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Estimation of maximum sustainable yield (MSY) of hilsa (*Tenualosa ilisha* Ham.) in the Meghna river of Bangladesh

M.S. Miah, M.A. Rahman*, G.C. Halder and M.A. Mazid[1]

Bangladesh Fisheries Research Institute, Riverine Station
Chandpur-3602, Bangladesh
[1]FRI, Mymensingh-2201
**Corresponding author*

Abstract

MSY per recruit of *Tenualosa ilisha* in the Meghna river was predicted as 112 g per recruit at the F_{msy}=0.6 /yr and at T_c=0.6 /yr. But Y/R=95 g per recruit was obtained at the existing fishing level, F=1.14 /yr and at T_c = 0.6 /yr. Existing F level was nearly double than the F_{msy} level. Fishing pressure should be reduced immediately from F=1.14 /yr to F_{msy}=0.6 /yr. F_{msy}=1.14 /yr was the same at first capture, T_c=1.0, 1.2 and 1.4 /yr, and MSY could be obtained as 142 g, 162 g and 176 g per recruit respectively. It is easier to change the first capture age (T_c) rather than changing of F level. So, hilsa fishery manager may adopt F_{msy}=1.14/ yr while age at first capture must be increased from T_c=0.6 /yr (3 cm size group) to T_c=1.4 /yr (25 cm size group), by which 1.8 times production could be increased than the present production. MSY also possible to obtain as 201 g and 210 g per recruit at F_{msy}=2.0 /yr and 4.0 /yr at T_c=1.7/yr and 1.9 /yr respectively. Under both the situations, hilsa production could be increased 2 times than the present production. To obtain the MSY=210 g per recruit the fishing level could be increased upto F = 4.0 /yr at T_c = 1.9/yr (34 cm size group). Economic point of view, hilsa fishery managers may choose to obtain the economic MSY as 201 g per recruit at F_{msy}=2.0 /yr and T_c=1.7 yr (31 cm size group) in the Meghna river of Bangladesh.

Introduction

Maximum Sustainable Yield (MSY) is the peak yield of optimum exploitation level (F_{msy}). The optimum exploitation level is that fishing level at which MSY could be obtained without causing damage of a stock in the long run from an open water body. On the other way, if any fishery is situated in such a position that either the fishery is in under fished or over fished condition than the F_{msy} level, both the conditions are not desirable. The MSY also predicts a yield model at a particular fishing level, which gives the highest steady yield year after year. Estimation of maximum sustainable yield for a fish population, Yield per recruit (Y/R) model has been developed by Beverton and Holt (1957). When reasonable estimates are available of the total yield (by species), MSY is estimated by using yield and CPUE through "Surplus Production Model" which was introduced by Gramhan (1935) but often referred to as Schaefer model. Recently another programme has been developed by Sparee and Willmann on Bio-economic Analysis Method (BEAM) for economically biomass estimation but still it is not popular method. So, Beverton and Holt model is the most popular model to estimate MSY through yield per recruit analysis of a fish population in the open water system. Furthermore, for the estimation of MSY, yield per recruit model (Beverton and Holt model) has been applied in fish population management by some earlier workers (Gulland 1973, Pauly 1984, Pauly and Soriano 1986, Silvestre 1986).

Yield per recruit (Y/R) is the measurement unit (in g) of yield of fish population in the open water system. Shortly it can be expressed, Y/R is a yield measurement index for the open water fishery. Yield basically depends on the rate of recruitment pattern, age at first capture, fishing strategies and environmental condition. Recruitment is a continous process and a crucial phase for a fish population in the open water system.

Hilsa (*T. ilisha*) is a wild fish species and most important exploited fishery which is contributing about 22-25% to the total fish production in Bangladesh. Being such an important exploited fishery in the open water system, knowledge about its MSY, F_{msy} level is necessary for judicious management and at the same time the hilsa population has to be managed in such a way that the fishery is ready to give the MSY for long term condition. Moreover, estimation of MSY also helps to indicate the present fishing level of any fish population either the fishery is under fished or over fished. This paper mainly deals with the MSY per recruit under various F and T_c levels of *T. ilisha* in the Meghna river.

