Australian Journal of Basic and Applied Sciences, 4(12): 5780-5786, 2010
ISSN 1991-8178

# Population Dynamics and Stock Assessment of Hilsa Shad, *(Tenalosa ilisha* Hamilton-Buchanan, 1822) in Coastal Waters of Iran (Northwest of Persian Gulf)

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**Abstract:** Population Dynamics and stock Assessment Of Hilsa Shad ,*Tenalosa ilisha* were studied from April 2007 to March 2008. Data were collected from two landing sites (Hendijan and Abadan) and analyzed by using FiSAT II software. $L_{\infty}$, K, $t_0$, **Φ**, M, F, Z and E indices were calculated 43.32cm, 0.78 ($year^{-1}$), - 0.18 ($year^{-1}$), 3.16, 1.29 ($year^{-1}$), 3.24 ($year^{-1}$), 4.53($year^{-1}$), 0.72 ($year^{-1}$) respectively. Relative yield per recruitment (Y'/R): 0.062, relative biomass per recruitment, (B'/R): 0.12, precautionary average target ($F_{opt}$=0.64 $year^{-1}$) and limit ($F_{limit}$=0.85 $year^{-1}$) biological reference points for Hilsa Shad stock was calculated. Exploitation rate U=0.7 , annual total stock at beginning of year (P=6635.71 tons), annual standing stock (b=1433.64 tons)and MSY= 3247.19 tons were estimated for this species. Result showed that Hilsa Shad is over fishing and some management policy should be taken to reduce fishing effort.

**Key words:** Hilsa Shad, Population dynamic, Stock assessment

## INTRODUCTION

The Hilsa shad (*Tenualosa ilisha*, Clupeidae) is an important migratory species in the Indo-Pak subcontinent and the Persian Gulf region, especially in Bangladesh and India **(**Nurulamine *et al*.,2004**)**. *Tenualosa ilisha* (Hamilton) occurs in river estuaries and coastal waters and appears to be restricted to the northern end of the Persian Gulf because this is the only part with large spawning rivers. This species an anadromous stock from the Shatt al Arab migrates to warmer waters off Bushehr during January, February and March (Hussain *et al*., 1994). 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.

Collectively, this species of landings in the Northwest of Persian Gulf representing about 11% of the total annual catch. During2008, 4645 tones of *Tenualosa ilisha* were landed in the Khuzestan Province (Northwest of Persian Gulf). *T.ilisha* mainly was caught in strings by fiber glass dories and traditional wooden dhows. 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. Different aspects of biological work of hilsa have been done by different authors (maramazi *et al*., 1995, parsamansh *et al*., 2003 and mohammadi *et al*., 2005) but little work has been done on stock assessment of this species in Iran.

The present study was undertaken to estimate the key parameters of stock assessment and population dynamics of *T.ilisha* such as asymptotic length(L∞), growth coefficient(K), Tzero(to), total mortality(Z),natural mortality(M),fishing mortality(F),exploitation rate (E),relative yield per recruit(Y'/R) and relative biomass per recruit(B'/R).This information is necessary in formulating management and conservation policies as well as in the development of the fishery for this species in Iran.

## MATERIAL AND METHODS

Length-frequency data of *T.ilisha* were collected monthly from the commercial catches from the landing sites of Abadan and Hendigan , from April 2007 to March 2008(Fig.1). Fish were selected at random from landings and recorded to the nearest cm fork length (*L*F) using a measuring board.

The data were then pooled monthly from different landing sites and subsequently grouped into classes of 1.5centimeter intervals. The data were analysis using FiSAT II (FAO-ICLARM Stock Assessment Tools) as explained in details by Gayanilo Jr. *etal*. (1996).

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Growth was calculated by fitting the von Bertalanffy growth function to length frequency data. The von Bertalanffy growth equation is defined as follows (Sparre and Venema, 1998): $L_t=L_\infty$ [(1-exp (-K (t-$t_0$))]

Where $L_t$ is length at time t, $L_\infty$ the asymptotic length, K the growth coefficient and $t_0$ is the hypothetical time at which length is equal to zero.

