwait, Indonesia, and Pakistan) cover only 15%, 4% and 5%, respectively **(Islam *et al*., 2016)**. Tropical anadromous fish hilsa **(Riede, 2004)** often shows schooling behavior **(Hossain *et al*., 2019)** and migrate from the Bay of Bengal into inland freshwater primarily the Meghna, Tetulia and Andermanik rivers to spawn **(Hossain *et al*., 2014)**. After developing into juveniles (locally known as *Jatka*) fish hilsa return to the open sea. The Meghna River ecosystem is a major spawning ground of hilsa from where 18% of the total country hilsa production is introduced **(Hossain *et al*., 2018)**.

Length frequency distribution (LFD) provides information on reproductive potential **(Khatun *et al*., 2018)**, dynamic growth rates, recruitment and mortality **(Neuman and Allen, 2001)** of fish population as well as definite the river health **(Ranjan *et al*., 2005)**. Growth pattern can be identified using morphometric studies *i.e.*, length-weight relationship (LWR) throughout the study period. Growth pattern of fish are used to execute the seasonal deviation of growth and conditions to compare the life history and to assess the unit stock differences **(King, 2007; Hossen *et al*., 2020; Khatun *et al*., 2020; Sabbir *et al*., 2020)**. Physiological status of fish (*i.e*., ideal, fatty or lean) helps to recognize the physiology of an individual fish species **(Sutharshiny *et al*., 2013)** which supports fisheries' management as well as consumer preference.

Several studies have been conducted on *T. ilisha* on the basis of population biology **(Amin *et al*., 2000; Halder *et al*., 2001; Amin *et al*., 2002; Halder & Amin 2005; Ahmed *et al*., 2008)**, exploitation status **(Amin *et al*., 2008)**, stock assessment and management **(Amin *et al*., 2004; Bhaumik, 2016; Rahman *et al*., 2018)**, Jatka fishing and sustainability **(Rahman *et al*., 1995; Miah *et al*., 2000)**, length weight relationship **(Dutta *et al*., 2012; Nima *et al*., 2020)** etc. However, to the best of our consciousness, none of these studies has covered the demographic information of growth pattern or the physiological condition of *T. ilisha*. Therefore, to describe the growth pattern and physiological status of *T. ilisha*, the present investigation was conducted in the Meghna River, southeastern (SE) Bangladesh using a monthly data over one year.

MATERIALS AND METHODS

***Study site and* sampling:** This research was done in the Meghna River in southeastern Bangladesh from July 2018 to June 2019. A total of 1433 individuals of *T. ilisha* were sampled randomly on monthly basis from the commercial catch at several palces in Chandpur region, SE Bangladesh. Fishers used traditional fishing gears seine net (*Ber jal*; mesh size: 2.5-6.5 cm), and gill net (*Chandi* or *ilish jal*; mesh size: 9-12 cm, *Chap jal*; mesh size: 7-15 cm) to catch the fish. After collection, they were immediately preserved in ice at the site.

***Fish* measurement:** In the laboratory, total length (TL) was estimated by a measuring board nearest to the 0.01 cm. For body weight (BW), an electric balance to the precision of 0.01 g accuracy was used for each individual.

***Length-frequency distribution (LFD) and Growth* pattern:** The length-frequency distribution for *T. ilisha* was estimated by using 1 cm intervals of TL. The growth pattern was estimated by length-weight relationship: $BW = a \times TL^b$, where BW was the total body weight (g) and TL was the total length (cm). The parameters *a* and *b* were calculated through: $ln\ (W) = ln\ (a) + b\ ln\ (L)$. Furthermore, 95% confidence limits of *a*, *b* and the coefficient of determination r^2 were assessed. Extreme outliers from the regression analyses were omitted according to **Froese (2006)**. The value of exponent (*b*) provides information on growth pattern of fish. A value of 3 specifies an isometric growth and other than 3 indicates that the growth is allometric **(Beverton & Holt, 1996)**. To validate the growth pattern *i.e*., isometric or allometric (negative or positive) for significant divergence from the isometric value of *b*, a t-test was applied **(Sokal & Rohlf, 1987)**.