Materials and methods

The research program was designed for the estimation of maximum sustainable yield per recruit following the Beverton and Holt model. The experiment was undertaken at the Bangladesh Fisheries Research Institute, Riverine Station, Chandpur, during July '93 to June '95. For the estimation of MSY of hilsa population in the Meghna river, length-frequency data were collected through experimental fishing as well as from commercial fishing. The Meghna river was selected under this study as the Meghna river is a major migratory route and nursery ground of *T. ilisha* in the riverine system of Bangladesh.

Length-frequency data of 8040 specimens of hilsa of the river Meghna were analyzed for the estimation of maximum sustainable yield (MSY) per recruit. Length-frequency data were randomly collected in each month during the period of study. Sample was collected by using 'F.B. ilish gobeshona' boat of FRI, Chandpur. Mesh sizes of the experimental fishing gear were 8.5 cm, 10.0 cm and 11.0 cm which are usually used by the commercial fishermen. Samples were collected from both day and night fishing. Commercial jaggat ber jal with mesh size of 0.5 to 1.5 cm and experimental ber jal with mesh size of 1.0 cm were used to catch jatka (juvenile hilsa). Samples from artisanal fisherman's net (a kind of monofilamentous gill net locally called *current jal* with mesh size 3.5 cm to 7.0 cm) were also considered for the purpose. Length-frequency data of the specimens of hilsa were analyzed through length-based stock assessment method with the help of computer package programme of XL-staistica and Microstate Data management. The results of the growth parameters (L, k,& t_0), mortality parameters (Z, M,& F), asymptotic weight (W), relative condition factor (K_n), recruitment age (T_r) and age at first capture (T_c) are necessary to calculate the yield per recruit (Y/R). So, the growth parameters were calculated by using the following Von-Bertalanffy (1934) growth equation model.

$L(t) = L_\alpha*(1-\exp(-K*(t-t_o))$ -----------------------------(i)

Here, the model expresses the length L, as a function of the age of the fish t, K is the curvature parameter and L_α is the asymptotic length of fish.

Total mortality (Z) was calculated by Length Converted Catch Curve method. Natural mortality (M) was estimated by following Pauly's empirical relationship (Pauly 1980) of L_α , k and mean annual temperature, T^0C.

$\ln M = -0.0152 - 0.279*\ln L_\alpha + 0.6543*\ln T$ ---------------(ii)

Asymptotic weight was calculated by using the following formula (Sparre and Venema 1992).

$W_\alpha = K_n x L^3$---(iii)

Recruitment age (T_r) and age at first capture (T_c) were also calculated by the Inverse von-Bertalanffy growth equation model (Sparre and Venema 1992).

$t(L) = t_0 - 1/k*\ln(1-L/L_\alpha)$-----------------------------(iv)

The yield per recruit (Y/R) were calculated by using the Beverton and Holt model such as :

$Y/R = F * \exp.(-M *(T_c-T_r)*W_\alpha *(1/z-3S/(z+k) +3S^2/(z+2k)-S^3 /(z+3k)$.-------------(v)

Where $S= \exp.(-M*(T_c-t_0)$ and $Z=F+M$.

Finally, the Y/R and MSY per recruit under various fishing levels (F) and age at first capture (T_c) of *T. ilisha* in the Meghna river were calculated.

Results and discussion

The length-frequency analyses by different methods gave the following calculated populational parameters of hilsa *viz;* asymptotic length, L_α = 57 cm, curvature character, k=0.66 /yr , initial age, t_o= 0.5 yr, total mortality, Z= 2.03/yr, natural mortality, M=0.89/yr, fishing mortality, F= 1.14/yr, asymptotic weight,W =2981 g, when the average relative condition factor of the hilsa population in the Meghna river was K_n=0.0145 g per cubic cm. The age at first capture (T_c) of hilsa in the Meghna river was T_c=0.6 yr and when hilsa is recruited at the Meghna river their age was calculated as recruitment age T_r=0.58 yr. So, it was observed that the difference between the age at recruitment (T_r) and age at the first capture (T_c) having a very little difference which was not a good sign for hilsa population to obtain a sustainable yield.

