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POPULATION DYNAMICS OF ESCUALOSA THORACATA FROM ESTUARINE SET BAG NET FISHERY OF BANGLADESH

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ABSTRACT

Population parameters of Escualosa thoracata were estimated with length-frequency data collected from Estuarine Set Bag Net Fishery of Chittagong, Bangladesh from November 2002 to October 2004. The asymptotic total length (L_∞) and growth constant (K) were calculated to be 12.08 cm and 1.40 y^{-1}, respectively. The instantaneous rate of total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate (E) were estimated to be 8.08 y^{-1}, 2.82 y^{-1}, 5.26 y^{-1} and 0.65, respectively clearly pointing toward over-fishing condition ($E > 0.50$) for this fish in Bangladesh. The probability of capture analysis showed that almost 50% of the fishes are being caught at the length of 6.26 cm. The length-weight relationship was found to be $W = 0.0216L^{2.57}$ signifying non-isometric growth for this species. Virtual population analysis estimated that the maximum numbers of E. thoracata are caught between 6.5 cm to 8.5 cm with maximum F value (6.93 y^{-1}) in the mid length of 7.5 cm. Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) suggested that the fishing mortality should be reduced to 4.15 y^{-1} to obtain maximum sustainable exploitation rate ($E_{\max} = 0.514$) for the species in ESBN fishery of Bangladesh.

Key words: Fish population dynamics, asymptotic length, growth coefficient, over-fishing, virtual population analysis.

INTRODUCTION

The marine capture fisheries of the Bay of Bengal are of multigear and multispecies characters (White and Khan, 1985; Islam et al., 1993) like most fisheries in the tropical regions (Silvestre et al. 2003) where artisanal fishery is the most dominant one (Islam, 2003). In Bangladesh, about 95% of the total marine production is contributed from artisanal fisheries (DOF, 1998), of which about 30% is supplied from the estuarine set bag net (ESBN) (Islam, 2003) – one of the most conventional fishing gears widely used in the shallow coastal waters (3–10 m water depth) of Bangladesh. The ESBN is considered as a destructive fishing gear (Rahman et al., 2003) since it catches juveniles of a large variety of shrimp and finfish species (Kamal, 2000). The species Escualosa thoracata Val. belonging to the family 'Clupeidae' is commonly known as 'white sardine' (FishBase, 2009) and occurs in the Indo-pacific region, Northern Indian Ocean, Indonesia, the Philippines, Papua New Guinea, and Australia (FishBase, 2009). This fish forms school in the shallow coastal waters, juveniles apparently enters the lower part of rivers, but later return to the sea (Froese and Pauly, 2000). It is one of the

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notable fish species caught in the ESBN of Bangladesh. Its common name in Bangladesh is 'Samudric Mola Mach'.

Population may be defined as a group of individuals of the same species that occupies some specified area in a unit time. Study on the fish population dynamics gives a clear picture of the life history pattern of a specific fish species (Pauly and Morgan, 1987; King, 1995). In fish population dynamics growth, mortality, recruitment, length at first capture, yield per recruit, biomass per recruit etc. are generally studied for a single or group of species, which finally contribute to assess fishery dynamics and total standing stock. However, the system is dynamic and values of these parameters fluctuate between different stocks and places of the same species (Nabi et al., 2007). Although a remarkable research work has been conducted to study the population dynamics of different fishes of Bangladesh, few works has been concerned with the population biology of E. thoracata. Hence, it is necessary to evaluate the population parameters of this species especially those are caught from ESBN to ensure the proper management of this fishery. For this reason, the present study was designed to study on the population dynamics of E. thoracata collected from the ESBN operated in the coastal waters of Bangladesh.