The $t_0$ value estimated using the empirical equation (Pauly, 1979).

$$Log_{10}(-t_0) = -0.3922 - 0.2752\ Log_{10}L_\infty - 1.038\ Log_{10}K$$

The fitting of the best growth curve was based on the ELEFAN I programm (Pauly and David 1981), which allows the fitted curve through the maximum number of peaks of the length-frequency distribution. With the help of the best growth curve, 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).

$$\Phi' = Log_{10} K + 2\ Log_{10}L_\infty$$

The annual instantaneous rate of total mortality (*Z*) was obtained using length converted catch curves adapted to incorporate seasonal growth patterns (Gayanilo and Pauly, 1997).Pooled length frequency samples were converted into relative age frequency distributions using parameters of the von Bertalanffy growth function.

The annual instantaneous rate of natural mortality (*M*) was estimated using the empirical equation derived by Pauly's empirical relationship (Pauly,1980).

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

Where $L_\infty$ is expressed in cm and T, the mean annual environmental water temperature in ºC. Here it is 25C. Fishing mortality (F) was obtained by subtracting M from Z and exploitation rate (E) was obtained from F/Z.

Pauly and Soriano (1986) was used to predict the effects of increasing the existing mean size at first capture ($L_{50}$) to that at which yield per recruit would be maximized(Lmax). Resource status was evaluated by comparing estimates of the fishing mortality rate with target ($F_{opt}$) and limit ($F_{limit}$) biological reference points (BRPs), which were defined as $F_{opt}$=0.5M and $F_{limit}$ = 2/3M, following Patterson (1992).

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 (Sparre and Venema,1998).

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 $U = F(1- e^{-z}) /Z$. To estimate the annual catch (Y), the landing data of hilsa were collected from the Department of Fisheries, Iran (Khuzestan). Then by using the values of U, F and Y the total annual stock (P=Y/U) and average standing stock (b=Y/F) were determined. The approximate MSY was then calculated using the relationship proposed by Gulland (1979).

$$MSY = Zt \times 0.5\ Bt$$

Where, Zt is the instantaneous total mortality in the year t and Bt the standing stock size in the year (Sparre and Venema, 1998).

## RESULTS AND DISCUSSION

***Length Frequency Distribution:***

The total length of 9317 fish were measured in the size range 20 to 39 cm using a meter scale(1±mm).Major and minor range length fishery supporting in the 29-30.5 and 38-39.5 cm range respectively. Length frequency percentage groups of *T. ilisha* during period from April 2007 to March 2008 is presented in Fig 2.

***Growth Studies:***

Growth parameters of von Bertalanffy growth formula for *T. ilisha* were estimated as L∞ = 43.32cm and K = 0.78 $yr^{-1}$ . For these estimates through ELEFAN I the response surface (Rn ) was 0.178 for the curve.

The computed growth curves produced with those parameters are shown over its restructured length distribution in fig3. The Φ' and $t_0$ was found to be 3.16 and -0.18 year respectively.

***Mortality Estimate:***

The mortality rates M and Z computed were 1.29 and 4.53 respectively. Figure 4 represents the catch curve utilized in the estimation of Z. The 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 fishing mortality rate (F) was taken by subtracting M from Z and was found to be 3.24 $yr^{-1}$.

***Exploitation Rate:***

The rate of exploitation (E) was estimated as 0.72. 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 over fished.

***Yield per Recruit and Biomass per Recruit:***

Values of the sizes where the probability of capture was 50% ($L_{50}$) and 100% ($L_{100}$) were 22.30 and 28.5cm (TL), respectively. Fish were recruited to the fishery at a mean size of $L_{50}$ = 22.30 cm.

The relative yield-per-recruit (Y'/R), relative biomass-per-recruit (B'/R) and Exploitation rate(U) were 0.062, 0.12 and 0.76, and Lc/ L∞ and M/K were 0.51 and 1.65 respectively(Fig5).

***Stock Assessment:***

Values of annual catch, total annual stock, standing stock and MSY recorded were 4645 t, 6635.71t, 1433.64t and 3247.19 t respectively. From these results it is evident that the value of MSY is below the annual catch, immediate necessary step must be undertaken to reduce the fishing pressure on the stock i.e., the present fishing pressure (3.24$yr^{-1}$ ) needs to be reduced near to 0.97 $yr^{-1}$ to obtain MSY from the stock.