***Physiological* status:** Individual physiological condition (*i.e.*, ideal, lean or fatty) for *T. ilisha* was estimated using equation provided by **King (2007)** as: $\bar{a} = BW/TL^b$. If $\bar{a}$ is near to the *a* value (*a* is the LWR parameter), it point to the fish is in ideal condition, whereas variation from the *a* value is revealing of either fatty or lean fish ($\bar{a} > a$ point to fatty fish and $\bar{a} < a$ to lean fish).

***Statistical analysis*:** All statistical analyses were implemented through GraphPad Prism 6.5 software in this study considering a significance level of 5% ($p < 0.05$). Before analysis, similarity and normality of data were checked.

RESULTS

Length-frequency distribution (LFD)

The LFD for *T. ilisha* exposed that the smallest individual was 15.3 cm in TL while the largest one was 57.8 cm in TL (Table 1). LFDs showed that the 35-42 cm TL size group was numerically dominant in the stock (Figure 1). Additionally, most of the individuals were of 36-37 cm TL size group, that is about (6.62%), while those from 40-41 cm were 6.35% individuals.

Table 1. Descriptive statistics on Total Length (TL) and body weight (BW) measurements and their 95% confidence limits of the *Tenualosa ilisha* (Hamilton, 1822) in the Meghna River of southeastern Bangladesh

Sampling month	*n*	Total length (cm)				Body Weight (g)			
		Min	Max	Mean ±SD	95% CL	Min	Max	Mean±SD	95% CL
Jul. 2018	72	17	53	34.58±6.80	32.98-36.18	78	1458	513.19±294.94	443.89-582.50
Aug.	103	27.5	51	37.95±4.45	37.08-38.82	248	1555	686.47±262.66	635.13-737.80
Sep.	120	27	48	36.77±3.84	36.07-37.46	200	1265	588.93±208.78	551.19-626.66
Oct.	130	25.5	48	35.49±3.89	34.82-36.17	174	1185	493.12±193.91	459.47-526.76
Nov.	124	28.5	47	36.51±3.93	35.81-37.20	225	1056	536.07±182.36	503.66-568.49
Dec.	226	19.7	44.5	34.45±6.09	33.65-35.25	54.98	969	511.55±25158	478.57-544.52
Jan. 2019	72	18	41.6	28.24±6.74	26.66-29.83	54.98	921	328.27±228.43	274.59-381.95
Feb.	76	18.9	46.2	31.26±8.92	29.22-33.30	70.68	1100	408.22±318.76	335.38-481.05
Mar.	35	26	42.5	31.56±4.34	30.07-33.05	173	933	345.63±175.25	285.43-405.83
Apr.	79	15.3	43.6	27.49±5.82	26.18-28.79	37.17	929	238.16±183.75	197.00-279.32
May	209	15.3	55.5	34.2±8.43	33.05-35.35	37.17	1800	473.10±344.44	426.14-520.07
Jun.	187	18.5	57.8	32.05±8.37	30.84-33.26	68	2250	415.87±324.24	369.09-462.65

n, Sample Size; Min, Minimum; Max, Maximum; SD, Standard Deviation; CL, Confidence Limit

