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Age and growth of hilsa shad, *Tenualosa ilisha* (Hamilton, 1822) of the river Tentulia in Bangladesh

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Abstract

This study was carried out on age and growth of hilsa shad, *Tenualosa ilisha* in river Tentulia in Bhola district using monthly samples from January to December 2009 by checking annual rings or growth checks on hard parts. Age and growth of *T. ilisha* got progressed by direct fit of length frequency data both to standard and to modified von Bertalanffy growth models with ELEFAN I procedure where the predicted maximum total length were (TL_∞) 41.88 cm for male and 52.40 cm for female. Powell-Wetherall procedure gave an initial asymptotic total length (TL_∞) for both male and female 40.42 cm, 50.61 cm respectively. The values of Z/K were 3.362 for male and 2.626 for female. The growth co-efficient (K) was obtained as 1.40 $year^{-1}$ for male and 1.00 $year^{-1}$ for female. The von Bertalanffy growth equations in terms of body weight (BW) for both male and female were $BW_t=799.26[1-\exp\{-1.40(t+0.002)\}]^3$ and $BW_t=1717.82[1-\exp\{-0.99(t+0.013)\}]^3$ respectively. The length-weight relationship for both sexes were $BW=0.0101\ TL^{3.02}$ for male and $BW=0.0086\ TL^{3.08}$ for female. The value of coefficient of determination (R^2) was estimated for both male and female species were 0.969 and 0.968.

Keywords: Hilsa shad, *Tenualosa ilisha*, von Bertalanffy growth, asymptotic length, growth co-efficient

INTRODUCTION

Hilsa shad, *Tenualosa ilisha* (Hamilton, 1822) locally known as Ilish belongs to the family Clupeidae has been designated as the national fish of Bangladesh. It is an anadromous and highly fecund fish. In Bangladesh waters, the size at first maturity is reported as 26.5-30.5 cm for males and 30.0-35.0 cm for females (Dunn 1982). The percentage occurrence of males and females in different stages of maturity revealed that spawning of hilsa takes place in the month of August to November and subsidiary spawning in June-July and January-March (Islam *et al.* 1987, Moula *et al.* 1991).

The estimation of population parameters (age, growth, recruitment, reproduction etc.) are used to suggest management strategies for hilsa fishery. Age and growth studies are important aspects of modern fishery biological researchers, as information on these are essential for scientific interpretation of the fluctuations from time to time and place to place and to evolve economic management policies for the concerned fisheries whether marine or otherwise. Four main methods or their modifications are considered for determining the age and growth rates of fishes; (1) Petersen's method length frequency analysis, (2) study of annuli or annual rings occurring in the scales, otoliths, or other hard parts of the body along with some other biological studies, (3) rearing the fishes in captivity under controlled or near natural conditions and observing their growths well as ring formation in the scales, otoliths etc. and (4) tagging different sizes of the live fishes noting data on their size, weight and scales and examining the recovered fishes for all the noted characters. Among them the length-frequency analysis method of Petersen is well known, commonly used in Bangladesh and gives good result to assess the age and growth of target fish. The number of work on age and growth of fish are studied in both marine and freshwater species by using scales, otoliths and other hard parts like the operculum, clavical, vertebral centra and even the fin rays. More recently, Quddus (1982) found otoliths are a good tool for ageing the fish. In hilsa the radii on the scales are arranged transversely. Chacko and Zobairi (1949) commented that the scales of hilsa, instead the radii provide a better evidence of the age. In these cases, it is necessary to use alternative methods for ageing, such as direct fit of length-frequency data by using ELEFAN 1 method. The program ELEFAN is incorporated into a new suit of fisheries tools called FISAT. The method ELEFAN 1, in particular, has been widely used to analyze multiple samples length-frequency distributions.

According to Job (1942), hilsa grows at 2.54 cm/month and attains a size of about 26.48 cm in year. Fecundity and ability to compete for mates and resources also increase with size.

If there is a lacking of knowledge on age and growth of hilsa, there would be a chance of exploitation of this population. As such, information about age and growth is extremely important in almost every aspect of fisheries (Jobling 2002). The present study was undertaken on age and growth of *T. ilisha* in the river Tentulia to find out the age of both male and female hilsa, scrutinize body weight relationship; depict and contrast the growth pattern of both sexes that would be useful to put away our hilsa fishery from overexploitation and gain utmost production.