***Discussion:***

It was assumed for the analysis that sampling was randomly done despite the fact that the migration of pelagic fish stocks might have affected the representatives of the samples, and that bias could have been due to the introduction by the schooling behavior of migratory species (Kedidi *et al*., 1993).

The values of L∞ and K were calculated as 43.32cm and 0.78 ($year^{-1}$). Our results also appeared to be of the right order in comparison with a range of published estimates of von Bertalanffy growth equation derived from length frequency (Table1). Maramazi., 1995 reported L∞=61.2cm for hilsa Shad but in this study it was calculated 43.32cm ,it reveals a steep decrement in L∞. L∞ and K of hilsa Shad were calculated in Hoology river(India) for both sex male(44.7 and 0.65) and female (46.01 and 1.03), study in Mandapan(India)showed L∞(51.1) and K(0.49). these parameters were also estimated in Chittagong of Bangladish(56.4,0.91) and Bengal bay(65.5,0.97) .Results of calculation L∞ and K in other countries were : Kuwait(61.5, 0.83) ; Chittagong, Bangladish, 2001:55.74, 0.84 and 2002: 60,0.82 and 2005:male56.5,0.53, female:51.5,0.51. These parameters reported in Khuzestan by:Maramazi,(61.2, 0.2) parasamansh *etal*.,(60, 0.43) and mohamadi *etal*.,( 42.74, 0.77).

Differences between recorded L∞ and K is influenced by ecological characteristics, population size and gene frequency of species considering their habitat and according to natural selection, appear different adaptation pattern during their life (Adams, 1980). L∞ and K amounts have reverse correlation and with decrement L∞, amount of K increases and vise versa (Sparre and Venema, 1998). Differences in growth rates between regions indicated a stock separation (Devaraj, 1981) which has, in some cases, supported a genetic difference (Begg and Sellin, 1998).

Φ' was estimated 3.16 that is in range of 2.89-3.49 that reported in others researches (table1). In general, the correlated parametric values adjust themselves to provide a similar growth pattern represented by Φ' (Sparre and Venema, 1998). Age at zero length ($t_0$) was calculated as -0.18 year. With negative $t_0$ values, juveniles grew more quickly than the predicted growth curve for adults, and with positive $t_0$ values, juveniles grew more slowly (Sparre and Venema, 1998).


