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Population Dynamics and Stock Assessment of Hilsa Shad, *Tenualosa ilisha* in Iran (Khuzestan Province)

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ABSTRACT

Monthly data of length composition for *Tenualosa ilisha* landed between April 2006 to March 2007 in north of Persian Gulf were used to estimate the growth, mortality and exploitation parameters of the stock. Maximum total length and weight were 43 cm and 949 g, respectively. Nonlinear least square fitting provided a complete set of von Bertalanffy growth estimate: $L_{8 =}$ 42.74 cm total length, K= 0.77 and t_0 = -0.21 years^{-1}. The estimated value of total mortality based on length converted catch curve using these growth parameters is Z= 2.55 years^{-1}. Natural mortality based on growth parameters and mean environmental temperature (T = 23 C) is 0.75 years^{-1}. Fishing mortality computed for *T. ilisha* was 1.8 years^{-1}. The exploitation rate (E) was 1.8 years^{-1}. The higher value of E indicates over fishing during in period. Population dynamics and stock assessment of *Tenualosa ilisha* in Iran waters was studied using the length-frequency based analysis of FiSAT software to evaluate the growth parameters, mortality rates, exploitation rate and Maximum Sustainable Yield (MSY). The study showed that *T. ilisha* is in over fishing pressure.

Key words: Growth, mortality, exploitation rate, maximum sustainable yield, Persian Gulf

INTRODUCTION

Among fishes of the family Clupeidae (which includes the shads), about 29 species are diadromous, most of them anadromous, though one is amphidromous and two are caradromous. The hilsa shad, *Tenualosa ilisha,* belonging to the sub-family Alosinae of the family Clupeidae (Mazumder and Alam, 2009).

Hilsa shad (*Tenualosa ilisha*), an important diadromous fish species of South and South-East Asia, is habitant in Persian Gulf too. Hilsa shad supports a commercial fishery and in the early 1970s composed more than 95% of the total commercial catch (Coad *et al.*, 2003).

Hilsa shad is widely distributed in almost the major rivers, estuaries and marine waters of Iran. It is capable of withstanding a wide range of salinities and migrating long distances upstream (up to 1287 km). The majority of the population feed and grow mainly in the sea before migrating to fresh water for spawning. Juveniles develop and grow in fresh water, but soon migrate to the ocean, where they spend most of their lives (Haroon,1998). The reduction of the depth and discharge of rivers due to construction of dams and barrages has affected the spawning, feeding and migration of this fish (Mizanur, 1997).

In Persian Gulf this fish migrate in Arvand and Bahmanshir rivers for spawning. The average annual landing of this species in 2006 was 4989.83 t and constituted about 15% of Khuzestan's total commercial fish landing. It supports a large fishery that is very important to Bangladesh and comprises 75% of the total world catch of this species and represents about 25% (250,000 t) of the total fish production in Bangladesh (Salini *et al.*, 2004).

The delicious taste and contribution of this fish has lead to its position as one of the most economically important fish in this country (Mazumder and Alam, 2009).

Different aspects of biological studies on Hilsa have been done by different authors in world and Iran (Pillay, 1957; Pillay and Rosa, 1963; Islam and Talbot, 1968; Marammazi, 1994; Marammzi *et al.*, 1998; Rahman and Cowx, 2006) but few study has been done on the stock assessment of this species in Iran but in Bangladesh many works has been done (Amin *et al.*, 2005, 2008; Mazid *et al.*, 2007; Haldar and Amin, 2005).

Length-based methods have lately found widespread use for the estimation of growth in fish populations, especially in tropical areas, because of the various disadvantages presented ageing techniques such as otolith or scale examinations or tagging experiments. As for other tropical fish, ageing of hilsa is problematic, because of the absence of annual rings on scales (Ahmed *et al.*, 2008).

Growth studies are an essential instrument in the management of fisheries resources because these studies contribute to estimates of production, stock size, recruitment and mortality of fish populations (Issac, 1990). The fundamental purpose of fisheries stock assessment is to provide a background for the elaboration of management plans envisioning optimum long-term exploitation of natural aquatic resources (Hilborn and Walters, 1992). FAO-ICLARM Stock Assessment Tools (FiSAT) has been most frequently used for estimating population parameters of fin-fish and shell-fish (Al-Barwani *et al.*, 2007).

The present study was undertaken to estimate key parameters of stock assessment and population dynamics of *T. ilisha*.