MATERIALS AND METHODS

Data collection: During the period of November 2002 to October 2003 unsorted E. thoracata was collected every month directly from the ESBN fish landing center of Firingibazar Chittagong, Bangladesh. This landing center was chosen because the ESBN fishermen from various fishing grounds land their catch here and sale their fish in unsorted condition to the wholesale market. Around 29 to 311 fish species were collected in each month (depending on its availability) and their total length and corresponding body weight were measured nearest to 0.01 cm by a scale and 0.01 g by an electronic balance, respectively. At the end of data collection, monthly length frequency distribution database and length – weight database was prepared in an excel spreadsheet for parameters estimation. All the growth parameters of E. thoracata were analyzed using FiSAT software (Gayanilo et al., 1996).

Estimation of asymptotic length (L_∞) and growth coefficient (K): Total asymptotic length (L_∞ cm) and growth coefficient (K y^{-1}) was calculated using the collected length-frequency distribution data through VonBertalanffy growth equation (VonBertalanffy, 1938; Beverton and Holt, 1957). The L_∞ and K value were determined following the Powel-Wetherall method (Wetherall et al., 1987) using ELEFAN I and ELEFAN II routines incorporated in FiSAT software (Gayanilo et al., 1996). This method was used to provide an initial estimate of L_∞ (Silvestre and Garces, 2004). This initial estimate of L_∞ was then used as seed value to estimate the value of K (Silvestre and Garces ,2004; Nabi et al., 2007). This led to a rough estimates of L_∞ and K values and were used to obtain "probabilities of capture" for their respective length classes using the routine incorporated in FiSAT (Silvestre and Garces, 2004; Nabi et al., 2007). This "probabilities of capture" was used to correct the length frequency distribution data to account for incomplete selection and recruitment and the final estimates of L_∞ and K were obtained using these corrected length distribution data through ELEFAN I (Silvestre and Garces, 2004; Nabi et. al., 2007).

Mortality (rate of total, natural and fishing mortality) and exploitation rate: Following the ELEFAN II routine incorporated in FiSAT (Gayanilo and Pauly, 1997), the rate of total mortality, $Z\,(y^{-1})$ (Beverton and Holt, 1957, 1966) was estimated using the length-converted catch curve

(King, 1995) by means of the final estimates of L_∞ and K of E. thoracata. The rate of natural mortality ($M\ y^{-1}$) was calculated using Pauly's empirical formula (Pauly, 1980) $Log_{10}M = -0.0066 - 0.279 Log_{10}L_\infty + 0.06543 Log_{10}K + .04634 Log_{10}T$.

Here, T = mean annual temperature and was taken as $27^0 C$ (Silvestre and Matdanan, 1992). The rate of fishing mortality ($F\ y^{-1}$) was obtained by subtracting M from Z (King, 1995; Nabi et al., 2007), i.e. $F = Z - M$. The rate of exploitation (E) was calculated by the following formula (Beverton and Holt, 1966; Gulland, 1971) $E = F/(F+M)$.

Probability of capture (L_{25}, L_{50} and L_{75}) and optimum harvestable length (L_{opt}): The values of L_{25}, L_{50} and L_{75} i.e. lengths at which 25%, 50% and 75% of the fish will be vulnerable to the gear (Pauly, 1984), were determined through probability of capture, calculated from the length-converted catch curve routine incorporated in FiSAT.

The optimum harvestable length (L_{opt}) was calculated using the following formula $L_{opt} = 3 * L_\infty / (3 + M/K)$ (Froese and Binohlan, 2000).

Recruitment pattern: Recruitment pattern was calculated by the backward projection of the frequencies onto the time axis of a time-series of samples along course defined by the VonBertalanffy growth curve (Gayanilo et al., 2005); this routine reconstructs the recruitment pulses from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse (Gayanilo et al., 2005; Nabi et al., 2007).