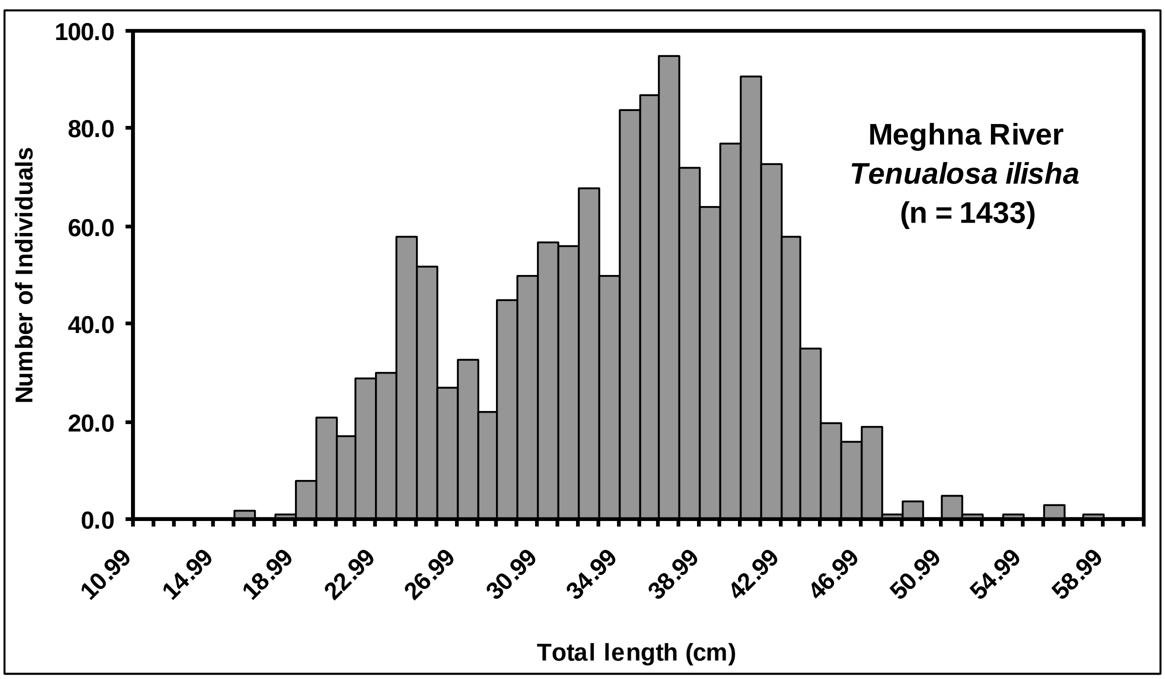

Figure 1. Length frequency distribution of the *Tenualosa ilisha* in the Meghna River of southeastern Bangladesh

Growth pattern

The BW of *T. ilisha* ranged from 37.17–2250 g during the study period from the Meghna River. Monthly descriptive statistics estimated parameters of the LWR of *T. ilisha* in the Meghna River were shortened in Table (2).