MATERIALS AND METHODS

Totaly, 10071 fish were collected monthly from April 2006 to March 2007 from two commercial landing centers of Khuzestan Province, Choebdeh in Abadan and Sajafi in Hendijan (Fig. 1). These samples of *T. ilisha* were caught by gillnet. Total Length (TL) was taken to the nearest mm for all fish and Total Weight (TW) of individual fish to the nearest 1 g was measured wherever possible.

The relationship between length (TL) and weight (TW) was estimated using linear regression analysis. To convert the exponential curve ($W = aL^b$) to linear, both variables were transformed using ln x. The line of best fit for the linear relationship was described by Pauly (1983): ln TW = lna + blnTL.

The length frequency data were pooled into groups with 2 cm length intervals.

Growth was investigated by fitting the Von Bertalanffy growth function to length frequency data. The von Bertalanffy growth equation is defined as follows (Sparre and Venema, 1998):

$$L(t) = L\infty(1 - \exp(-K(t - to)))$$

where, L_t is length at time t, L_8 the asymptotic length, K the growth coefficient and t_0 is the hypothetical time at which length is equal to zero. FiSAT (FAO-ICLARM Stock Assessment Tools) programme (Gayanilo *et al.,* 2003) provided estimated L_8 and K. Asymptotic length (L_8) was estimated using the methods of Powell-Wetherall (Pauly, 1983).

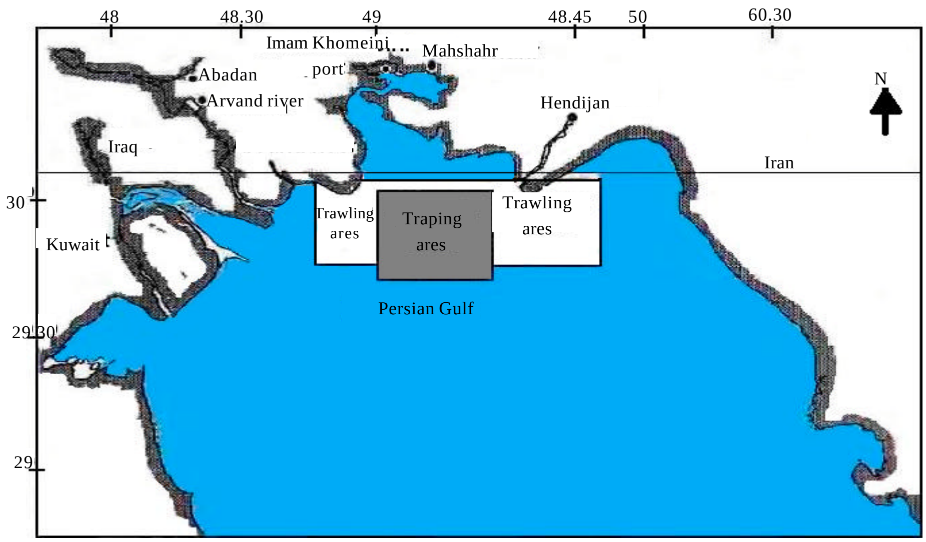

Fig. 1: Location of landing centers where *T.ilisha* were sampled

$$L - L' = a + bL',\ L_\infty = -a/b \text{ and } Z/K = -(1+b)/b$$

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.

t_0 was estimated by employing the equation of Pauly (1980):

$$\text{Log}(-t_0) = -0.3922 - 0.2752 \text{ Log } L_\infty - 1.038 \text{ Log } K$$

And the growth performance index (φ') was calculated using the following formula (Pauly and Munro, 1984):

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

Total mortality rate (Z) estimated by using length converted catch curve method, which has been incorporated in to the FiSAT programme (Gayanilo *et al*., 2003). Natural mortality (M) calculated using the equation of Pauly (1980) which incorporates water temperature and the VBGF growth parameters L_8 and K. The annual mean water temperature for the study was 23°C.

$$\text{Log } M = -0.006 - 0.279 \log L_\infty + 0.6543 \log k + 0.4634 \log$$

The *Clupeidae* have values of M generally differing from those obtained through the proposed equations. It is tempting to attribute this schooling behavior that is so strongly developed in this group (Nikolsky, 1969). Correction factors 0.6 are given for factor M. The instantaneous fishing mortality (F) was taken as the difference between total and natural mortality: F=Z-M.

