Asian Fisheries Science **17** (2004): 51-59
ISSN: 0116-6514
https://doi.org/10.33997/j.afs.2004.17.1.006

Asian Fisheries Society, Manila, Philippines

Stock Assessment and Management of *Tenualosa ilisha* in Bangladesh

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Abstract

The stock assessment of *Tenualosa ilisha* of Bangladesh water is studied using length based analysis to evaluate growth parameters, mortality rates, exploitation rate, maximum sustainable yield (MSY) and the corresponding fishing pressure. The study reveals that the fishery is harvested at a higher level than the optimum fishing pressure. This fishing pressure may be reduced near to 1.76/yr i.e., 21.08% from the present level of 2.23/yr, to obtain an average MSY of 1,65,271 t.

Introduction

Tenualosa ilisha (Hamilton), a diadromous fish, locally known as "hilsa" provides the largest single species fishery in Bangladesh especially during the monsoon in almost all the principal river system, estuaries and the sea of Bangladesh. It contributes about 22 to 25% of the total fish production of the country (Rahman et al. 1998). It is harvested mainly by gill net and about 2% of the total population of Bangladesh is directly or indirectly employed in this fishery.

Hilsa shad (*T. ilisha*) is capable of withstanding a wide range of salinity and travel great distances upstream as far as 1287 km. It feeds and grows

mainly in the sea, but migrates to fresh water for spawning (Haroon 1998). Juveniles develop and grow in fresh water, but soon migrate to the ocean, where they spend most of their lives. Although, *T. ilisha* is the largest single species fisheries in the sea, coastal, and riverine waters of Bangladesh, detailed study on the stock assessment of this species has not been attempted so far except the studies carried out by Rahman et al. (1999 2000 and 2001) and Amin et al. (2000a 2000b and 2002).

In the present study, the population dynamics parameters of *T. ilisha* were estimated to assess the stocks in the Bangladesh waters and make appropriate management recommendations.

Materials and Methods

Length-based stock assessment method was used for the present study. For this purpose, length-frequency data of *T. ilisha* were collected monthly from the commercial catches at different landing sites from January - December for three years from 1997 to 1999. Total length and weight of the specimens were measured in 'cm' and 'g' using a meter scale and a Salter spring balance, respectively. The data from different landing sites were then pooled month-wise and subsequently grouped into length classes by 2 cm interval. Then the data were analyzed using the FiSAT (FAO-ICLARM Stock Assessment Tools) software as explained in detail by Gayanilo Jr. et al. (1996). Asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy growth equation were estimated by means of ELEFAN-1 (Pauly and David 1981, Saeger and Gayanilo 1986); and additional estimate of L_∞ and Z/K values were also done, using the methods of Wetheral (Pauly 1986).

'L-L'= a + bL'

where, L_∞ = -a/b and Z/K = -(1 + b)/b

where 'L is defined as the mean length, computed from L' upward, in a given length-frequency sample, while L' is the limit of the first length class used in computing a value of 'L.

The growth performance index (ϕ') of *T. ilisha* in terms of growth in length was estimated using the formula of Pauly and Munro (1984).

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

The total mortality rate (Z) was estimated using the length-converted catch curve method. Natural mortality rate (M) was estimated using empirical relationship of Pauly (1980).

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

where L_∞ is expressed in cm and T is the mean annual environmental temperature in°C, which is 27°C

Fishing mortality rate (F) was obtained by subtracting M from Z. The length at first capture (L_c) was estimated using the Beverton and Holt's Z-equation, Beverton and Holt (1956).

$$Z = \frac{K(L_\infty - \bar{L})}{\bar{L} - L_c}$$

where, $\bar{L}$ = average length of fish in the total catch. Recruitment pattern was determined by backward projection on the length axis of a set of length frequency data as described in the FiSAT routine.