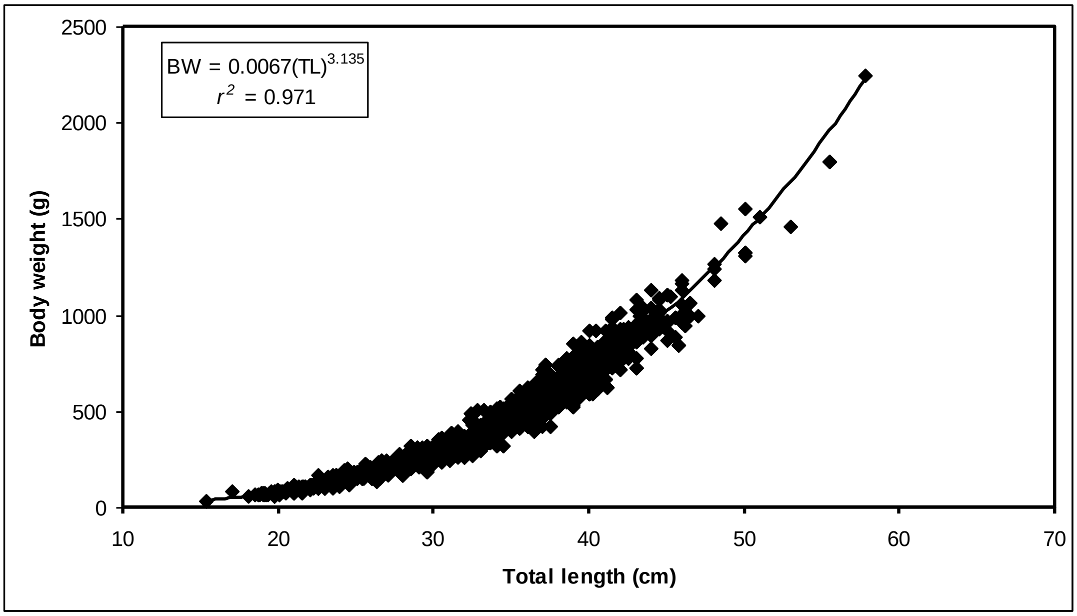

Figure 2. Length weight relationship of the *Tenualosa ilisha* in the Meghna River of southeastern Bangladesh

The allometric coefficient (b) for the LWR indicated a positive allometric growth pattern in most cases. Negative allometric growth was found in February while isometric growth showed up in June, July and December. However, the overall b value designated a positive allometric growth (b = 3.135) that is shown in Figure (2). Monthly deviations of length for hilsa shad are stated in Figure (3), whereas Figure (4) shows the variation of b value. All LWRs were highly significant ($p < 0.0001$), with all r^2 values ≥ 0.950.

Table 2. Descriptive statistics and estimated parameters of the length-weight relationships ($BW = a \times TL^b$) of the *Tenualosa ilisha* in the Meghna River of southeastern Bangladesh

Month	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	***b***				
Jul. 2018	0.0078	3.098	0.0048-0.0126	2.962-3.235	0.967	I
Aug.	0.0058	3.201	0.0034-0.0097	3.057-3.345	0.951	A+
Sep.	0.0048	3.238	0.0030-0.0078	3.106-3.371	0.952	A+
Oct.	0.0018	3.492	0.0010-0.0032	3.332-3.652	0.936	A+
Nov.	0.0066	3.130	0.0042-0.0105	3.001-3.258	0.950	A+
Dec.	0.0095	3.050	0.0069-0.0131	2.959-3.141	0.951	I
Jan. 19	0.0049	3.273	0.0035-0.0067	3.175-3.372	0.984	A+
Feb.	0.0108	2.998	0.0085-0.137	2.928-3.067	0.990	A-
Mar.	0.0051	3.202	0.0030-0.0086	3.052-3.352	0.983	A+
Apr.	0.0053	3.181	0.0035-0.0082	3.051-3.311	0.969	A+
May	0.0068	3.104	0.0056-0.0082	3.050-3.157	0.984	A+
Jun.	0.0078	3.079	0.0066-0.0091	3.033-3.125	0.989	I
Overall	0.0067	3.135	0.0060-0.0074	3.107-3.163	0.971	A+

Min, Minimum; Max, Maximum; SD, Standard Deviation; CL, Confidence Limit; GT, Growth Type

Length-length relationships (LLRs) were also estimated that were greatly correlated with r^2 values ≥ 0.983 and presented in Table (3) and Figure (5). By LLRs one can compare different body length (*i.e.*, TL, FL & SL).

Table 3. The estimated parameters of the length-length relationships ($y = a + b \times x$) of *Tenualosa ilisha* in the Meghna River of southeastern Bangladesh

Equation	Regression parameters		95% CL of *a*	95% CL of *b*	r^2
	a	***B***			
TL = *a* + *b*× FL	1.2800	1.094	1.0872 to 1.4728	1.088 to 1.101	0.988
TL = *a* + *b*× SL	1.9414	1.174	1.7216 to 2.1613	1.182 to 1.166	0.983
SL = *a* + *b*× FL	-0.3366	0.925	-0.498 to -0.176	0.919 to 0.930	0.988

TL, total length; FL, fork length; SL, standard length; *a* and *b* are the regression parameters; CL, confidence intervals; r^2, co-efficient of determination