The exploitation ratio (E) is equal to the fraction of fishing mortality. Maximum Constant Yield (MCY) is defined as the maximum constant catch that is estimated to be sustainable.

Table 1: Guide to the relationship between natural mortality, M and natural variability factor, c

c	Natural mortality
1	0.05>
0.9	0.05-0.15
0.8	0.16-0.25
0.7	0.26-0.35
0.6	0.35 <

The MCY represents the average catch that can be taken from a stock taking into account the natural variability inherent in the particular stock. MCY is calculated by the equation, MCY = c Y_{av} where c is the natural variability factor related to natural mortality (Table 1) and Y_{av} is the average catch across the appropriate time series. Resource status was evaluated by comparing of the fishing mortality rate with target (F_{opt}) and limit (F_{limit}) Biological Reference Points (BRP) which were defined as: F_{opt} = 0.5M and F_{limit} = 2/3M (Patterson, 1992).

The total annual stock size, average standing stock size and also MSY of *T. ilisha* were 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 shad were collected from the Fisheries Resources of Iran, then by using the values of U, F and Y the total annual stock (Y/U) and average standing stock or B_t (Y/F) were determined.

The approximate MSY was then calculated using the relationship proposed by Gulland (1977).

$$MSY= Z_t \times 0.5 \times B_t$$

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

RESULTS

The linear regression analysis of the length-weight data allowed the estimation of the constants, a and b of the length-weight relationship represented by the equation:

$$W = 0.012\ L^{2.968}$$

with a regression coefficient R^2 = 0.916 (Fig. 2)

Growth parameters of von Bertalanffy growth formula for *T. ilisha* were estimated as L_8 = 42.74 cm and K= 0.77 $year^{-1}$. Figure 3 shows the method of powell-wetherall plot for *T. ilisha* in Iran. Calculated growth performance index (φ') was found to be 3.14.

The yearly growth curve of this species using the von Bertalanffy growth parameters was calculated (Fig. 4).

$$L(t) = 42.74(1-e^{-0/77(t)})$$

The value of t_0 was taken as -0.21 and φ' was estimated from the parameters as 3.14.

The annual instantaneous rate of total mortality (Z) derived from length-frequency catch curve was 2.55 $year^{-1}$ (Fig. 5), the annual instantaneous rate of natural mortality (M) derived from the Pauly (1983) equation was estimated as 0.75.

