Population Structure, Mortality Rate and Exploitation Rate of Hilsa Shad (Tenualosa ilisha) in West Bengal Coast of Northern Bay of Bengal, India

Sachinandan Dutta, Sourav Maity, Abhra Chanda and Sugata Hazra

School of Oceanographic Studies, Jadavpur University, Kolkata 700 032, India

Abstract: The population dynamics of Hilsa was investigated by using FiSAT II software of FAO on length based data, was collected from the three main fish landing centers of West Bengal between June 2010 and March 2011. The asymptotic length (L8) was 477.75 mm and the von Bertalanffy Growth Function (VBGF) growth constant (K) was 1.900 year\(^{-1}\). The total mortality (Z) was 1.98 year\(^{-1}\) and the fishing mortality (F) was 0.73 year\(^{-1}\). The natural mortality (M) of Hilsa Shad was 1.25 year\(^{-1}\) by using Pauly’s M empirical equation, where the mean habitat temperature was 27.9 °C. FiSAT shows the observed extreme length was 455.00 mm where predicted maximum length was 453.58 mm and the growth performance index (\(\alpha^2\)) was 3.637. The average size group of Hilsa population was observed to be comparatively smaller than that found in Bangladesh water. The exploitation rate (E) was found to be 0.37 (< 0.50). However, the apparent under exploitation of Hilsa population, (though \(E_{\text{max}}=0.555\)) may switch to overexploitation in future, if sustainable fishing is not implemented.

Key words: Population Dynamics %Length Based Data %Mortality %FiSAT II %Overexploitation

INTRODUCTION

Estimation of growth and mortality of exploitable species is very important since stock assessment and management rely on these population parameters [1]. Hilsa Shad (Tenualosa ilisha) is one of the most common and important anadromous fish of West Bengal. It is also a very important commercial fish and one of the most popular fish in Bengali cuisine. Several scientists have worked on different biological aspects of Hilsa Shad viz. Pillay and Rosa [2], Hora [3], Pillay [4, 5], Jones [6, 7], Mathur [8], Bhanot [9], De and Datta [10]. Tenualosa ilisha inhabits coastal shelf, estuaries and freshwater rivers in Indonesia, Sumatra, Myanmar, Bangladesh, India, Pakistan, Kuwait, Iraq and Iran. Out of these nations, maximum Hilsa fishes have been harvested from Bangladesh. Extensive Hilsa fishing is conducted from Bangladesh and comprises 75% of the total world catch of this species [11] and represents about 25% (2,50,000 t) of the total fish production in Bangladesh [12]. In the recent past, the fishery in inland waters of Bangladesh had been declining, but the total catch has remained stable (about 2,00,000 t annually) due to an increase in catch from the marine sector [13]. Several studies had been done on population dynamics of Hilsa from Bangladesh by Rahaman et al. [14], Nurul Amin et al. [15-17], Halder and Nurul Amin [18], Ahmed et al. [19], Amin et al. [13] and Rahman and Cowx [20]. Similar studies had been done by Hashemi et al. [21] and Roomian and Jamili [22] in Iran. The population dynamics of Hilsa has been comparatively less studied in this part of the country. In India only few authors researched the population dynamic of Hilsa viz. Reuben et al. [23]. In the present study, asymptotic length(L8), growth coefficient(K), total mortality(Z), natural mortality(M), fishing mortality(F), exploitation rate (E), relative coefficient per recruit(Y/R), relative biomass per recruit(B/R), maximum length, growth performance indexes (\(\alpha^2\)), requirement pattern, probability of capture, virtual population analysis (VPA) were evaluated by using FiSAT II software package to understand the status of Hilsa population in Northern Bay of Bengal of West Bengal coast. New FAO-ICLARM software for (mainly length-based) fish stock assessment, the FAO-ICLARM Stock Assessment Tools or “FiSAT” package, integrating the ICLARM’s Complete ELEFAN, FAO’s LPSA and various other routines, released in mid-1992 [24] have been used during the present study.
MATERIALS AND METHODS