The length-weight relationships of *T. ilisha* was established by the formula: $W = aL^b$ given by Le Cren (1951) where 'a' is a constant and 'b' is an exponent.

Relative yield-per-recruit (Y/R) and relative biomass-per-recruit (B/R) values were obtained for different levels of L_c and M/K, incorporating probabilities of capture at different size classes (Pauly and Soriano 1986). The Y/R and B/R calculations were carried out using the FiSAT software.

The values of L_∞, K, M, F, a (constant) and b (exponent) for the species were used as inputs to the VPA analysis. The t_o value in the von Bertalanffy equation was taken as zero.

The total annual stock, average standing stock and MSY of *T. ilisha* were also estimated. For these purposes, at first, exploitation rate (U) was estimated by the equation given by Beverton and Holt (1957) and Ricker (1975) as $U = F/Z\ (1 - e^{-z})$. Then by using the values of U, F and annual catch (Y), the total annual stock and average standing stock were determined. The approximate MSY was then calculated using the equation proposed by Cadima (in Troadec 1980) for exploited fish.

$$MSY = Z_t * 0.5 * B_t$$

where Z_t is the rate of total mortality in year t and B_t is the standing stock size in year t.

Results and Discussion

Growth parameters

The L_∞ values ranged from 61 to 66 cm and the range of K values were 0.67 to 0.83/yr and the values of response surface (R_n) were 0.111 to 0.179. The growth curves produced with those parameters have been shown over the restructured length distribution of the species in figures 1a, b and c.

The values of L_∞ and Z/K were in the range from 60.44 to 65.76 cm and 2.025 to 5.485, respectively (Figs. 2a, b and c). This additional estimate of L_∞ value was almost close to the L_∞ estimated through ELEFAN-I in 1997; however, the value of L_∞ was lower in 1998, but higher in 1999 than those estimated by ELEFAN-I (Table 1). This might be associated with the sampling error or variations in fishing intensity or environmental conditions. The ϕ' obtained for *T. ilisha* (3.34 to 3.50) were consistent (Table 1). Similar values of ϕ' were also obtained by Zafar et al. (1997a and 1997b).

Mortality

The values Z were 3.29, 3.43, and 3.77 during the year 1997 1998, and 1999, respectively. The M and F were 1.28, 1.25, 1.28 and 2.01, 2.18 and 2.49 in 1997 1998 and 1999, respectively (Table 1). Fishing mortality was higher than the natural mortality in all the years, which indicates that the species has been over fished.

Exploitation rate

Table 1. Population parameters of *T. ilisha* during 1997 and 1999 in Bangladesh.

Year	L_∞	K	Z	M	F	U	E_{max}	ϕ'	Lc	Rn	N	Lc/L_∞	M/K
1997	61.50	0.83	3.29	1.28	2.01	0.59	0.69	3.50	29.81	0.150	6123	0.37	1.54
1998	66.00	0.67	3.43	1.25	2.18	0.61	0.60	3.34	27.06	0.111	6189	0.41	1.37
1999	60.00	0.82	3.77	1.28	2.49	0.64	0.59	3.47	22.80	0.179	10922	0.38	2.13
AV.	62.50	0.77	3.50	1.27	2.23	0.61	0.63	3.48	26.56	0.147		0.39	1.68