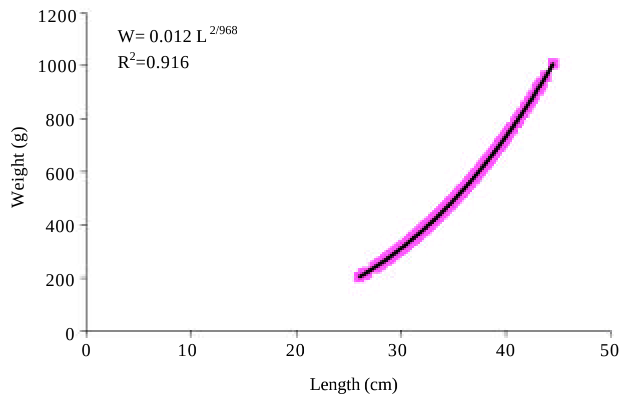

Fig. 2: The length-weight relationship curve for *T. ilisha*

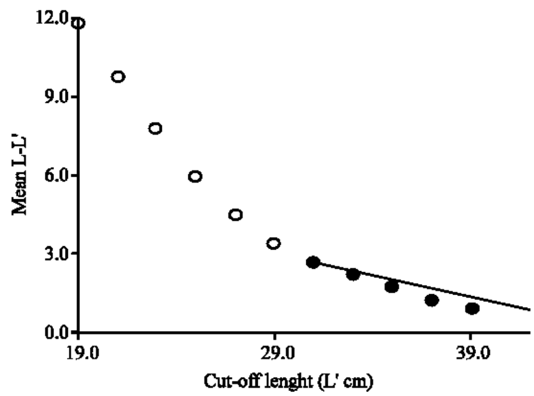

Fig. 3: Estimation of L_8 using of Powll-Wetherall plot for *T. ilisha*

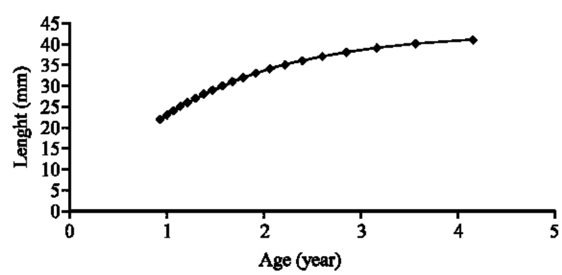

Fig. 4: Growth curve of *T. ilisha*

Annual instantaneous rate of fishing mortality was 1.8 years^{-1} and the exploitation rate (E) was 0.7. The annual instantaneous rate of fishing mortality (F =1.8 year^{-1}) was considerably greater than the target (F_{opt} = 0.37) and limit (F_{limit} = 0.5) biological reference points, suggesting that the stock was heavily overexploited.

The estimate of MCY was calculated here using the more reliable time series of commercial catch data from 1994 -2006. The resulted in an estimate of MCY for *T. ilisha* fishery of 2248 t.

M = 0.75, c = 0.6 (Table 1), Y_{av} (1994-2006) = 3747 t

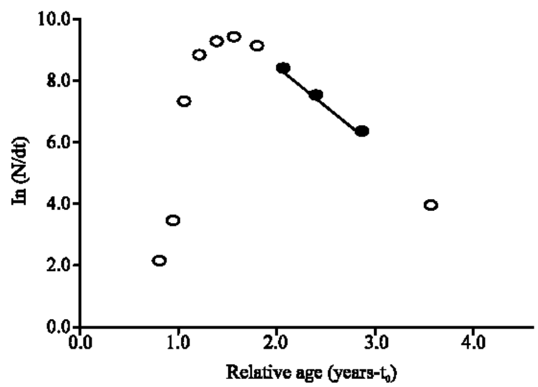

Fig. 5: FISAT graphic output of the catch curve analysis

$$MCY = 3747 \times 0.6 = 2248 \text{ t}$$

The estimate of MSY was calculated using the relationship proposed by Gulland (1977). The resulted in an estimate of MSY for *T. ilisha* 2653 t.

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 representative of the samples and that bias could have been due to the introduction by the schooling behaviour of migratory species.

The length-weight relationship observed during the present study is given below:

$$W = 0.012\ L^{2.968}$$

The b parameters values in the weight-length model, $W = aL^b$ are close to 3 for the *T. ilisha* indicating isometric growth (King, 1995) (Table 2).

The reasons for the variation of b in the different regions are said to be due to seasonal fluctuations in environmental parameters, physiological conditions of the fish at the time of collection, sex, gonadal development and nutritive conditions in the environmental of fish (Biswas, 1993). The values of L_8 and K were calculated as 42.74 cm and 0.77 $year^{-1}$. Present results also appeared to be of the right order in comparison with a range of published estimate of von Bertalanffy growth equation derived from length frequency (Table 3). For *T. ilisha*, differences in growth rates between regions indicated stock separations (Quddus *et al.*, 1984) which has, in some cases, supported a genetic difference (Mizanur, 1997). In general, the correlated parametrics values adjust themselves to provide a similar growth pattern represented by φ' (Sparre and Venema, 1998). The index of phi prime is suitable for comparing and computing the overall growth performance of different species of fish stocks (Amin *et al.*, 2009).

Notably, the values estimated for *T. ilisha* were comparable to those for other stocks of *T. ilisha* in different regions, suggesting a similar growth pattern across different population (Table 3).

The data set for estimating Z by the length converted catch curve method should satisfy the primary assumption that the stock was is in equilibrium (Al-Hosni and Siddeek, 1999). In a declining stock, such as that of *T. ilisha*, this assumpting may have been violated because of a declining trend in recruitment tends to under estimate Z by roughly the some percentage of decline.

