

Population Dynamics and Stock Assessment of Hilsa Shad, *Tenualosa ilisha* in Bangladesh

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Abstract

Population dynamics and stock assessment of *Tenualosa ilisha* in Bangladesh waters is studied using the length-frequency based analysis of FiSAT software to evaluate the growth parameters, mortality rates, exploitation rate, maximum sustainable yield (MSY) and the corresponding fishing mortality at this level. The study reveals that the fishes are harvested at a higher level than the optimum fishing mortality. This fishing pressure should be reduced to about 1.88 yr^{-1} from the present level of mortality, 2.49 yr^{-1} to obtain MSY of 1,62,396 tonnes.

Introduction

Tenualosa ilisha (Hamilton), a diadromous fish, is the largest single fishery in both the inland and marine waters of Bangladesh. About 16% of the country's total fish production (1.3 million tonnes) is generated by this fishery. This fishery provides livelihood directly or indirectly to about 2.5 million people (2% of the total population). The reduction in the depth and discharge of rivers due to construction of dams and barrages has affected the spawning, feeding and migration of this fish. Despite increasing fishing effect in the upstream rivers, landing of hilsa from the inland waters has sharply declined. However, total production has remained stable due to an increased harvest by the marine sector. Until 1972, the upstream rivers were characterized by high abundance of hilsa. Subsequently, abundance in the upstream rivers started declining gradually, though simultaneously it increased in the downstream, the estuaries and the sea. Different aspects of biological work of hilsa have been done by different authors (Miah et al. 1997, Rahman et al. 1998 and Rahman

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et al. 2000) but little work has been done on the stock assessment of this species in Bangladesh. The present study was undertaken to estimate the key parameters of stock assessment and the population dynamics of *T. ilisha* such as asymptotic length (L_{∞}), growth co-efficient (K), total mortality (Z), natural mortality (M), fishing mortality (F), exploitation rate (E), recruitment pattern (R), relative yield per recruit (Y/R), relative biomass per recruit (B/R) and virtual population analysis (VPA). This information is necessary in formulating management and conservation policies as well as in the further development of the fishery for this species in Bangladesh.

Materials and Methods

Length-frequency data of *T. ilisha* were collected monthly from the commercial catches from the landing stations of Goalundo, Chandpur, Khulna, Barisal and Chittagong, Bangladesh, from January 1999 to December 1999. These samples of *T. ilisha* were mainly caught by gill net. The total length of 10,922 fish were measured in the size range 3.0 to 57.0 cm using a meter scale ($1 \pm \text{mm}$) and weighed using a Salter spring balance. The data were then pooled monthly from different landing sites and subsequently grouped into classes of two centimeter intervals. The data were analysed using the FiSAT (FAO-ICLARM Stock Assessment Tools) as explained in details by Gayanilo Jr et al. (1996). The fitting of the best growth curve was based on the ELEFAN I programme (Pauly and David 1981), which allows the fitted curve through the maximum number of peaks of the length-frequency distribution. With the aid of the best growth curve, the growth constant (K) and asymptotic length (L_{∞}) were estimated.

The growth performance (ϕ') of *T. ilisha* population in terms of length growth was computed using the index of Pauly and Munro (1984).i.e,

$$\phi' = \text{Log}_{10}K + 2 \text{Log}_{10}L_{\infty}$$

Total mortality (Z) was estimated using the length converted catch curve method, which has been incorporated into the FiSAT programme (Gayanilo Jr et al. 1996). The natural mortality rate (M) was estimated using Pauly's empirical relationship (Pauly 1980) i.e.,

$$\text{Log}_{10}M = 0.0066 - 0.279 \text{Log}_{10}L_{\infty} + 0.6543 \text{Log}_{10}K + 0.4634 \text{Log}_{10}T$$

where L_{∞} is expressed in cm and T, the mean annual environmental water temperature in °C. Here it is 28°C. Fishing mortality (F) was obtained by subtracting M from Z and exploitation rate (E) was obtained from F/Z .

The recruitment pattern was obtained by backward projection on the length axis of a set of length-frequency data as described in the FiSAT routine. Relative yield per recruit (Y/R) and relative biomass per recruit (B/R) values as a function of E were determined from the estimated growth parameters and probability of capture by length (Pauly and Soriano 1986).

The estimated length structured VPA and cohort analysis were carried out from the FiSAT routine. The values of the L_{∞} , K , M , F , a (constant) and b (exponent) for the species were used as inputs to a VPA analysis in the FiSAT routine. The t_0 value was taken as zero. The method was published by Fry (1949) and subsequently modified by many authors. Practical reviews of VPA methods are, among others, given by Pauly (1984) and Jones (1984).