The total length of *T. ilisha* were measured weekly between June 2010 and March 2011 by using a metric scale from the major marine fish landing centers of West Bengal viz. Kakdwip, Namkhana and Frasergunj (Figure 1) for the population dynamics study. The fishes were collected by gill net from the Northern Bay of Bengal. The fishes were randomly selected for its measurement. A total of 464 *T. ilisha* were measured for **M** and **K** from the equation; the difference between (Z) and (M) from the equation; 

\[
F = Z - M
\]

The rate of exploitation E was calculated by the quotient between fishing and total mortality: 

\[
E = \frac{F}{Z}
\]

Then the data was put month wise into the FiSAT II in an interval of 50 mm. The analysis was done in FiSAT II (FAO-ICLARM Stock Assessment Tools) software (Version 1.2.2). The von Bertalanffy Growth Function and length frequency were plotted based on ELEFAN I which is used to understand the seasonal oscillation along with the estimation of the L8, K and R. The predicted maximum length from extreme values was computed.

The natural mortality of Hilsa Shad was calculated by using Pauly’s M empirical equation [25], where the mean habitat temperature was 27.9 °C.

\[
\log_{10}M = 0.0066 - 0.279 \log_{10}L8 + 0.6543 \log_{10}K + 0.4634 \log_{10}T.
\]

The fishing mortality rate (F) was then calculated by the difference between (Z) and (M) from the equation; 

\[
F = Z - M
\]

The rate of exploitation E was calculated by the quotient between fishing and total mortality: 

\[
E = \frac{F}{Z}
\]

In the present study we also estimated the probability of capture from gill net selection criteria. One year recruitment pattern was also figured out in Hilsa population and the length-structure virtual population analysis was done by using M, K, L8, Ft parameters as an input in FiSAT-II.

RESULTS AND DISCUSSION

Different types of population parameters of Hilsa population were calculated by using the FiSAT II.

**Growth Parameters:** The L8 of 477.75 mm and K of 1.9 year\(^{-1}\) from K scan (Figure 3) routine were observed by using direct fit of length frequency data in ELEFAN I and the response surface (R) was found to be 0.674 for the von Bertalanfyy growth curve (Figure 2). The growth performance index (\(Z\)) was observed to be 3.637. Rahaman and Cows [20] estimated \(Z\) as 3.47 for marine population of Hilsa and Roomiani and Jamili [22] calculated \(Z\) as 3.14 in Hilsa. The L8 and K values of Hilsa were different from other authors. Nurul Amin et al. [16] recorded L8 60.00 cm and K=0.82 year\(^{-1}\) in Bangladesh water while Hashemi et al. [21] estimated L8=43.32 cm and K= 0.78 year\(^{-1}\) and Roomiani and Jamili [22] calculated L8= 42.74 cm and

![Fig. 1: Map of Northern Bay of Bengal with three fish landing centers.](image1)

![Fig. 2: von Bertalanffy growth curve for *Tenualosa ilisha*.](image2)
K= 0.77 year\(^{-1}\) in coastal water of Iran. In the Ganga-Brahmaputra-Meghna (GBM) basin the Hilsa population was found comparatively at much higher density in Bangladesh water because of more freshwater input and it was also established [16] that Hilsa population was overexploited from Bangladesh water.

**Maximum Length Estimation:** The observed extreme length (Figure 4) in Hilsa population was 455 mm and the predicted extreme length was 453.58 mm and the range at 95% confidence interval was 434.43 to 472.73.

**Mortality Estimation:** The total mortality (Z) was 1.98 year\(^{-1}\) from length-converted catch curves (Figure 5), the natural mortality (M) was 1.25 year\(^{-1}\) and the fishing mortality (F) was 0.73 year\(^{-1}\) in case of *Tenualosa ilisha*.

**Exploitation Rate:** The exploitation rate (E) in Hilsa population of Bengal coast was 0.37 and the E\(_{\text{max}}\) value recorded as 0.555. If the value of E would have been more than 0.50 then it could be concluded that the fish is overharvested from the particular area during this period [28]. The exploitation rate of Hilsa were 0.66 [14], 0.67 in male, 0.68 in female, 0.61 in adult and 0.61 in juvenile [18] in Bangladesh water, whereas 0.72 [21] and 1.8 [22] in Iranian water. So it is clear that the Hilsa was overfished in Bangladesh and Iran but Hilsa population is yet to rich overfishing stage (E\(_{\text{max}}\)=0.555) in West Bengal, India during the study period.