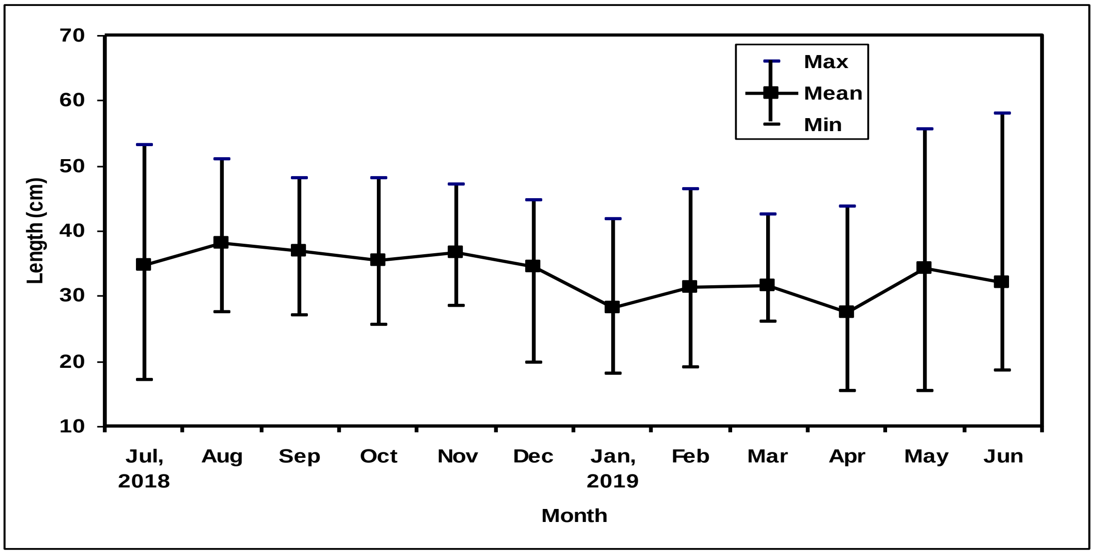

Figure 3. Monthly variation on minimum, mean and maximum length of the *Tenualosa ilisha* in the Meghna River of southeastern Bangladesh

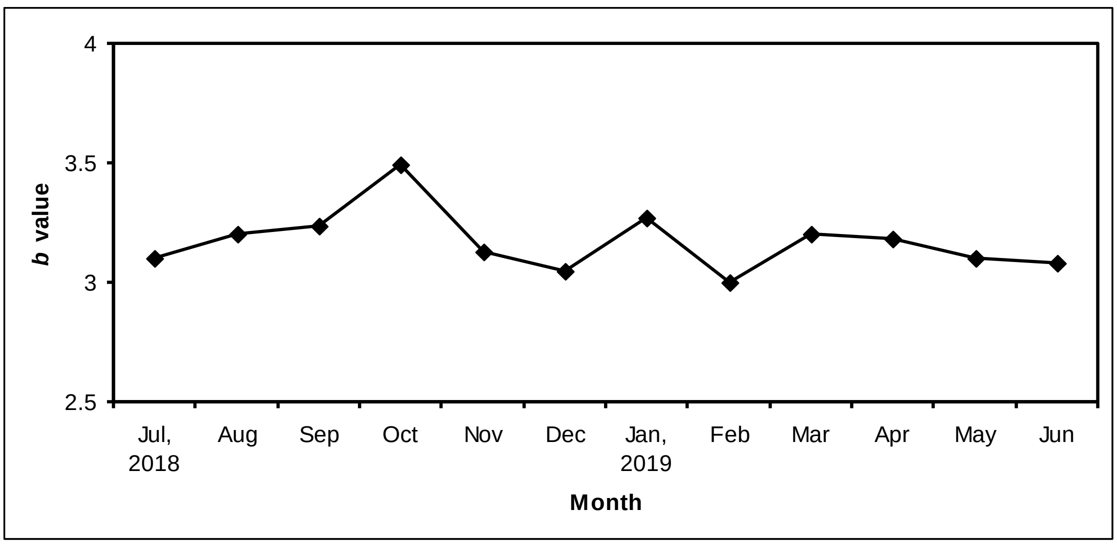

Figure 4. The generalized ln-ln relationships between total length and body weight of the *Tenualosa ilisha* in the Meghna River of southeastern Bangladesh

Physiological status

In the current study, the maximum proportion of fatty fish was found in December (44%). The percentage of fatty fish started to increase in April and continued until July. Beginning from August, fatty fish began to decrease gradually and reached its minimum in October. After November, it gradually increased and continued to increase before February. The maximum percentage of lean fish was found in February (41%) and the lowest was in September (22%). The monthly deviations of physiological condition *i.e.*, ideal, lean or fatty for *T. ilisha* are given in Figure (6).