Y/R was calculated by the derived formula of Beverton and Holt model and it was obtained Y/R=95 g per recruit at the existing fishing pressure, F=1.14 /yr and age at first capture of T_c=0.6 /yr (3 cm size i.e. catch starts from juvenile hilsa). If it is not possible to protect the catch at their juvenile stage i.e. if it is continued to catch jatka (T_c=0.6 yr), maximum sustainable yield could be possible to obtain MSY= 112 g per recruit at the F_{msy} = 0.6 /yr. But the present fishing level is F=1.14 /yr which is nearly double fishing pressure than the F_{msy} level (Fig-1a). So , fishing level (F) should be reduced from F=1.14 /yr to F_{msy}=0.6 /yr immediately. Moreover, the probable MSY and F_{msy} were also calculated under the combinations of various fishing levels (F) and age at first capture (T_c) which were shown in Figures 1a, 1b and 1c.

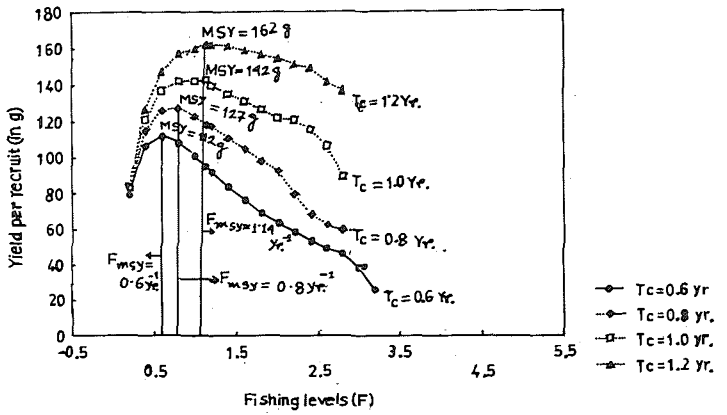

Fig.1a. Probable MSY per recruit and F_{msy} under the combinations of various F and T_c levels of *T. ilisha* (i.e. F=0.2 to 4.0 /yr and T_c=0.6, 0.8, 1.0 & 1.2 /yr).

From Fig.1a, it was observed that the MSY=127 g per recruit and F_{msy}=0.8 /yr at T_C=0.8 yr (10 cm size group), MSY=142 g per recruit and F_{msy} =1.14 /yr at T_C=1.0 yr (18 cm size group), and MSY=162 g per recruit and F_{msy}=1.14 /yr at T_C=1.2 yr (22 cm size group) were obtained.

The probable MSY were calculated at T_C= 1.14, 1.5, 1.6 and 1.7 yr were shown in Fig.1b.

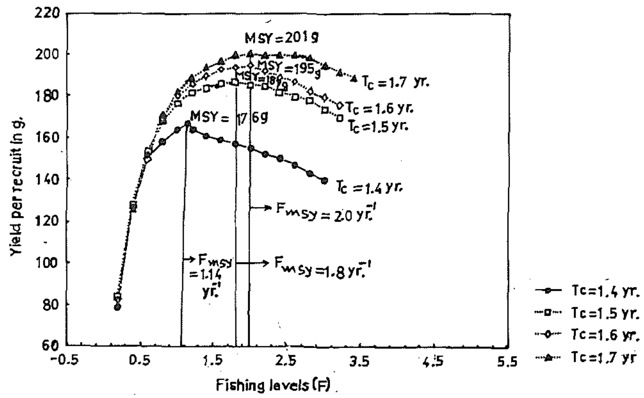

Fig.1b. Probable MSY per recruit and F_{msy} under various combinations of F and T_c levels of *T. ilisha* (F=0.2 to 4.0 /yr and T_c=1.4, 1.5, 1.6 & 1.7 yr).

From Fig.1b, the probable MSY per recruit and F_{msy} were calculated under various ages at first capture T_c=1.4 yr (25 cm size group), T_c=1.5 yr (27 cm size group) T_c=1.6 yr (29 cm size group) and T_c=1.7 yr (31 cm size group). The probable MSY=176 g, 187 g, 195 g, and 201 g per recruit at F_{msy}=1.14 /yr, 1.8

/yr, 2.0 /yr and 2.0 /yr at the first capture age T_c= 1.4, 1.5, 1.6, and 1.7 yr respectively. F_{msy} is the same as 2.0 /yr for both at first capture age T_c=1.6 and 1.7 yr (Fig.1b).