Length-weight relationship: Length-weight relationship of E. thoracata was calculated using the following formula $W = cL^n$ (LeCren, 1951; King, 1996)
where 'c' is a constant, 'n' is an exponent, 'W' is the weight and 'L' is the corresponding total length of the weight. The exponential form of this formula may be converted in the natural logarithmic form a follows
$\ln W = \mathrm{c} + n \ln L$.
The value of 'c' and 'n' was calculated by using the following mathematical relationship
$$\ln(c) = \frac{\Sigma \ln W \Sigma(\ln L)^2 - \Sigma \ln L \Sigma(\ln L \ln W)}{N\Sigma(\ln L)^2 - (\Sigma \ln L)^2}$$ and, $$n = \frac{\Sigma \ln W - N \ln(c)}{\Sigma \ln L}$$ (LeCren, 1951; Hile, 1936; Rounsefell and Everhart, 1953; Nabi et al., 2007),
where N = number of the classes used in the calculation.

Virtual population analysis: Terminal population (N_t) were estimated from $N_t = C_t(M + F_t)/F_t$ (Gayanilo and Pauly, 1997; Gayanilo et al., 2005); where, 'C_t' is the terminal catch and 'F_t' is the terminal fishing mortality and 'M' is the natural mortality (Nabi et al., 2007).

Starting from 'N_t', successive values of 'F' were estimated, by iteratively solving $C_i = N_i + \Delta t(F_i / Z_i)(exp(Z_i \Delta t_i) - 1)$ (Gayanilo et al., 2005) where, $C_i =$ catch (in number) for a population during a unit time period i, $\Delta t_i = (t_{i+1} - t_i)$, and $t_i = [t_0 - (1/K) ln(1 - (L_i / L_\infty))]$ (Gayanilo and Pauly, 1997; Gayanilo et al., 2005). The population sizes (N_i) was computed from $N_i = N_{i+\Delta t_i} exp(Z_i)$ (Gayanilo and Pauly, 1997; Gayanilo et al., 2005). The last two equations were used alternatively, until the population sizes and fishing mortality for all length groups have been computed (Jones and VanZalinge, 1981; Pauly, 1984; Gayanilo and Pauly, 1997; Gayanilo et al., 2005). Relative yield-per-recruit (Y'/R) was computed using the following formula (Beverton and Holt, 1966; Gayanilo and Pauly, 1997; Gayanilo et al., 2005).

$$Y'/R = EU^m \left(1 - \frac{3U}{(1+m)} + \frac{3U^2}{(1+2m)} - \frac{U^3}{(1+3m)}\right)$$

where, $U = 1 - (L_c / L_\infty)$, $m = (1-E)/(M/K) = K/Z$, $L_c \cong$ means length of fish at first capture i.e. length at which 50 percent of the fish are retained by the gear (L_{50}) and $E = F/Z$.

Relative biomass-per-recruit (B'/R) was estimated from the following relationship $B'/R = (Y'/R)/F$ (Gayanilo and Pauly, 1997; Gayanilo et al., 2005). The value of maximum sustainable exploitation rate ($E_{\max}$) was estimated by using the first derivative of this function (Gayanilo et al., 2005).

RESULTS

Asymptotic length (L_∞) and growth coefficient (K): The length range obtained in the present investigation was 2.50 cm to 11.90 cm. The values for asymptotic length (L_∞) and the growth parameter (K) estimated by the ELEFAN I were found to be 12.08 cm and 1.40 y^{-1}, respectively (Figure 1).