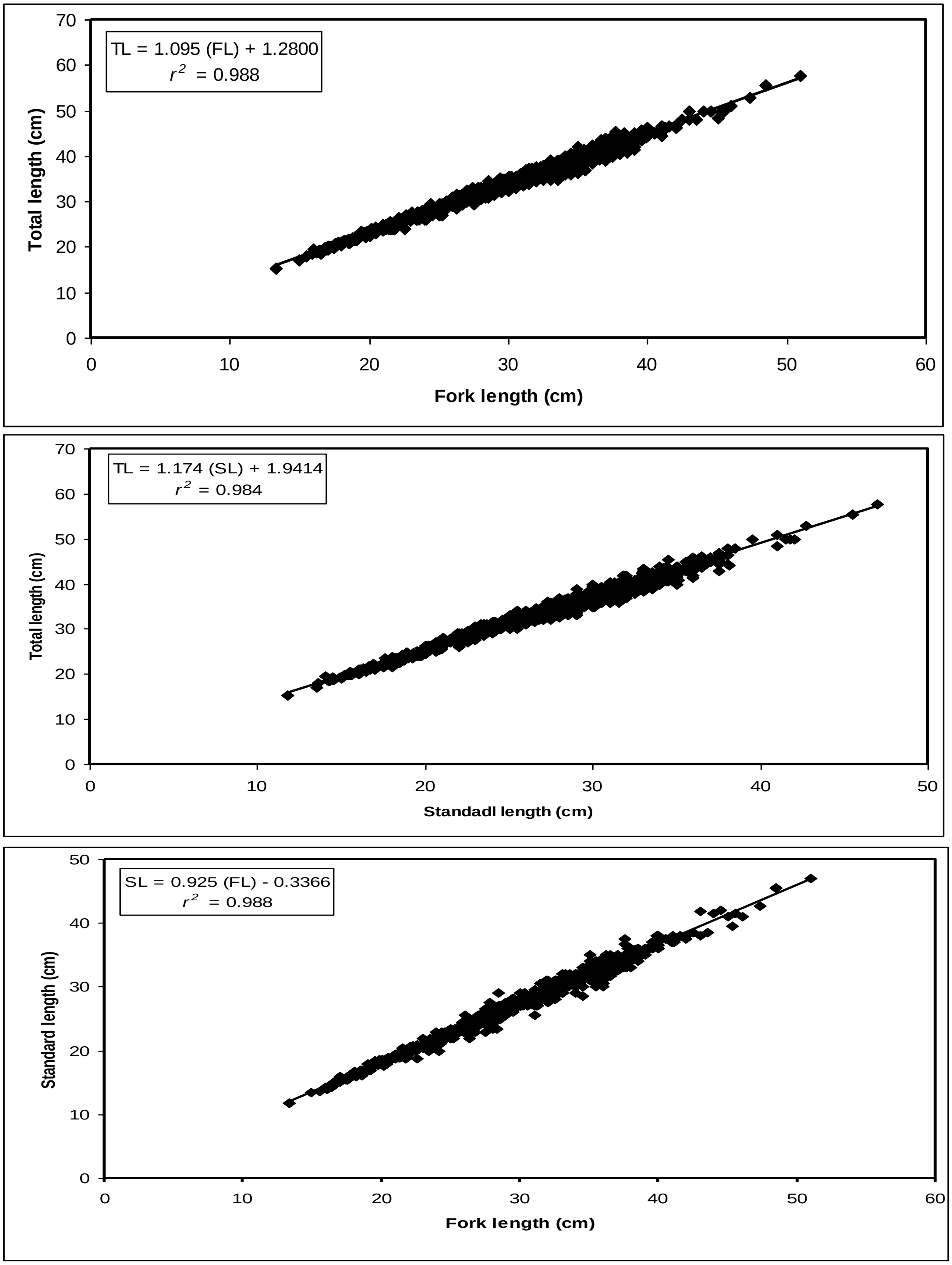

Figure 5. Length-length relationship (TL *vs.* FL, TL *vs.* SL & SL *vs.* FL) of the *Tenualosa ilisha* in the Meghna River of southeastern Bangladesh