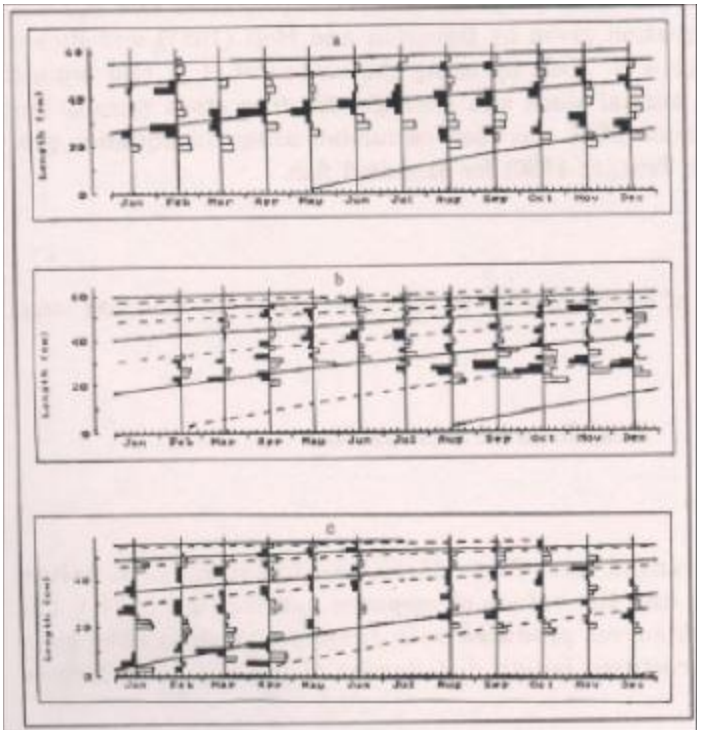

Fig. 1. Growth curves of *T. ilisha* in Bangladesh (a for 1997, b for 1998 and c for 1999).

The U values varied between 0.59 and 0.64 and that of the maximum allowable limit of exploitation (E_{max}) values ranged from 0.59 to 0.69 (Table 1) for highest Y/R. The higher value of U in 1997 to 1999 indicated over fishing during this period. According to Gulland (1971), the yield is optimised when F=M; therefore, when U is more than 0.5, the stock is over fished.

Recruitment pattern

Figures 3a, b and c show the recruitment patterns of *T. ilisha*, in Bangladesh. Recruitment occurs more or less continuously with one major peak of recruitment from June - September. The peak of recruitment varied year to year as shown in figure 3c. The major recruitment of *T. ilisha* occurred in summer during 1997 to 1998, but during 1999, the peak recruitment occurred in April. Rahman et al. (1998 and 2000) also observed the peak recruitment of this species in the summer. The length at first captures (L_c) varied from 22.80 to 29.81 cm (Table 1).

Yield-per-recruit and biomass-per-recruit

The relative yield-per-recruit (Y/R) and biomass-per-recruit (B/R) were determined as a function of L_c/L_∞ and M/K. The L_c/L_∞ values ranged from 0.37 to 0.41 and M/K values were 1.37-2.13 for different years (Table 1). The exploitation rate of *T. ilisha* obtained in 1998 to 99 exceeded the maximum allowable limit based on yield per recruit calculation (Figs. 4b and c). This suggests that exploitation of this stock has exceeded the maximum fishing level and thereby the fishing mortality seems to be a great concern for this stock. Thus, there is no scope to increase fishing pressure on this stock for optimizing the yield.