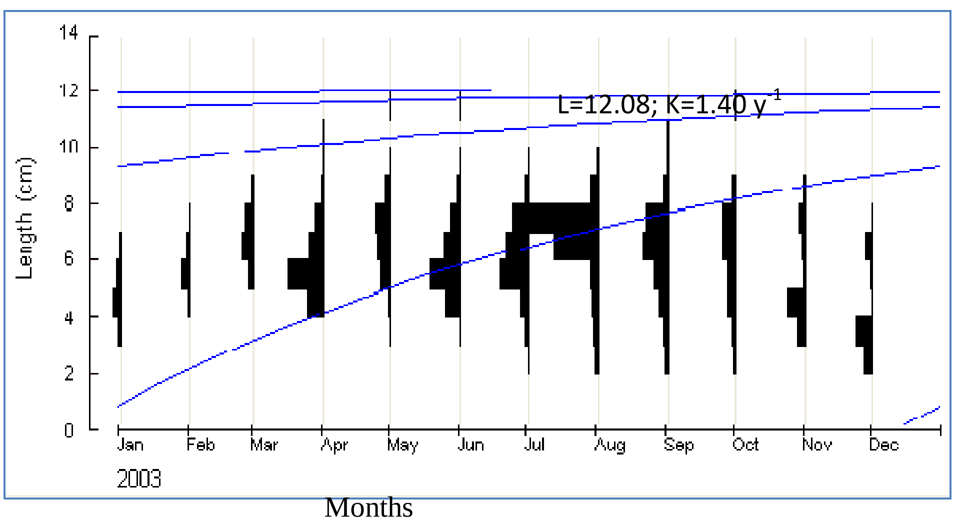

Figure 1. Mortality (rate of total, natural and fishing mortality) and exploitation rate

The length converted catch curve of Escualosa thoracata is shown in Figure 2. The values for instantaneous total mortality co-efficient ($Z\ y^{-1}$), natural mortality co-efficient ($M\ y^{-1}$), fishing mortality co-efficient ($F\ y^{-1}$) and the exploitation rate (E) calculated in the present investigation was found to be 8.08 y^{-1}, 2.82 y^{-1}, 5.26 y^{-1} and 0.65, respectively.

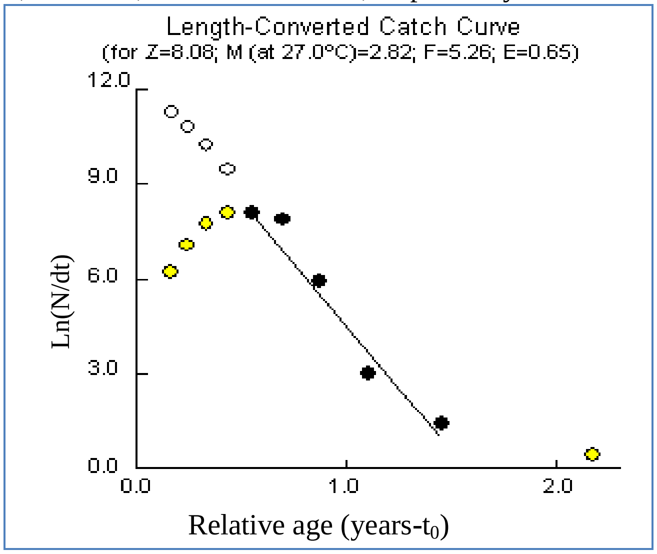

Figure 2: Length converted catch curve of E. thoracata.

Probability of capture (L_{25}, L_{50} and L_{75}) and optimum harvestable length (L_{opt})

Figure 3 shows that the estimated length sizes for 25 % (L_{25}), 50 % (L_{50}) and 75 % (L_{75}) probabilities of capture appeared to be 4.45 cm, 6.26 cm and 7.08 cm, respectively for E. thoracata.

The optimum harvestable length (L_{opt}) was calculated to be 7.20 cm.

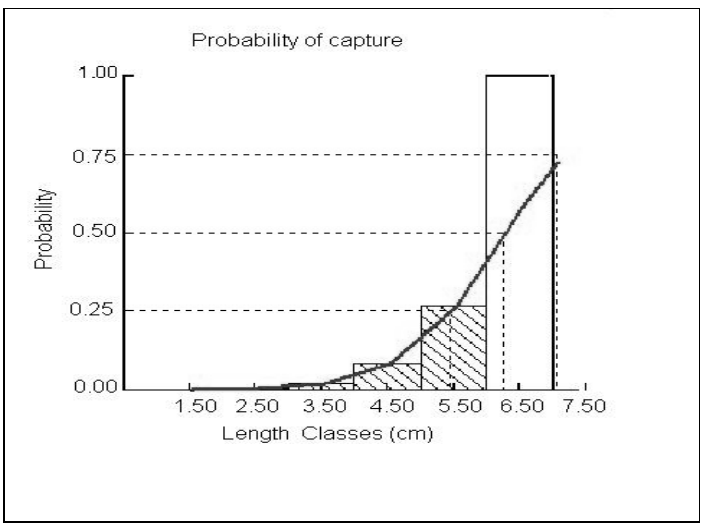

Figure 3. Selection pattern of E. thoracata obtained from probability of capture analysis.