METHODOLOGY

Sampling spot: The experiment was conducted in Tentulia River (Figure 1) of Bhola district in Barisal division. The river Tentulia is a flow of the Lower Meghna river and originates from the Meghna at north of Bhola district.

Sampling of fish: Length-frequency data of *T. ilisha* were composed monthly from the commercial catches at dissimilar landing sites from January to December, 2009 in randomly selected transect of the river Tentulia. A total of 1200 specimens (607 males and 593 females) of hilsa were utilized for length-frequency study and only 15 specimens of different sizes were used for otolith study.

Figure 1: Map of Tentulia River in Barisal district

At each sampling, emphasis was given on the fact that at least 100 specimens were collected. After ending of sampling of each month, fish samples were conserved with crushed ice in fish boxes at the same time as early as possible to keep away from decomposition of fish which would degrade otolith and gonad quality. Then the formalin conserved samples were transferred to the laboratory for research purposes. Total length (TL) and body weight (BW) of the specimens were measured in 'cm' and 'g' using a meter scale and a specific electronic weight balance, respectively and the size ranging from 15.90-50.50 cm in total length and 33.20-1600.00 gin body weight (Table 1).

Table 1: Collection record of *T. ilisha* from the river Tentulia

Sampling date	No of male	Size range		No of female	Size range	
		TL(cm)[1]	BW(g)[2]		TL(cm)[1]	BW(g)[2]
15 January 2009	61	21.0-36.0	97.8-556.0	39	24.0-39.4	166.2-759.0
16 February	55	22.4-33.3	101.0-410.3	45	26.5-44.1	185.8-1027.1
14 March	40	19.2-34.8	72.9-456.0	60	26.6-42.4	198.0-974.2
17 April	52	27.8-39.2	186.0-626.6	48	27.0-49.0	202.0-1450.0
18 May	44	20.7-35.7	116.0-499.0	56	22.5-38.8	130.6-674.0
16 June	47	19.9-36.4	92.7-555.7	53	25.6-47.2	170.4-1000.2
17 July	49	22.0-38.0	92.9-587.0	51	22.8-50.5	118.9-1600.0
18 August	56	18.0-37.7	65.0-698.0	44	25.7-44.0	193.2-963.0
16 September	64	18.2-36.5	57.9-598.4	36	30.4-41.5	283.0-929.0
19 October	45	15.9-36.2	33.2-505.7	55	23.6-46.0	129.6-1391.0
15 November	51	21.7-34.0	102.0-511.0	49	21.4-40.8	104.6-943.0
14 December	43	20.3-35.0	101.0-506.0	57	24.1-41.2	155.6-802.0

1, Standard length; 2, Body weight

Data collection of length and weight: Fishes were washed with running tap water to remove dirt and surplus water was removed with blotting paper. Then fish was left in room temperature for about half an hour for leasing the moisture completely. Finally the total body length and total body weight of each fish were measured by using a measuring scale to the nearest centimeter and the body weight in gram by an electronic digital balance. Total length (TL) was measured from the tip of the snout (mouth closed) to the end of upper caudal fin.

Collection of gonad and determination of sex: By cutting the ventral portion of fishes with the help of scissors and forceps gonads were extracted with more awareness and their weights recorded to the nearest 0.001 g. Female gonads were preserved into small vial along with 10% formalin solution to avoid any damage. If it was not possible to ascertain whether the gonad was an ovary or testis then the sex of each fish was determined macroscopically. Individuals that could not be sexed were recorded as juveniles. In subsequent analysis, juveniles were randomly assigned to either male or female.

Age group analysis: The monthly collected samples were constructed on the basis of total length frequency distributions by sex with 1 cm interval. A series of component normal distributions were fitted to the frequency distribution for each sample by sex using a computer analysis (FiSAT) based on Bhattacharya's method (Bhattacharya 1967). Each component nominal distribution is assumed to represent an age group in the population. This analysis provided the mean TL, standard deviation and proportion of each age group explained by each component normal distribution.