**Fig. 1:** Location of two landing sites where *T. ilisha* were sampled

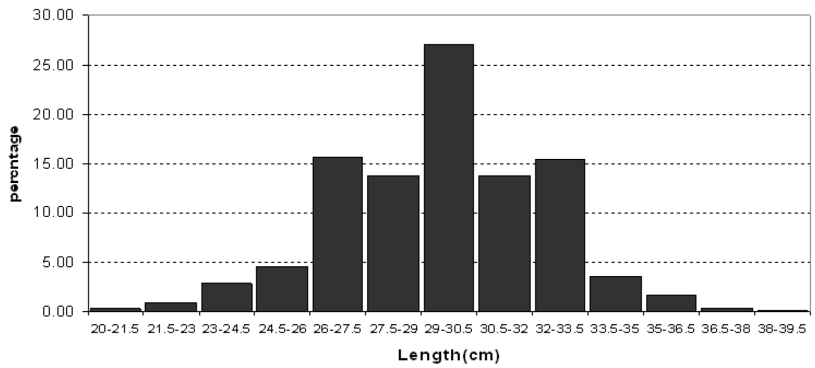


**Fig. 2:** Percentage frequency of length *T. ilisha* in Coastal Waters of Iran during 2007-08.

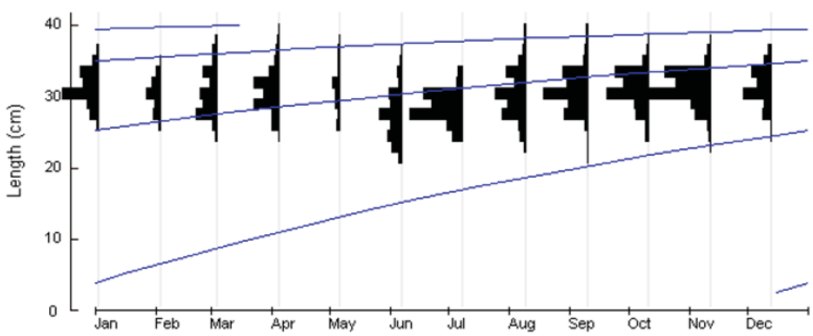


**Fig. 3:** Growth curve of T. ilisha from Iran by ELEFAN I superimposed on the restructured length-frequency diagram (L∞ = 43.32 cm and K = 0.78 yr-1 .).

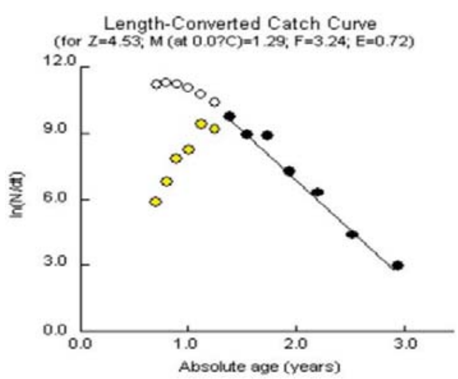


**Fig. 4:** Length converted catch curve of *T. ilisha*.

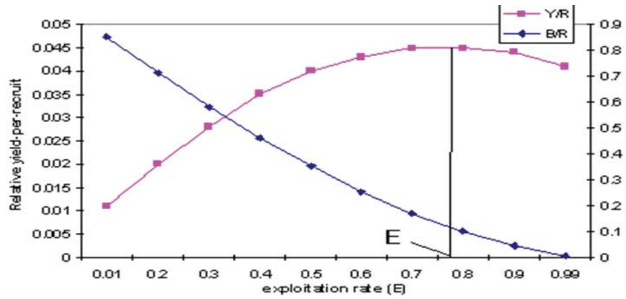


**Fig. 5:** Relative yield-per-recruit and Relative biomass-per-recruit showing the existing exploitation rate *(E)* *T. ilisha.*

**Table 1:** Summary of the growth and mortality parameters estimates of T.ilisha

| Reference | Local | | L∞(cm) | K($year^{-1}$) | Φ | M($year^{-1}$) | F($year^{-1}$) | Z($year^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Hoolgy | | (Male) | 44.7 | 0.65 | 3.11 | - | - | - |
| Pillay (1985) | | Female)) | 46.1 | 1.03 | 3.34 | | | |
| Banerji and Krishnan(1987) | Mandapam | | 51.1 | 0.49 | 3.11 | - | - | - |
| Van der knapp(1987) | Chittagong | | 56.4 | 0.91 | 3.46 | 1.39 | 1.59 | 2.98 |
| Van der knapp(1987) | Bangal Bag | | 65.5 | 0.97 | 3.49 | 1.42 | 0.9 | 2.31 |
| Al-baz and Grove(1995) | Kawit | | 52.5 | 0.36 | 3 | - | - | - |
| Rahman etal (2000) | Bangladesh | | 61.5 | 0.83 | 3.49 | - | - | - |
| Nurul Amin etal(2001) | Chittagong | | 55.74 | 0.84 | 3.41 | 1.34 | 2.39 | 3.73 |
| Nurul Amin etal (2002) | Chittagong | | 60 | 0.82 | 3.47 | 1.28 | 2.49 | 3.77 |
| Nurul Amin etal (2004) | Bangladesh | (male) | 60 | 0.82 | 3.47 | 1.25 | 2.18 | 3.43 |
| | | (Female) | 66 | 0.67 | 3.34 | 1.28 | 2.49 | 3.77 |
| | | (both) | 61.5 | 0.83 | 3.49 | 1.28 | 2.01 | 3.29 |
| Haldar and Nurul amin(2005) | Bangladesh | (male) | 56.5 | 0.53 | 3.14 | 0.92 | 1.95 | 2.87 |
| | | (Female) | 51.5 | 0.51 | 3.34 | 1.01 | 2.07 | 3.08 |
| | | (both) | 54.6 | 0.52 | 3.19 | 0.98 | 1.18 | 2.16 |
| Maramazi(1995) | Khozestan(Iran) | | 61.2 | 0.2 | 2.89 | - | - | - |
| Parsamansh etal.,2003 | Khozestan(Iran) | | 60 | 0.43 | 3.19 | 0.77 | 6.13 | 6.9 |
| Mohammadi etal.,2005 | Khozestan(Iran) | | 42.74 | 0.77 | 3.14 | 0.75 | 1.8 | 2.55 |
| Peresent study,2008 | Khozestan(Iran) | | 43.32 | 0.78 | 3.16 | 1.29 | 3.24 | 4.53 |