Recruitment pattern: Two recruitment peaks were found in the present investigation – one during mid June and another during September – October (Figure 4). However, from Table 2 it is clear that recruitment is present in almost every month in the ESBN fishery of Bangladesh for E. thoracata though its intensity is lower during dry season (December – February).

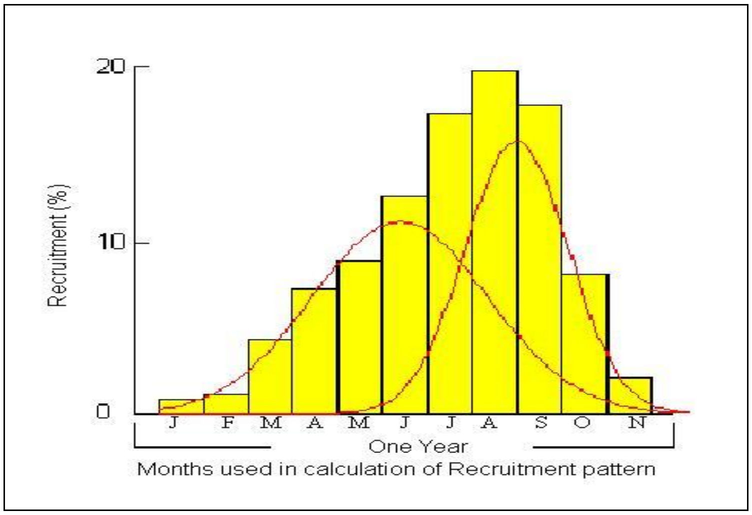

Figure 4. Recruitment pattern of E. thoracata during the investigated time.

Length-weight relationship: The total lengths varied between 2.50 cm and 11.90 cm and total weights between 0.22 g and 8.90 g. The exponential form of the equation was found to be $W = 0.0216L^{2.57}$. The coefficient of correlation between total length and body weight was found to be highly significant at 5% level of significance (r=0.97; t=10.54 and t0.05=1.81) (Figure 5).

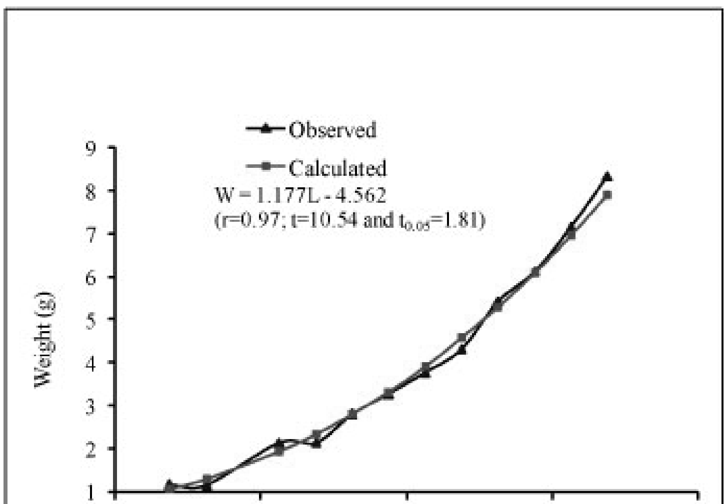

Figure 5. Length-weight relationship of E. thoracata (unsexed).