Collection and preparation of otoliths and scales: To examine annual growth formed on scales and otoliths of hilsa otolith and scale of 15 specimens were detached randomly for investigation. Scales were observed by microscope fitted with reflected light with the magnification of 30 to 50x and fitted with transmitted light with the magnification of 100 to 1000x. Among the three pairs of otoliths, the right otoliths (sagittae) were used for age determination; the left sagittae were used if the right sagittae were damaged when extracted from the fish or during the sectioning process. The dried otoliths were then transported to the laboratory. Otoliths length were measured under microscope and weighed with a balance. Measured otoliths are embedded in epoxy resin, a mixture Dodencenyl Succinic Anhydride (DDSA), Epok 812, Methyl Nadic Anhydride (MNA), Dimethyl Ameminomethyl Phenol (DMP). Embedded otoliths were cut with a micro cutter and polished using a grinder in order to make transverse sections crossing the focus, leaving a thin slice of approximately 0.2 mm thick and mounted on a glass slide and coated with nail enamel.

Multiple samples length- frequency analysis: In multiple samples, the number of size cohorts in the length-frequency histograms for each sequential month was estimated by visual inspection to fit a normal curve to the size distribution of each cohort in each length-frequency histogram by using Bhattacharya method (A method of separating a length-frequency distribution into its component).

Direct fit of length-frequency data of hilsa shad, *Tenualosa ilisha*

Electronic Frequency Analysis I (ELEFAN I): ELEFAN I is a routine that can be used to identify the (seasonally oscillating) growth curve that "best" fits a set of length-frequency data, using the value of Rn as a criterion. FiSAT II provides three options to the user to identify that "best" growth curve: (1) curve fitting by eye (2) scan of K-values, and (3) response surface analysis.

Powell-Wetherall plot: The value of TL_∞ and Z/K are estimated independently by the use of Powell-Wetherall plot, by pooling a series of length-frequency data collected at small time intervals. From the regression line, the value of Z/K is estimated from the slope, b, as: Z/K = -(1+b) / b. A useful result of the analysis is that L may be estimated from the intercept, a, with the X-axis as: L = -a /b.

Analysis pathway: Total length frequency distribution by sex with 1 cm interval was constructed for each monthly sample and graphed as histograms to represent an age group in the population. This analysis provided the mean TL, standard deviation and proportion of each mode explained by each component normal distribution by Bhattacharya method. Bhattacharya method, Powell-Wetherall plots, and ELEFAN I methods were performed using the suite of fisheries tools called FISAT software (Gayanilo and Pauly 1997) in the study. The growth patterns of both male and female *T.ilisha* were established by fitting the von Bertalanffy growth equation to the mean body weights at ages. Body weights and ages were calculated from a few corresponding total lengths of both by means of respective length-weight relationships approximated by the allometric equation of Huxley (1932). The growth parameters in terms of BW for both male and female were obtained by non-linear methods based on a direct search for the parameters that best fitted to body weight at age data using a routine that performs a Gaussian elimination by Delta Graph 4.5 software (Delta Point Inc., Monterey, CA, USA).

RESULTS AND DISCUSSION

Total length and body weight: The range of total length and body weight of both sexes were 15.90 to 50.50 cm and 33.20 to 1600.00 g respectively. The total length of male ranged from 15.90 to 39.20 cm and the body weight ranged from 33.20 to 698.00 g. The total length of female ranged from 21.40 to 50.50 cm and the body weight from 104.60 to 1600.00 g. Sex ratio of male: female were 1.02:1.00, which did not deviate significantly from parity (Chi-squared test; $P > 0.05$).