The total annual stock size, average standing stock size and MSY of *T. ilisha* were also estimated. For this purpose, at first exploitation rate (U) was estimated using the equation given by Beverton and Holt (1957) and Ricker (1975) as $U = F/Z (1 - e^{-Z})$. To estimate the annual catch (Y), the landing data of hilsa were collected from the Fisheries Resources Survey System, Department of Fisheries, Bangladesh. Then by using the values of U , F and Y the total annual stock ($\bar{Y}$) and average standing stock ($\bar{Y}$) were determined.

U

F

The approximate MSY was then calculated using the relationship proposed by Gulland (1979).

$$MSY = Z_t * 0.5 B_t$$

where, Z_t is the instantaneous total mortality in the year t and B_t the standing stock size in the year.

The length-weight relationship of *T. ilisha* was estimated using the formula: $W = aL^b$, where 'a' is a constant and 'b' is an exponent.

Results

Growth and mortality parameters

Growth parameters of von Bertalanffy growth formula for *T. ilisha* were estimated as $L_{\infty} = 60.00$ cm and $K = 0.82$ yr⁻¹. For these estimates through ELEFAN I the response surface (R_n) was 0.179 for the curve. The computed growth curves produced with those parameters are shown over its restructured length distribution in figure 1.

Calculated growth performance index (ϕ') was found to be 3.47. The annual mortality rates M , F and Z computed were 1.28, 2.49 and 3.77, respectively. Figure 2 represents the catch curve utilized in the estimation of Z . The

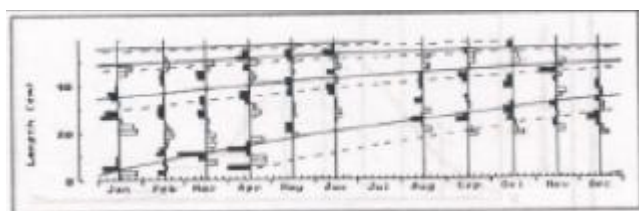


Fig. 1. Growth curve of *T. ilisha* from Bangladesh by ELEFAN I superimposed on the restructured length-frequency diagram ($L_{\infty} = 60.00$ cm and $K = 0.82$ / yr⁻¹.)

darkened circles were used in calculating the value of Z through the least square linear regression. The blank circles represent the points either not fully recruited or very close to L_{∞} . Good fit to the descending right hand

limits of the catch curve was considered. The r-value for the regression was - 0.992 ($a = 13.88$, $b = - 3.77$). The fishing mortality rate (F) was taken by subtracting M from Z and was found to be 2.49 yr^{-1} .

Exploitation rate

The rate of exploitation (E) was estimated as 0.66 and that of the E_{max} value recorded as 0.59. The higher value of E is indicated over fishing during that period. This assumption is based on Gulland (1971). He stated that suitable yield is optimized when $F=M$ i.e., when E is more than 0.50, the stock is generally considered to be overfished.

Recruitment pattern

The recruitment pattern (Fig.3) shows that this species was recruited in the fishery throughout the year with one peak. The peak pulse produced 19.81% of the recruits on the average.

Yield per recruit and biomass per recruit

The relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were determined as a function of L/L_{∞} and M/K were 0.38 and 2.13, respectively. Figure 4 shows that the present exploitation rate ($E = 0.66$) exceeds the maximum exploitation level ($E_{\text{max}} = 0.59$) which produces maximum yield.

Virtual population analysis (VPA)

The length-structured VPA is a powerful tool for stock assessment by which the size of each cohort is estimated alongwith the annual mortality caused by fishing. VPA results indicated that a maximum number of hilsa shads are caught between 31 and 45 cm, 53 and 55 cm with values of F exceeding to 2.29 yr^{-1} in the mid-length of 43 cm. The highest peak of F occurs in the length range between 31 to 45 cm with values of F exceeding 2.29 yr^{-1} (Fig. 5) which might be associated with excessive use of *current jal* (monofilamentous net, mesh size 6 to 10 cm) and another smaller peak

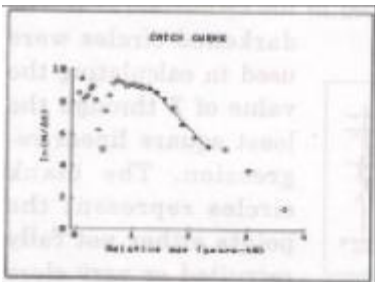


Fig. 2. Length converted catch curve of *T. ilisha*.