Virtual population analysis: The results of the length structured VPA of E. thoracata has been shown in Figure 6. The F-at-length array shows that the maximum fishing mortality is occurring in the length between 6.5 cm and 8.5 cm with the maximum in the length class of 7.5 cm. The total population, catch (in number), fishing mortality and steady-state-biomass (tones) per length class have been presented in Table 2. The total steady state biomass was found to be 1767.33 tones.

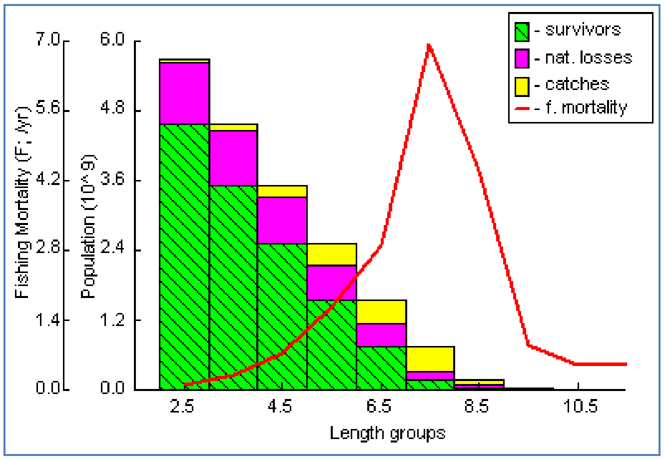

Figure 5. Length-group and Fishing mortality relationship of E. thoracata (unsexed).

Yield-per-recruit and biomass-per-recruit: The yield-per-recruit and biomass-per-recruit curve for different 'E' factor showed a parabolic curve (Figure 6). From this Y'/R and B'/R curve of E. thoracata the values of the rate of fishing mortalities for different exploitation rates were calculated (E_i) and produced a $E_{\max}$ value (0.514) from which $F_{\max}$ was calculated to be $4.15\,y^{-1}$ (Table 3).

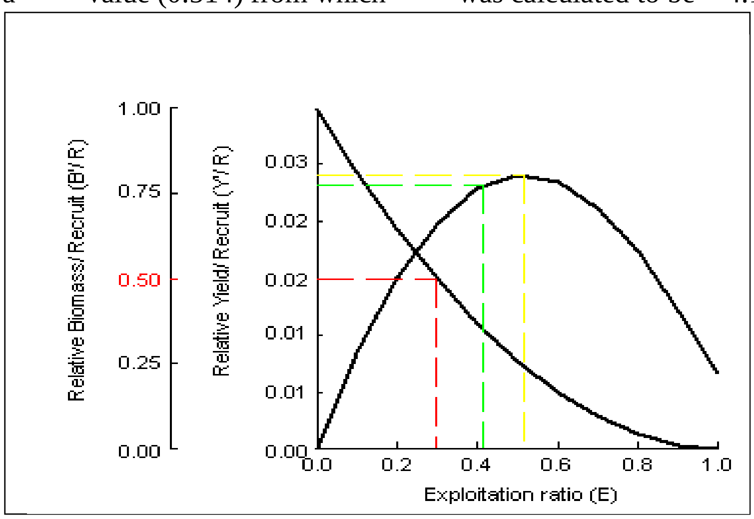

Figure 6. Yield-per-recruit and biomass-per-recruit

DISCUSSION

Asymptotic length (L_∞) and growth coefficient (K): The minimum length was found to be 2.70 cm during October while the maximum length 11.90 cm was observed during June. The asymptotic length was found to be 12.08 cm which is higher then the present maximum length and suggests that the fish had a chance to grow larger under favourable condition. This result agrees with the result of Whitehead (1985) where the calculated total length was found to be11.82 to 12.05 cm from the western coast of Indian Ocean. The value of the growth coefficient K for E. thoracata was estimated as $1.40\,y^{-1}$.

Table 2. Recruitment pattern of E. thoracata during the present investigation showing that the maximum rcruitment is occuring during the months of June – September.