**Recruitment Pattern:** The recruitment pattern (Figure 6) of Hilsa population was significantly high in the primary breeding season of Hilsa as it indicates the strong seasonal recruitment. The prolonged recruitment was noticed in June to October with a peak in September, which marks the highest amplitude of Hilsa in counts.
Fig. 6: Recruitment pattern of *Tenualosa ilisha* in Northern Bay of Bengal.

Fig. 8: The virtual population analysis in *Tenualosa ilisha* in West Bengal coast.

Fig. 7: Logistic selection curve for probability of capture, showing 25%, 50% and 75% selection length of *Tenualosa ilisha* in Northern Bay of Bengal.

**Probability of Capture:** Probability of capture was estimated from the type of net (gill net) used for fishing. From this finding it is estimated that the maximum probability of capture class size lies between 305 mm and 405 mm (Figure 7). The selection length of 25 % or $L_{25}$ was 237.06 mm, 50% or $L_{50}$ was 265.55 mm and the 75 % or $L_{75}$ was 294.03 mm. From the probability of capture analysis using selection curve the estimated optimum length of Hilsa (TL, mm) at first capture ($L_c = L_{50}$) were 322 and 335 mm, TL, respectively for river and marine [20].

**Virtual Population Analysis:** Virtual population analyses (VPA) are very useful tool which allow the reconstruction of the population from total catch data by age or size. In this present study we estimated VPA from length based data (Figure 8). From this analysis we observe that the maximum numbers of Hilsa Shad were caught between 305 and 405 mm and the size class which faced maximum fishing mortality ($F = 1.47$) was 355 mm. From VPA it was indicated that the survival rate was highest in 155 mm size group Hilsa, so the juvenile capture in Bengal coast has been less during this study period which indicates that the Hilsa population is not under immediate threat due to overfishing.

**Relative 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 $L_{50}/L_{8}$ and $M/K$. The $L_{50}/L_{8}$ value is 0.351 and $M/K$ value are 0.789 for Hilsa (Figure 9). The $Y/R$ was 0.065 and the $B/R$ was 0.314. The selection ogive routine of FiSAT-II was used in the analysis of relative yield per recruit and biomass per recruit analysis (Figure 10) and produced values of $E_{10} = 0.507$, $E_{50} = 0.241$, $E_{max} = 0.555$. 

Fig. 9: Relative yield-per-recruit and biomass-per-recruit curves for *Tenualosa ilisha* from West Bengal Coast using the selection ogive option ($E_{10} = 0.507$, $E_{50} = 0.241$, $E_{max} = 0.555$).
Fig. 10: Isopleths, showing optimum fishing activity both in terms of fishing effort and size of first capture (depicted with a star in the central curve) of *Tenualosa ilisha*.

CONCLUSION

According to Froese [29] overfishing can be prevented by following certain rules. All of the mature fish population should be caught, those who have attained optimum length but the mega-spawners should not be targeted at all. In this present study, it is observed that the percentage of mature and optimum length size fishes were caught with maximum number and the percentage of mega-spawner catch were found to be minimum. Due to this reason overfishing of Hilsa population could not be established in West Bengal coast during this period, but the $E_{max}$ value of 0.555 denotes symptoms of overexploitation in near future. If any population is affected by the ‘recruitment overfishing’, the population might be seriously hampered to attain the sustainable yield in the long run [30], so the fishing regulation must be strong for Hilsa to make this species sustain for a long time in future. On the other hand, the average Hilsa size found here was quite smaller than Bangladesh, which indicates that it could be a different subspecies or race of Hilsa. Further long term monitoring is required to establish the Hilsa population dynamics, as well as phylogenetic study should be done in the West Bengal coast.

ACKNOWLEDGEMENTS

The authors are very grateful to the Indian National Center for Ocean Information Services of ‘Ministry of Earth Science’, Government of India for funding the Potential Fishing Zone Validation Project which enabled the authors to conduct the study. We also thank the Eco System for Life, a joint India-Bangladesh initiative by IUCN which facilitated some field studies during 2011. We are also thankful to all field staffs and fishermen for helping us during collection and measurement of the specimens on board and in harbours.

REFERENCES