Age and growth pattern: By analyzing hard parts such as scales and otoliths were used to observe the age of individual fish. For the scale less fish, checking should be done to observe any growth check on otoliths. In this study, otoliths study exposed neither annulus nor daily rings on that. So other method is adopted. This method is with arranging histograms sequentially of both sexes and analyzed by Bhattacharya plots for pseudo cohorts. The study on age and growth of *T. ilisha* got progressed by direct fit of length frequency data both to standard and to modified von Bertalanffy growth models with ELEFAN I procedure which was used to fit the seasonalized von Bertalanffy growth (VBG) function (Gayanilo and Pauly 1996) to 12 time-series total length-frequency data sets: $TL_t = TL_\infty (1 - \exp(-K(t - t_0) + Tt_s + Tt_0)$, $Tt_s = (CK/2\pi) \sin (2\pi (t - t_s))$, $Tt_0 = (CK/2\pi) \sin (2\pi (t_0 - t_s))$. Where $TL_t$is the total length at age t(cm), TL_∞ the asymptotic total length (cm), Kthe growth coefficient (year $^{-1}$), Cthe amplitude of oscillations, tthe age (year), t_0 the theoretical age at zero length (year), and t_s is the starting time of the sinusoid growth oscillation. Here, t_s was replaced with WP (winter point, which is the period when growth is slowest) as WP $= t_s + 0.5$.

The length-frequency histograms of both male and female of *T. ilisha* from samples were arranged one after the other. The analysis of the pooled length-frequency data of male *T. ilisha* by the Powell-Wetherall procedure gave an initial TL_∞ value of 40.92 cm and Z/K of 3.362 (Figure 2). By using TL_∞= 40.92 cm as a seeded value, the ELEFAN 1 analysis yielded to optimized and von Bertalnffy growth (VBG) curve with the following parameters: TL_∞= 41.88 cm, K=1.40 year $^{-1}$, C = 0, winter point (WP) = 0 and the goodness of fit index (Rn) = 0.115. By means of these parameters the computed growth curve is shown over the restructured total length-frequency histogram in Figure 3.

The growth curve male showed no seasonal oscillation in growth. The observed maximum total length was 39.20 (Table 1) cm and the predicted maximum total length was 41.88 cm. The value of the third parameter (t_0) of the von Bertalanffy growth functions during age and growth analysis was assumed to be zero.

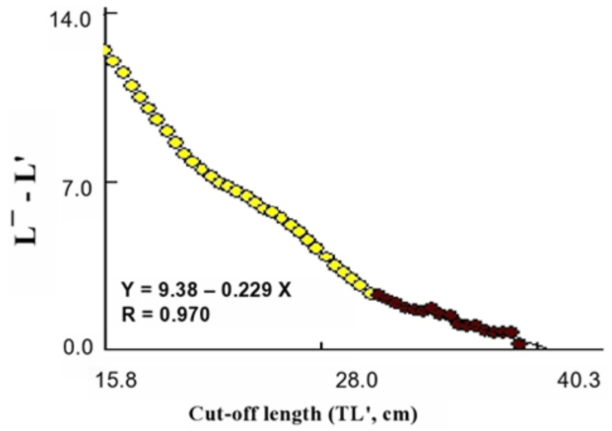

Figure 2: Powell–Wetherall plot for the male hilsa shad, *T. ilisha*. Solid black symbols are used in the regression which provides TL_∞ of 40.92 cm and Z/K of 3.362

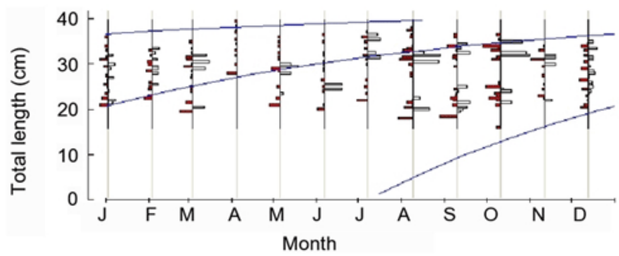

Figure 3: Von Bertalanffy growth curve (TL_∞ = 41.88 cm, K = 1.40 year^{-1}, C = 0, winter point (WP) = 0, Rn= 0.115) of the male hilsa shad, *T. ilisha* as superimposed on the restructured total length-frequency histograms

On the other hand, the analysis of the pooled length-frequency data of female *T. ilisha* by the Powell-Wetherall procedure gave an initial TL_∞ value of 50.61 cm and Z/K of 2.626 (Figure 4).