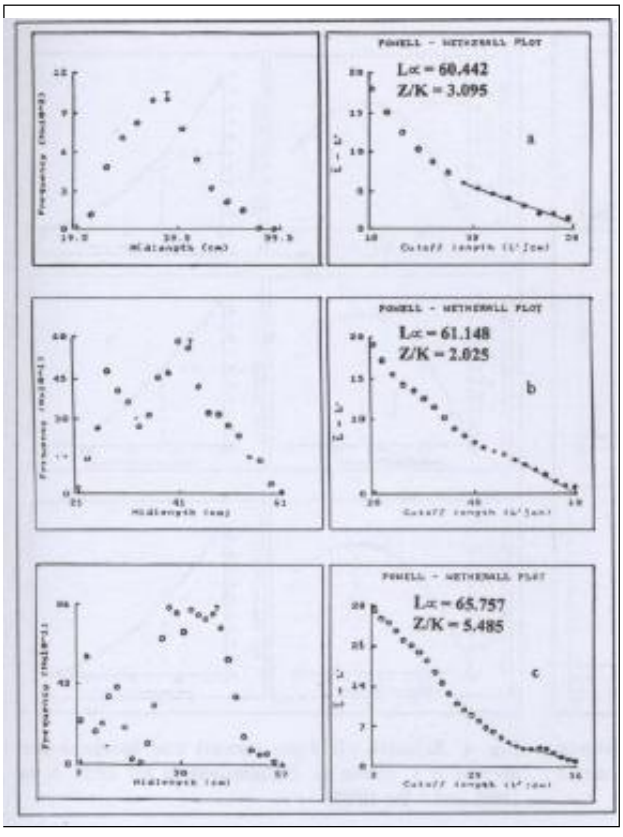

Fig. 2. Estimation of L_∞ and Z/K using the method of Powell-Wetherall plot for *T. ilisha* in Bangladesh (a for 1997, b for 1998 and c for 1999).

Virtual population analysis (VPA)

The results of length based VPA analysis are depicted in figures 5a, b and c. These figures show the fishing mortality in relation to mean length. Relatively higher fishing mortality of *T. ilisha* occurred in the length ranges 33 to 54 cm during 1997, 40 to 58 cm during 1998 and 32 to 44 cm during 1999.

Length-weight relationship

The length-weight relationships of *T. ilisha* for different years have been presented in table 2. The length-weight relationship was established in the logarithmic form LogW = Loga + bLogL.

The exponent 'b' estimated in different years were close to 3, which indicated that growth was more or less isometric. The correlation co-efficient values were above 0.99, which indicated that the relationships between total length and weight of this species were highly significant. This finding agrees with the findings of Ahmed and Saha (1996) and ARG (1986).

Stock size and MSY estimation

The estimates of stock size and MSY for *T. ilisha* are given in table 3.

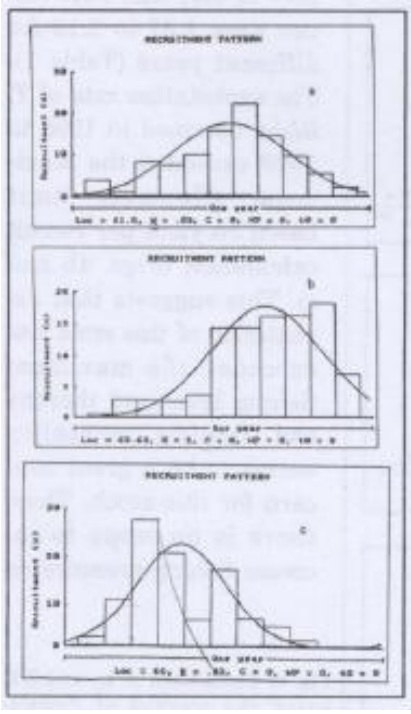

Fig. 3. Recruitment pattern of *T. ilisha* in Bangladesh (a for 1997, b for 1998 and c for 1999).

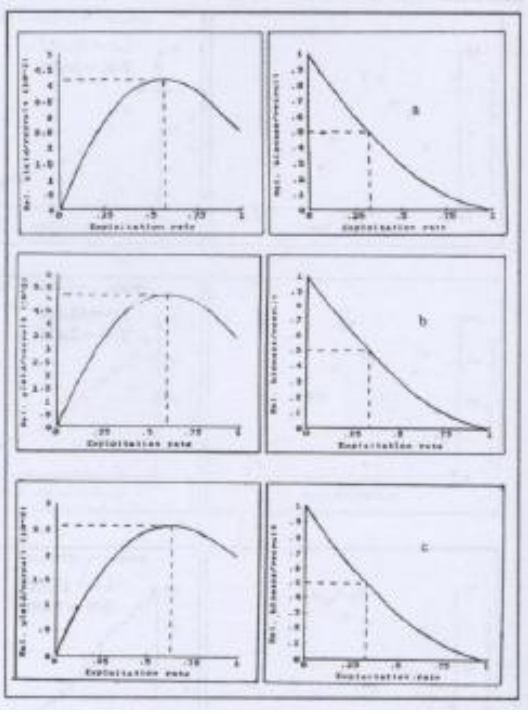

Fig. 4. Relative yield-per-recruit and biomass-per-recruit of *T. ilisha* in Bangladesh (a for 1997, b for 1998 and c for 1999).