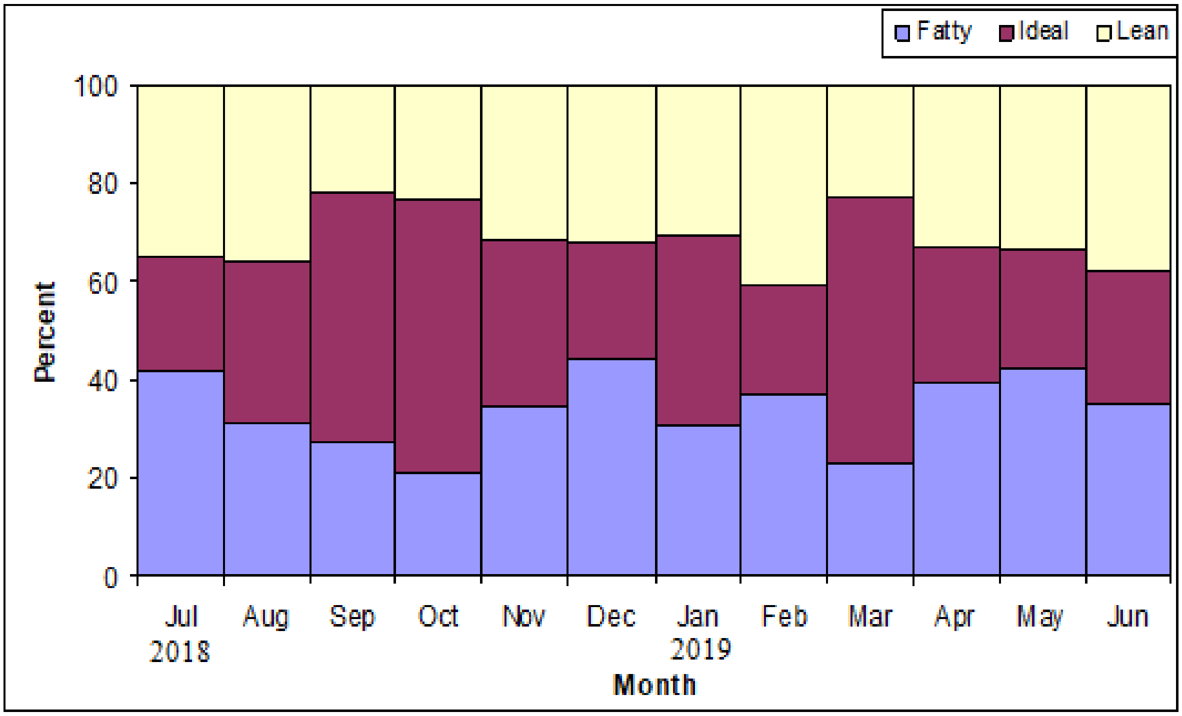

Figure 6. Monthly variation of physiological condition (*i.e.*, ideal, fatty or lean) for *Tenualosa ilisha* in the Meghna River of southeastern Bangladesh