From Figs.1a and 1b, it was observed that F_{msy}=1.14 /yr was the same in case of T_c=1.0 yr,1.2 yr and 1.4 yr age groups of hilsa. It might be said that if it is not possible to change (i.e. either increase or decrease) the present fishing level, F=1.14 /yr , first capture age of hilsa definitely should be increased from T_c=0.6yr to 1.4 yr and then the probable MSY would be obtained as 176 g per recruit at F_{msy}=1.14 /yr. In the management point of view, it is difficult to change the fishing level (F) but it might be easier to change the first capture age (T_c) by mesh size regulation through fish conservation law. It was also observed that the probable maximum sustainable yield MSY=201 g per recruit at F_{msy}= 2.0 /yr and age at first capture T_c= 1.7 yr (31 cm size group) could be possible to obtain 2 times production than the present yield (consideraing the yield measurement index as, present Y/R = 95 g at F=1.14 /yr and T_c=0.6 /yr.). Therefore, in this case, age of first capture definitely should be increased from T_c=0.6 yr. to T_c=1.7 /yr. and thereby fishing pressure also could be increased from F=1.14 to F_{msy}= 2.0 /yr for hilsa fishing in the Meghna river.

From Fig.1c, similarly the probable MSY and F_{msy} were calculated at the age of first capture (T_c) = 1.8 yr (33 cm size group), 1.9 yr (34 cm size group) and 2.0yr (36 cm size group). It will be possible to obtain MSY= 206 g, 210 g, and 201 g per recruit at the F_{msy}=3.0 /yr, 4.0 /yr and 2.6 /yr at T_c=1.8,1.9 and 2.0yr respectively. Thereby, MSY=210 g per recruit could be possible to obtain at the F_{msy} = 4.0 /yr.

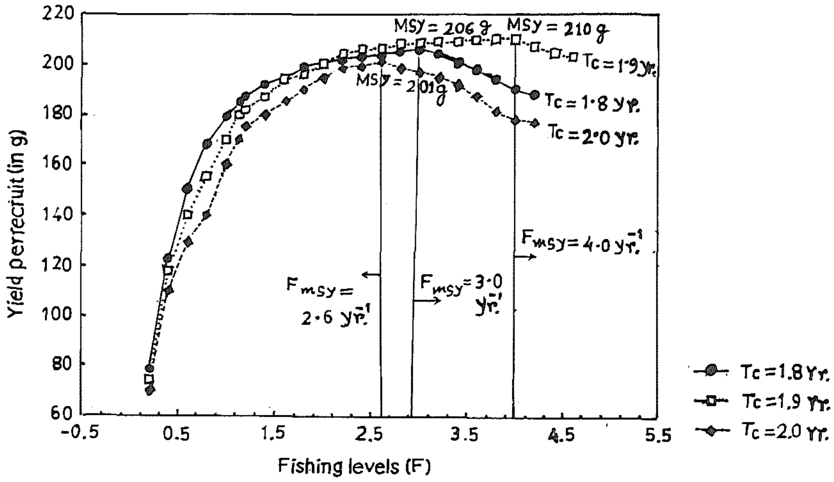

Fig.1c. Probable MSY per recruit and F_{msy} under combinations of various F and T_c levels of *T. ilisha* (F=0.2 to 4.0 /yr and T_c=1.8, 1.9 & 2.0 yr)

So, fishing pressure could have been increased from F=1.14 to F_{msy} = 4.0 /yr at the age of first capture T_c=1.9 yr In that case, fishing pressure could have been increased 4 times than the present fishing level and hilsa production could have been obtained 2 times than the present production level. But in the long run growth overfishing might occur and as a result parent hilsa might be affected. From Fig-1b and 1c, it was seen that yield per recruit is the decreasing trends at the age at first captures, T_c=2.0 yr. Yield of hilsa could be obtained 2 times at both the fishing levels, F_{msy}= 2.0 /yr and 4.0 /yr at the T_c=1.7 yr and 1.9yr. So, economic point of view, hilsa fishery managers may choose to obtain the economic MSY as 201 g per recruit at F_{msy}=2.0 /yr instead of F_{msy}=4.0 /yr. The calculated yield with a combined effect of various F and T_c levels which would be maintained as the long term condition and which do not change (Sparre and Venema 1992).

Conclusions

So, for the proper management as well as economical fishing, it might be concluded that fishing pressure should be maintained at the level of F_{msy}=2.0 /yr and the probable MSY would be obtained in MSY=201 g per recruit at the age of first capture T_c =1.7 yr, which will be more economically viable level of F_{msy} for hilsa fishing at the same time hilsa production will be double.

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