Table 2: Length-weight relationship of *T. ilisha* in different area of world

Area	b	a	References
Bangladesh	2.82	0.00003013	Quddus *et al.* (1984)
Chilka	3.12	0.0045	Ramakrishnaiah (1972)
Canal Ashar in Iraq	3.16	0.0064	AL-Nasiri and AL-Mukhtar (1988)
Kuwait	3.14	0.0064	AL-Matar *et al.* (1990)
Kuwait	2.98 M	0.011	AL-Baz and Grove (1995)
	3.1 F	0.007	
Bangladesh	3.07	0.01351	Nurul *et al.* (2009)
Bangladesh (2005)	3.07	0.0087	Haldar and Amin (2005)
Iran (Khuzestan)	3.266	0.0000031	Marammazi (1994)
Iran (Khuzestan)	2.968	0.012	Present study

M: Male and F: Female

Table 3: Summery of the growth parameters estimates of *T. ilisha* in different area

Area	φ'	(1/Y) K	L8 (cm)	References
Mandapam in India	3.11	0.49	51.10	Banerji and Krishnan (1973)
Kuwait	3.00	0.36	52.50	AL-Baz and Grove (1995)
Bangladesh	3.49	0.83	61.50	Rahman *et al.* (2000)
Chittagong of Bangladesh	3.41	0.84	55.74	Amin *et al.* (2001)
Bangladesh	3.14 M	0.53	51.50	
	3.34 F	0.51	65.50	Haldar and Amin (2005)
Iran (Khuzestan)	3.19	0.43	60.00	Parsamanesh *et al.* (2003)
Iran (Khuzestan)	3.14	0.77	42.74	Present study

M : Male and F : Female

Table 4: Summery of the mortality parameters estimates of *T. ilisha* in differente area

Area	Tc⁰	M (1/Y)	F (1/Y)	ZM (1/Y)	References
Bangladesh	28	1.28	2.01	3.29	Rahman *et al.* (2000)
Bangladesh	28	1.28	2.49	3.77	Amin *et al.* (2002)
Bangladesh	27.5	0.01 M	2.07	3.08	Haldar and Amin (2005)
	27.5	0.92 F	1.95	2.87	
Iran (Khuzestan)	23	0.77	6.13	6.90	Parsamanesh *et al.* (2003)
Iran (Khuzestan)	23	0.75	1.80	2.55	Present study

M : Male and F : Female

Thus, the true values for F and E should have been higher than what we mentioned above. Reliable estimate of M can only be obtained for an unexploited stock (Al-Hosni and Siddeek, 1999).

The total mortality of *T. ilisha* estimated in this study differs from results of others (Table 4). This is maybe a result of different sampling regions and different rates of exploitation of *T. ilisha*. Also, as Sparre and Venema (1998) point out, if a length- based method is applied to a migratory stock, without taking the effects of migration into account, the results can be highly biased.

M values correlate strongly with growth parameters. In tropical fishes tend to have, for any asymptotic size, higher values of M than other fishes. This is similar for K, tropical fishes tend to have, for any value of K, higher values of M than temperature fishes (Pauly, 1998).

The fishing mortality rate of 1.8 year^{-1} was substantially greater than both the target (F_{opt} =0.37 year^{-1}) and limit (F_{limit} = 0.5) biological reference points. These results are important to fisheries management authorities as they suggest that the resource is heavily 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. According, the *T. ilisha* fish stock appears to have been overexploited (E = 0.7).

The values of MSY and MCY calculated as 2653 and 2248 t, were greater than commercial catch. The results indicating that the stock of *T. ilisha* is heavily exploited. 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. Although high fishing intensity and/or pollution could have caused stock depletion, the biological and ecological causes of this disappearance remain unknown (Zhang *et al*., 2009).

REFERENCES

Ahmed, M.S., A.S.M. Sharif and G.A. Latifa, 2008. Age, growth and mortality of hilsa shad, *Tenualosa ilisha* in the River Meghna, Bangladesh. Asian J. Biol. Sci., 1: 69-76.

Al-Barwani, S.M., A. Arshad, S.M.N. Amin, S.B. Japar, S.S. Siraj and C.K. Yap, 2007. Population dynamics of the green mussel *Perna viridis* from the high spat-fall coastal water of Malacca, Peninsular Malaysia. Fish. Res., 84: 147-152.

Al-Baz, A.F. and D.J. Grove, 1995. Population biology of sbour *Tenualosa ilisha* (hamilton-buchanan) in Kuwait. Asian Fish. Sci., 8: 239-254.

Al-Hosni, A.H.S. and M.S. Siddeek, 1999. Growth and mortality of the narrow-barred Spanish mackerel, *Scomberomorus commerson* in omani waters. Fish. Manage. Ecol., 6: 145-160.

Al-Matar, S.M., S.A. Hossin, A. Kazem, A. Al-Baz, M. Al-Mukhtar and A. Al-Saffar, 1990. The fishery biology and assessment of Iraqi and Kuwaiti fish stocks. Kuwait Institute for Scientific Research and University of Basrah.