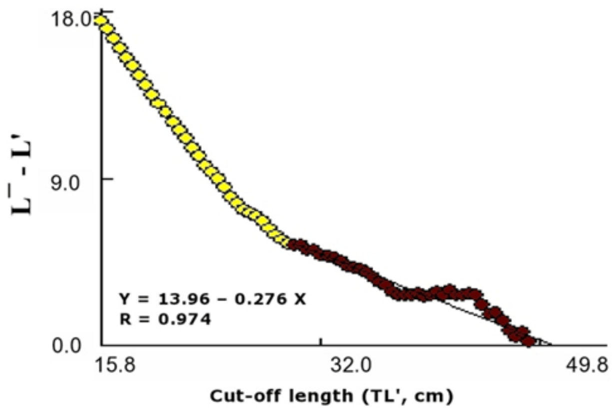

Figure 4: Powell–Wetherall plot for the female hilsa shad, *T ilisha*. Solid black symbols are used in the regression which provides TL_∞ of 50.61 cm and Z/K of 2.626

By using TL_∞= 50.61cm as a seeded value, the ELEFAN 1 analysis yielded to optimized and von Bertalnffy growth (VBG) curve with the following parameters: TL_∞ = 52.40

cm,K=1.0 year^{-1}, C = 0, winter point (WP) = 0 and the good of fit index (Rn) = 0.114. The von Bertalanffy growth curve of female as superimposed on the restructured total length-frequency histograms showed in Figure 5. The growth curve of female also revealed no seasonal oscillation in growth. The observed maximum total length was 50.50 cm (Table 1) and predicted maximum length was 52.40 cm.

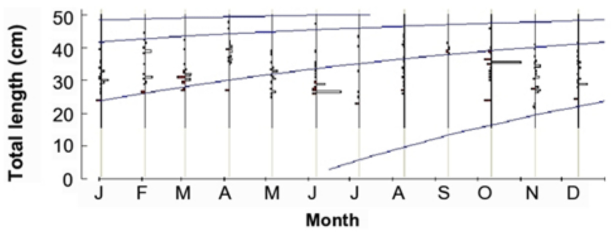

Figure 5: Von Bertalanffy growth curve (TL_∞ = 52.40 cm, K = 1.0 year^{-1}, C = 0, winter point (WP) = 0, Rn= 0.114) of the female hilsa shad, *T. ilisha* as superimposed on the restructured total length-frequency histograms

Table 2: Age-weight keys for both male and female *T. ilisha* to fit growth models. Body weights were calculated from respective length-weight relationship

Male		*Female*	
Mean BW (g)[1]	*Age (years)*	*Mean BW (g)[1]*	*Age (years)*
18.33	0.24	36.27	0.34
43.70	0.34	88.04	0.48
85.74	0.46	175.13	0.65
148.69	0.61	307.21	0.85
236.84	0.79	494.06	1.10
354.46	1.03	745.64	1.44
505.88	1.40	1072.00	1.96
695.38	2.22	1483.32	3.08

1, Body weight

Using the growth parameters (TL_∞, K) get from ELEFAN 1 method that put into von Bertalanffy growth equation and established relationship between age and total length. From the fitted growth equation age of several arbitrary total lengths in the life stage of both male and female population was calculated for both male and female separately (Table 2).

The relationships of pooled data of total length (TL) and body weight (BW) for male and female are given below (Figure 6 and 7):

Male: $BW = 0.0101\ TL^{3.02}$ (R^2 = 0.969)
Female: $BW = 0.0086\ TL^{3.08}$ (R^2 = 0.968)

From the established length-weight relationship body weight of several arbitrary total lengths in the life stage of both male and female population was calculated from above respective equations (Table 2).