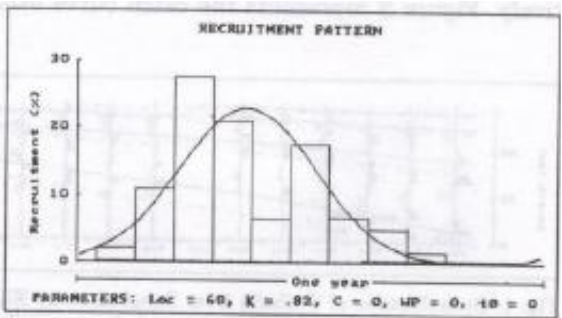


Fig. 3. Recruitment pattern of *T. ilisha*.

occurs in the length range between 53 to 55 cm which might be attributed to the *chandi jal* (gillnet, mesh size 12 to 16 cm).

Length-weight relationship

To study the length-weight relationship, a total of 982 specimens of *T. ilisha* for the individuals ranging in sizes from 3.0 to 57.0 cm in total length and weighing 0.44 to 2450 g were measured. From these, length-weight relationships were estimated with the form $W = aL^b$, using the logarithmic transformation $\text{Log}W = \text{Log} a + b \text{Log}TL$, where, a and b are constants estimated by linear regression of the log transformation varieties. The regression takes the form:

$$\text{Log } W = -2.06048 + 3.077 \text{ Log } TL \quad (r = 0.99) \quad (1)$$

$$\text{Corresponding to, } W = 0.01351 * TL^{3.077} \quad (2)$$

Stock assessment

The value of annual catch, total annual stock, standing stock and MSY recorded were 2,14,519 t, 3,35,185 t, 86,152 t and 1,62,396 t respectively. From these results it is evident that the value of MSY is below the annual catch, this indicates high fishing pressure on the stock in Bangladesh. Therefore, immediate necessary step must be undertaken to reduce the fishing pressure on the stock i.e., the present fishing pressure (2.49 yr^{-1}) needs to be reduced near to 1.88 yr^{-1} to obtain MSY from the stock.

Discussion

The estimated values of the growth parameters L_∞ and K for *T. ilisha* were 60.00 cm and 0.82 yr^{-1} respectively. These values did not show much difference when compared to the L_∞ and K values estimated by the other authors for the same species of Bangladesh waters (Rahman et al. 1998 and Rahman et al. 2000). The present exploitation level (0.66) indicates the high overfishing condition of hilsa fishery in Bangladesh. Miah et al. (1997) and Rahman et. al. (1998) also reported the overexploitation of the species in Bangladesh.

The instantaneous total mortality (Z) estimated using the length converted catch curve during the present study was 3.77 yr^{-1} . This value is higher than that of the Z values estimated for the same species, which were 2.61 yr^{-1} (Rahman et al.1998)

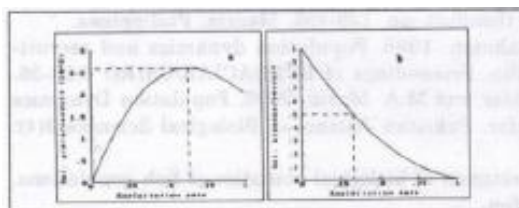


Fig. 4. Relative yield-per-recruit (a) and biomass-per-recruit (b) of *T. ilisha*.

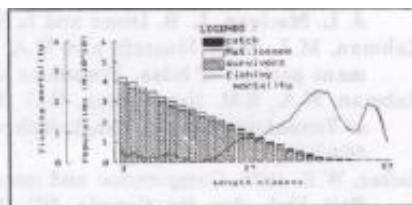


Fig. 5. Length-structured VPA of *T. ilisha*.

and 2.03 yr^{-1} (Miah and Shafi, 1995). This must be the effect of high fishing mortality of *T. ilisha* ($F=2.49 \text{ yr}^{-1}$) obtained from the present study.

The instantaneous natural mortality (M) estimated using Pauly's empirical formula during the present study was 1.28 yr^{-1} . This did not show much difference when compared to the instantaneous natural mortality (M) estimated for the same species which was 1.16 yr^{-1} (Miah and Shafi, 1995) and 1.18 yr^{-1} (Rahman et al. 1998 and Rahman et al. 2000).

From the above results it could be concluded that the recruitment pattern of the fish revealed that it recruits in the fishery throughout the year. The present fishing pressure is very high and it is essential to reduce this to obtain more sustained production. New policies for hilsa fishery should also be enforced.

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