Al-Nasiri, S.K. and M.A. Al-Mukhtar, 1988. On the biology of Sobour, *Hilsa ilisha* (Hamilton) from Ashar Canal, Basrah, Iraqi. J. Agric. Sci., 6: 97-104.

Amin, S.M.N., M.A. Rahman, G.C. Haldar and M.A. Mazid, 2001. Studies on age and growth and exploitation level of *Tenualosa ilisha* in the coastal region of Chittagong, Bangladesh. J. Inland Fish. Soc. Ind., 33: 1-5.

Amin, S.M.N., M.A. Rahman, G.C. Haldar, M.A. Mazid and D.A. Milton, 2002. Population dynamics and stock assessment of hilsa shad, *Enualosa ilisha* in Bangladesh. Asian Fish. Sci., 15: 123-128.

Amin, S.M.N., A. Arshad, G.C. Haldar, S. Shohaimi and R. Ara, 2005. Estimation of size frequency distribution, sex ratio and length-weight relationship of Hilsa (*Tenualosa ilisha*) in Bangladesh water. Res. J. Agric. Biol. Sci., 1: 61-66.

Amin, S.M.N., M.A. Rahman, M.A. Mazid, G.C. Haldar and D.A. Milton, 2008. Catch per unit effort, exploitation level and production of Hilsa Shad in Bangladesh waters. Asian Fish. Sci., 21: 175-187.

Amin, S.M.N., A. Arshad, S.S. Siraj and S.B. Japar, 2009. Population structure, growth, mortality and yield per recruit of segestid shrimp, *Acetes japonicus* (Decapoda: Sergestidae) from the coastal waters of Malacca, Peninsular Malaysia. Indian J. Mar. Sci., 38: 57-68.

Banerji, S.K. and T.S. Krishnan, 1973. Acceleration of assessment of fish population and comparative studies of similar taxonomic groups. Proceedings of the Symposium on Living Resources of the Seas Around India. (SLRSAI'73), CMFRI Special Publication, Cochin, India, pp: 158-175.

Beverton, R.J.H. and S.J. Holt, 1957. On the Dynamics of Exploited Fish Populations. Chapman and Hall, London, pp: 525.

Biswas, S.P., 1993. Manual of Method in Fish Biology. South Asian Publishers Pvt. Ltd., New Delhi, pp: 157.

Coad, B.W., N.A. Hussain, T.S. Ali and K.E. Limburg, 2003. Biodiversity, Status and Conversation of the World Shads. American Fisheries Society, Bethesda, Maryland.

Gayanilo, F.C., P. Sparre and D. Pauly, 2003. The FAO-ICARM Stock Assessment Tools (FiSAT) Users Guide. FAO, Rome, pp: 176.

Gulland, J.A., 1977. Fish Population Dynamics. John Wiley and Sons Ltd., London, pp: 422.

Haldar, G.C. and S.M.N. Amin, 2005. Population dynamics of male and female hilsa, *Tenualosa ilisha* of Bangladesh. 2005. Pak. J. Biol. Sci., 8: 307-313.

Haroon, A.K.Y., 1998. Hilsa shad fish for the teeming millions new management alternatives needed for the hilsa young. Shad J., 3: 7-10.

Hilborn, R. and C.J. Walters, 1992. Quantitative Fisheries Stock Assessment, Choice, Dynamics and Uncertainty. Chapman and Hall, London, pp: 570.

Islam, B.N. and G.B. Talbot, 1968. Fluvial migration, spawning and fecundity of Indus River hilsa, *Hilsa ilisha*. Trans. Am. Fish. Soc., 97: 350-355.

Issac, V.J., 1990. The Accuracy of Some Length-Based Methods for Fish Population Studies. ICLARM, Manila, Philippines, ISBN: 971-1022-86-9, pp: 81.

King, M., 1995. Fisheries Biology, Assessment and Management. Fishing News Books, Oxford, pp: 339.

Marammazi, J., 1994. Biological study of Soboor *Tenualosa ilisha* with emphasis on morphologic, growth, feeding aspects and gonad development stages during migration period in Bahmanshir River. M.Sc. Thesis, Collage of Natural Resources, Tarbiat Modarres University, pp: 78.