Relative time	Percent Recruitment
January	0.89
February	1.13
March	4.23
April	7.13
May	8.92
June	12.53
July	17.23
August	19.85
September	17.85
October	8.07
November	2.17
December	0.00

Table 3. Virtual population analysis showing the total population, catch (in number), fishing mortality, and steady state biomass per length class for E. thoracata.

Mid-Length	Catch (in numbers)	Population (N)	Fishing Mortality (F)	Steady-state Biomass (tones)
2.5	37000000	5670000000	0.0973	88.89
3.5	98000000	4560000000	0.2926	183.45
4.5	211000000	3520000000	0.7483	293.1
5.5	359000000	2510000000	1.6592	375.66
6.5	406000000	1540000000	2.8905	374.05
7.5	413000000	742000000	6.9377	228.77
8.5	75000000	161000000	4.3919	90.47
9.5	6000000	37821560	0.9126	46.33
10.5	2000003	13280019	0.5	86.61
Total Steady-state Biomass (tones)				1767.33

Table 3: Exploitation rate (E_i) and their corresponding Y/R, B/R and F values for E. thoracata.

E_i	Y/R	B/R	F
0.01	0.007	0.850	0.81
0.20	0.013	0.708	1.62
0.30	0.018	0.576	2.42
0.40	0.022	0.453	3.23
0.50	0.025	0.342	4.04
0.60	0.026	0.242	4.85
0.70	0.026	0.155	5.66
0.80	0.025	0.083	6.46
0.90	0.019	0.029	7.27
0.99	0.004	0.000	8.00
0.514			4.15

Mortality (rate of total, natural and fishing mortality) and exploitation rate: The total mortality (Z), natural mortality (M) and fishing mortality (F) were found to be 8.08 y^{-1}, 2.82 y^{-1}, and 5.26 y^{-1} for E. thoracata indicating high fishing mortality than the natural mortality and consequently high exploitation rate was observed (E=0.65). High fishing mortality and exploitation were also observed for ESBN fishes by Nabi et al., (2006) for Harpadon nehereus and Nabi et al., (2007) for Polynemus paradiseus collected from the coastal areas off Chittagong, Bangladesh.

Probability of capture (L_{25}, L_{50} and L_{75}) and optimum harvestable length (L_{opt}): From the probability of capture result it was found that about 75% of the fish is being harvested within the length of 7.00 cm. On the other hand, from the L_{opt} calculation it was found that this length should be 7.20 cm which is higher then the L_{75} value and gives an indication that the fish E. thoracata is being harvested bellow its optimum harvestable size.

Recruitment pattern: The recruitment pattern found through FiSAT routine (with the separation of the normal distribution of peaks by means of the NORMSEP program) showed that the annual recruitment consists of two seasonal pulse: one in the mid of June another is September-October. This is a very common phenomenon for the tropical estuarine fishes. In general there are two spawning period for the estuarine species (Blabber, 2000) – the longer one along with the starting of monsoon and the shorter one is at the postmonsoon which agrees with the present investigation. However, the present investigation revealed that the recruitment is present in almost every month for E. thoracata which agrees with the results of Kader et al., (1988) for Odentomblyopus rubicundus and Nabi et al., (2007) for Polynemeus paeadiseus which are also estuarine fishes.

Length-Weight Relationship: Hile (1936) proposed that the value of 'n' for an ideal fish should range between 2.5 and 4.0. In contrast, Ricker (1975) recommended that the value of 'n' should be exactly '3' when the growth is isometric. This cube law relationship is hardly expected as most of the species do changes their shape (Hile, 1936) and these changes are due to sex, maturity, seasons and even the time of day because of stomach fullness (Bagenal, 1978). Since, the value of 'n' (2.57) in the present investigation is not close to '3' it can be concluded that isometric growth is not expected in the fish E. thoracata. This non-isometric growth was also reported by Bashirullah and Kader (1970) for Trichiurus savala where the 'n' values were found to be 0.09351 and 2.1945 for male and female, respectively. The coefficient of correlation (r = 0.97) between total length and body weight was found to be highly significant at 5% level of significance from which it may be concluded that the high degree of linear association exist between length and weight of E. thoracata.