In this study exploitation coefficient calculated more than 0.5 and fishing mortality estimated more than natural mortality. The fishing mortality rate of 3.24 $year^{-1}$ was substantially greater than both the target ($F_{opt}$ = 0.64 $year^{-1}$) and limit ($F_{limit}$ = 0.85 $year^{-1}$) biological reference points. These results are important for fisheries management authorities as they suggest that the resource is overexploited and in addition to a revision of mesh size regulations, a substantial reduction in fishing effort would also be required if management objectives are to be achieved. Patterson (1992) observed that the fishing rate satisfying optimal E level of 0.5 tended to reduce pelagic fish stock abundance, and hence, the former author suggested that E should be maintained at 0.4 for optimal exploitation of those stocks.

In Chittagong area (Bingladish) M, F and Z were 1.39,1.59 and 2.98 respectively. These parameter in other studies were (table1) : Bengal bay :1.42, 0.9 and 2.31 ; Coastal water of Chitagong(Bengladish) :1.34,2.39,3.73; in this area in 2002 :1.28,2.49,3.77 ; and in 2004, 1.28 ,2.01 ,3.29(for both sexes) ; in 2005, 0.98,1.18,2.16 for both sexes respectively. In Khuzestan these parameters were recorded by Parsamanesh *etal.*,0.77, 6.13, 6.9 and Mohammadi *etal*., reported,0.75,1.8 and 2.55.

life history characteristics can be used to classify the vulnerability of a species to fishing pressure and the level of productivity within a population (Musick, 1999). The growth, mortality estimates derived here suggest that *Tenalosa ilisha* has a high resilience to exploitation (Hashemi etal.,2009).

Plot of biomass relative per relative against exploitation coefficient showed that the stock is over fished though exploitation is more than it's maximum and to have sustainable exploitation some of catch effort should be decreased. Exploitation of *T.ilisha* in Khuzestan waters has over passés it's MSY and to obtain the level of MSY it should be reduced about 31 percent.

In Bingladesh coastal water relative yield per recruit for sex male and female and relative biomass per recruit were 0.39, 0.31 and 0.04 respectively. The principal limitation of the yield per recruit analyses is the assumption that there is no relationship between the size of the spawning stock biomass and subsequent recruitment over a wide range of values of fishing mortality (Buxton, 1992). This is particularly restrictive for fast growing tropical species with high rates of natural mortality because it is difficult to estimate the point at which yield per recruit is maximized (Gayanilo and Pauly, 1997).

Maximum sustainable yield, total annual stock and standing stock of this species in Bangladesh were recorded 162.396,335.185 and 86.152 tons respectively and in other paper they were reported 161.584, 185.464, 320.711 – 363.477, 84066, 106.683 for male and female. The estimates of standing stock size and MSY for combined sexes of *T.ilisha* in Bangladesh are also reported 217.713 and 235.130 tones.

***Conclusions:***

Considering E,Y'/R,B'/R and MSY values it can be concluded that: catch rate and fishing mortality are more than maximum sustainable yield and to have MSY of hilsa Shad they must be decreased. Any increase in the existing fishing level/exploitation will most likely result in a reduction in the yield per recruit and thereby hamper the optimum level. 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.

## ACKNOWLEDGMENTS

We thank the manager and experts of the South of Iran aquaculture fishery research center,Ahwaz. We are also grateful to Reza Noori at the Iranian Fishery Organization, for helping the project work.

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