Marammzi, J., M.A. Al-Mukhtar and B.H. Kiabi, 1998. Comparison of morphometric and meristic traits and length frequency in soboor (*Tenualosa ilisha* Ham. Buch.1822) of the migration pathways in Khozestan province. Pajouhesj-va-Sazandegi, 11: 113-121.

Mazid, M.A., M.J. Rahman and M.G. Mustafa, 2007. Source and abundance of Jatka (juvenile hilsa, *Tenualosa ilisha*) in the *Gajner beel*, sujanagar, Pabna. Bangladesh J. Fish., 30: 37-51.

Mazumder, S.K. and M.D.S. Alam, 2009. High levels of genetic variability and differentiation in hilsa shad, *Tenualosa ilisha* (Clupeidae, Clupeiformes) populations revealed by PCR-RFLP analysis of the mitochondrial DNA D-loop region. Genet. Mol. Biol., 32: 190-196.

Mizanur, R., 1997. Studies on Population Structure of Shad in Bangladesh Waters with Emphasis on Population Genetics of Hilsa shad (*Tenualosa ilisha*). University of Bergen, Norway, pp: 157.

Nikolsky, G.W., 1969. Theory of Fish Population Dynamics. Oliver and Boyd, Edinburgh, pp: 382.

Nurul, A.S.M., A. Arshad, S.S. Siraj and S.B. Japar, 2009. Population structure, growth, mortality and yield per recruit of segestid shrimp, *Acetes japonicus* from the coastal waters of Malacca, Peninsular Malaysia. Indian J. Mar. Sci., 38: 57-68.

Parsamanesh, A., M.R. Shalbaf, G. Eskandari and M.T. Kashi, 2003. Investigating Aquatic Stocks of Khuzestan. FAO, Iran, pp: 69.

Patterson, K., 1992. Fisheries for small pelagic species: An empirical approach to management targets. Rev. Fish Biol. Fish., 2: 321-338.

Pauly, D., 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. ICES J. Mar. Sci., 39: 175-192.

Pauly, D., 1983. Some simple methods for the assessment of tropical fish stocks. FAO. Fish. Tech. Pap., 234: 52-52.

Pauly, D. and J.L. Munro, 1984. Once more on the comparison of growth in fish and invertebrates. Fishbyte, 2: 21-21.

Pauly, D., 1998. Tropical fishes, patterns and propensities. J. Fish Biol., 53: 1-17.

Pillay, S.R. and H. Rosa, 1963. Synopsis of biological data on hilsa ilisha (Hamilton). FAO Fish. Biol. Synops., 25: 1-6.

Pillay, T.V.R., 1957. A morphometric study of the populations of hilsa, *Hilsa ilisha* of the river Hoogly and of the Chilka lake. Indian J. Fish., 4: 344-386.

Quddus, M.M.A., M. Shimizu and Y. Nose, 1984. Meristic and morphometric differences between two types of *Hilsa ilisha* in Bangladesh waters. Bull. Jap. Soc. Sci. Fish., 50: 43-49.

Rahman, M.A., S.M.N. Amin, G.C. Haidar and M.A. Mazid, 2000. Population dynamics of *Tenualosa ilisha* of Bangladesh water. Pak. J. Biol. Sci., 3: 564-567.

Rahman, M.J. and I.G. Cowx, 2006. Lunar periodicity in growth increment formation in otoliths of hilsa shad (*Tenualosa ilisha*, Clupeidae) in Bangladesh waters. Fisheries Sci., 81: 342-344.

Ramakrishnaiah, M., 1972. Biology of *Hilsa ilisha* (Hamilton) from the Chilka lake with an account of its racial status. Indian J. Fish., 19: 35-53.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Broad Can., 191: 382-382.

Salini, J.P., D.A. Milton, J.J. Rahman and M.G. Hussain, 2004. Allozyme and morphological variation throughout the geographic range of the Shad, Hilsa *Tenualosa ilisha*. Fish. Res., 66: 53-69.

Sparre, P. and S.C. Venema, 1998. Introduction to tropical Fish Stock Assessment. Manual. FAO Fisheries Technical Paper 306/1, Rev. 2, Rome, pp: 407.

Zhang, J., T. Takita and C. Zhang, 2009. Reproductive biology of *Ilisha elongata* (Teleostei: Pristigasteridae) in Ariake Sound, Japan: Implications for estuarine fish conservation in Asia. Estuarine Coastal Shelf Sci., 81: 105-113.