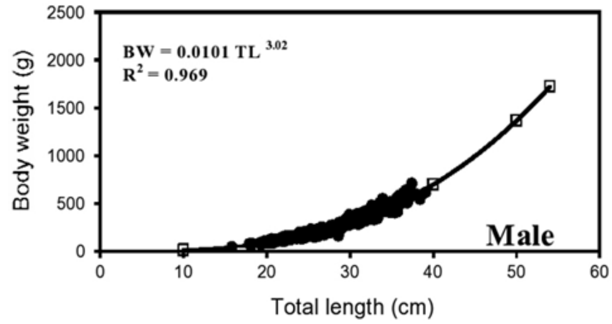

Figure 6: Length-weight relationship of male hilsa shad, *Tenualosa ilisha*

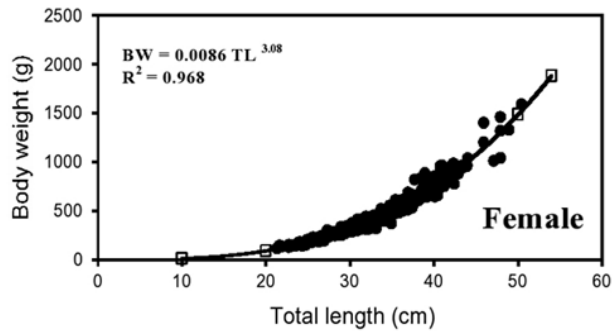

Figure 7: Length-weight relationship of female hilsa shad, *Tenualosa ilisha*

The von Bertalanffy growth curves fitted body weight-at-age data are shown in Figure 8 and 9 for both male and female separately. The equation for male was: BW_t= 799.26 [1-exp {-1.40 (t+0.002)}] ^{3}, R^2 = 0.992 (Figure 8).

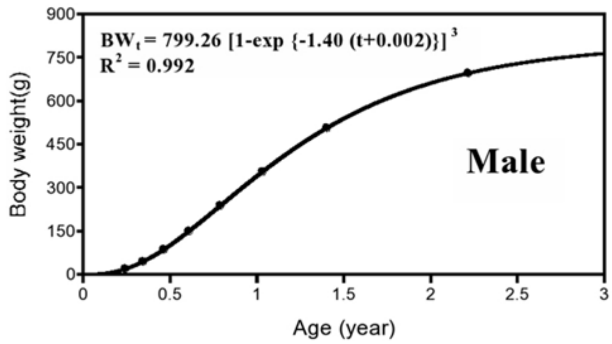

Figure 8: Relationship between age and body weight in male hilsa shad, *Tenualosa ilisha*

Above the fitted growth equation to understand that 799.26 g as the theoretical maximum or asymptotic body weight (BW_∞) was attained by male along with the growth coefficient (K) of 1.40 per year. The growth curve cut the age axis at -0.002; therefore, the theoretical age at zero length, t_0 was -0.005 years. The coefficient of determination (R^2) was 0.992, approached nearly 1 representing the high degree fit of the model. The equation for female was BW_t = 1717.82 [1-exp {-0.99 (t+0.013)}] ^{3}, R^2 = 0.999 (Figure 9).

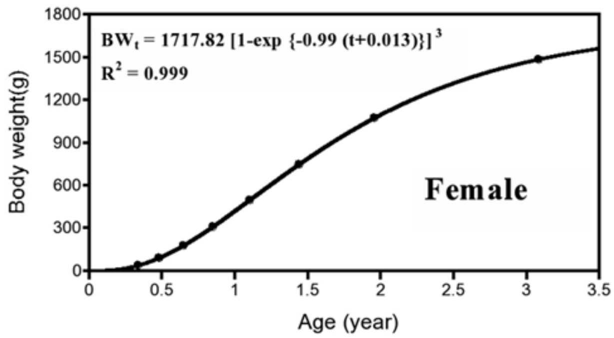

Figure 9: Relationship between age and body weight in female *Tenualosa ilisha*

Above the fitted growth equation to understand that 1717.82 g as the theoretical maximum or asymptotic body weight (BW_∞) was attained by female along with the growth coefficient (K) of 0.99 per year. The growth curve cut the age axis at -0.013; therefore, the theoretical age at zero length, t_0 was -0.013 years. The coefficient of determination (R^2) was 0.999, approached nearly 1 representing the high degree fit of the model.

CONCLUSION

Fish age, development and growth are a cornerstone in fishery research and management. Food availability, size increase, accumulation of energy reserves and timing of sexual maturation and reproduction of hilsa are closely linked. For this it is very important to determine the age and growth of hilsa by analyzing length-frequency of multiple samples. Subsequently an inclusive awareness with reference to age and growth of hilsa fish is crucial for accepting the population, behavior and migration of the stock in the diverse environments so as to embark on measures for management and promulgation of the population. In order to get better the present situation of hilsa fishery it is a precondition to fill this gap in our knowledge of the biological management of this commercial fish. This sensation has led the person behind to study the age and growth of hilsa.

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