From these results it is evident that the average value of MSY is below the average annual catch (Table 3). The number of recruits (19.5-21.5 length range) increased each year perhaps due to favorable environmental condition (Fig. 5) and for this reason the catches may exceed MSY. Therefore, immediate steps must be taken to reduce fishing pressure on the stock for which the present level of fishing pressure (2.23/yr) needs to be reduced near to 1.76/yr, i.e. 21.08% reduction, for obtaining MSY.

Table 2. Length-weight relationship of *T. ilisha* in Bangladesh

Year	Sample size (N)	Length range(cm)	Weight range(gm)	Exponential form of equation	r
1997	3209	23-57	202.50-2450	$W=0.01351TL^{2.974}$	0.99
1998	1207	21-61	144.00-2950	$W=0.02132TL^{2.820}$	0.98
1999	982	3-57	0.44-2450	$W=0.0087TL^{3.077}$	0.99

Table 3. Estimation of stock (in tonnes) *T. ilisha* during 1997 and 1999 in Bangladesh.

Year	Catch	Annual stock	Ave. standing	MSY
1997	2,14,434.00	3,63,447.46	1,06,683.58	1,75,494.49
1998	2,05,739.00	3,31,837.10	94,375.69	1,61,854.31
1999	2,09,326.00	3,27,071.88	84,066.67	1,58,465.67
Av.	2,09,833.00	3,41,181.57	95,143.79	1,65,271.49

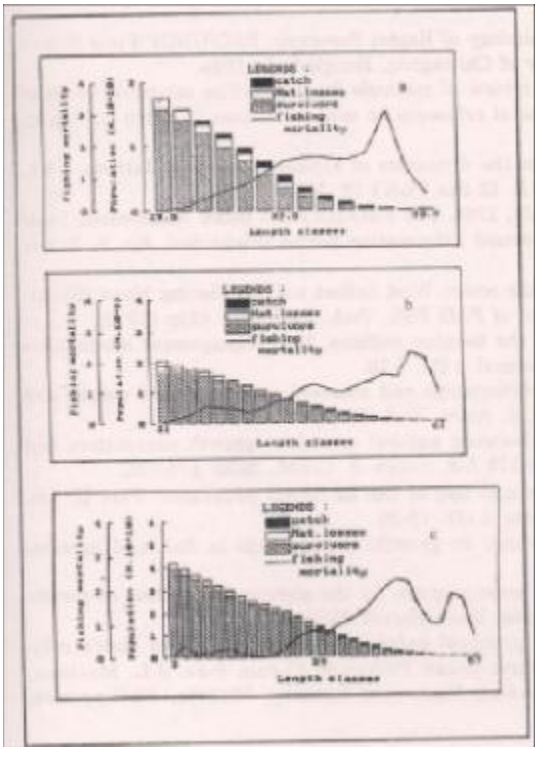

Fig. 5. Length-based virtual population analysis of *T. ilisha* in Bangladesh (a for 1997, b for 1998 and c for 1999)

Conclusion

The results indicated that the stock of *T. ilisha* is heavily exploited. Any increase in the existing fishing level/exploitation will most likely result in a reduction in the yield-per-recruit and thereby hamper the MSY. It is necessary to immediately impose fishing regulation on the stock and this can be done by gradually increasing the mesh size of the gears or by restricting fishing for certain seasons or declaring fish sanctuaries in certain areas, especially in spawning areas.

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Manuscript received 29 June 2001; Accepted 22 October 2003