DISCUSSION

A few studies have been presented on several aspects of Hilsa shad *T. ilisha.* However, a study on physiological condition *i.e.*, ideal, lean or fatty of Hilsa has not been conducted so far. To fill the gap, the present investigation was done in the Meghna River, SE Bangladesh by collecting a large number of individuals covering different body length throughout the year. Absence of specimens smaller than 15.3 cm can be accredited to fishing gear selectivity or absence of smaller individuals throughout the sampling **(Azad *et al*., 2020; Islam *et al*., 2020)**. In the present study, 57.8 cm fish was found which was more or less similar to the study (57 cm) of **Rahman *et al*. (1999)**, **Amin *et al*. (2002)** in Bangladesh. Furthermore, **Al-Baz and Grove (1995**) found a 57 cm fish in Kuwait. In comparison, that was smaller than the study (61 cm) of **Amin *et al*. (2004)** though fishbase showed a maximum length of 60 cm **(Forese & Pauly, 2020)**. On the contrary, other researchers **(Bhaumik *et al*., 2011; Roomiani & Jamili, 2011; Sarker *et al*., 2017; Bhakta *et al*., 2019)** have reported that the body lengths were smaller than the current study. However, difference in body length may be ascribed to geographic distribution and influences of environment like water temperature, food availability, etc.. **(Hossain *et al*., 2015; Hassan *et al*., 2020)**.

The value of *b* from the LWRs may vary between 2 and 4 though, values ranging from 2.5-3.5 are also common **(Hassan *et al*., 2020)**. When the value of *b* is close to 3

(b≈3.0) it indicates an isometric growth, but any significant difference from 3 indicates allometric growth pattern. When the value is > 3 would indicate a positive allometric and < 3 gives a negative allometric **(Tesch, 1971)**. The present study remained the value of b within 2.998 to 3.492 which was in the expected range for fish species **(Froese, 2006)**. The overall b value (b = 3.135) of the current study showed positive allometric growth. The present findings are similar to those of **Sujansingani (1957)** and **Bhaumik *et al*. (2011)** from Hoogly estuary (India). Moreover, current results agree with those of **Al-Baz & Grove (1995)** from Kuwait. Isometric growth pattern was stated by **Amin *et al*. (2002)** in Bangladesh, **Bhakta *et al*. (2019)** in Gujarat India and **Mahamed *et al*. (2016)** in Iraq. A negative allometric growth was observed by some other researcher including **Rahman *et al*. (2000), Amin *et al*. (2004),** and **Rahman *et al*. (2018)** in Bangladesh**, Das *et al*. (2019), De & Datta (1990), Sarker *et al*. (2017)** in India, **Roomiani & Jamini (2011)** in Persian Gulf, Iran. However, the variation in growth pattern might be associated with various reasons including fish health, sex, food availability, gonad maturation, nitration, habitat suitability, seasonal environmental effect on habitat, preservation method and differences in the observed length ranges of the captured specimens **(Hossain *et al*., 2013; Hasan *et al*., 2020),** which were not taken into account during this study.

In the present study, minimum number of fatty fish was found in October and the lowest percentage of lean fish was in September due to peak-spawning season **(Rahman *et al*., 2012)**. Percentage of fatty fish started to increase in November and the maximum fatty fish (44%) was found in December attributable to resting phase after peak-spawning season. The maximum percentage of lean fish was found in the month of February (41%). **Hossain *et al*. (2019)** indicated that the abundance of juvenile hilsa was found during January to May in the River Meghna. A minor peak-spawning was also detected throughout February to April by **Mathur (1964)** and **Moula *et al*. (1991)**. The percentage of fatty fish started to increase in April and continued until July. Juvenile fish become nourished in the Meghna River that is the largest nursery ground for hilsa and return to Bay of Bengal with their parents **(Hossain *et al*., 2019)**. Physiological status of fish may also be fluctuating due to environmental effect on habitat, habitat changes, primary productivity, food availability or nutrition etc.

CONCLUSION

The current study designated temporal variation of growth pattern and physiological status of *T. ilisha* from the river Meghna, Bangladesh. The findings would be cooperative for consumer preference as well as support to maintain a sustainable management of hilsa fishery in the Meghna River ecosystem and other adjacent water bodies.

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