Virtual population analysis: From the result of the virtual population analysis it may be concluded that the fish E. thoracata is highly fished between the length groups of 5.5 cm to 8.5 cm and is not getting the chance to reach its maximum size. Hence, special attention should be given to the control of ESBN mesh size so that the undersized E. thoracata are not caught. This will reduce the value exploitation rate (E) and ultimately help in the management of this fishery.

Yield –per recruit (Y/R) and biomass-per-recruit (B/R): The relative yield-per-recruit and biomass-per-recruit analysis suggest that the fishing mortality should be reduced to 4.15 y^{-1} (around 78.90% of the present mortality rate) to obtain maximum sustainable exploitation rate ($E_{\max} = 0.514$) for this species. Nabi et al., (2007) also suggested about the reduction of fishing mortality for Polynemus paradiseus collected from the ESBN of the coastal waters of Bangladesh.

CONCLUSION

High fishing mortality was observed for the fish E. thoracata collected from the ESBN fishery of Bangladesh. To sustain this species in the coastal waters of the Bay of Bengal fishing pressure should be reduced and the present investigation suggests about 21.10% reduction in the fishing effort for this purpose.

REFERENCES

Bashirullah, A.K.M. and Kader, M.A. 1970. The length-weight relationship and condition of Trichiurus savala Guv. and Vahi. Pakistan Journal of Scientific and Industrial Research, 13: 414 – 419.

Begenal, T. B. 1978. Methods for assessment for fish production in freshwater (3rd Edition), Blackwell Scientific Publication, London, UK.

Beverton, R.J.H. and Holt S.J. 1957. On the dynamics of exploited fish populations. Fishery Investigation Series II, 19: 5 - 33.

Beverton, R.J.H. and Holt S.J. 1966. Manual of methods for fish stock assessment, Part 2; tables of yield functions, Fisheries Technical Paper No. 38, Rome, Italy: Food and Agricultural Organization of the United Nations.

Blaber, S.J.M. 2000. Tropical estuarine fishes, Blackwell Science, London, UK.

BOBP (Bay of Bengal Program). 1995. Marine small scale fisheries of Bangladesh: A general description, BOBP/INF/08, Madras, India, 1985.

DOF. 1998. Fish catch statistics, various issues, 1994–1998. Department of Fisheries, Government of the People's Republic of Bangladesh.

Fish Base. 2009. http://www.fishbase.org/Summary/speciesSummary.php?ID=1522 and genusname =Escualosa and speciesname=thoracata&lang=English; retrieved on 16/05/2009.

Froese, R. and Binohlan, C. 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of Fish Biology, 56:758-773.

Froese, R. and Pauly, D. (eds). 2000. FishBase 2000: concept, design and data sources. ICLARM contribution no. 1594, International Centre for Living Aquatic Resource Management, Manila, The Philippines.

Gayanilo, F.C. and Pauly, D. 1997. The FAO-ICLARM Stock Assessment Tools (FiSAT); Reference Manual. Computerized Information Series (Fisheries) No. 8, Food and Agriculture Organization of the United Nations, Rome, Italy.

Gayanilo, F.C., Sparre, P. and Pauly, D. 2005. FAO-ICLARM Stock Assessment Tools II (FiSAT II), User's Guide, Computerized Information Series (Fisheries) No. 8, (Revised Version), Food and Agriculture Organization of the United Nations, Rome, Italy.

Gayanilo, F.C., Sparre, P. and Pauly, D.1996. FAO-ICLARM Stock Assessment Tools (FiSAT): user's Guide, FAO computerized information Series (Fisheries), No.8, Rome, FAO, 266p.

Gulland, J.A. 1971.The fish resources of the ocean. West Bay fleet, Survey, Fishing News (Books) Ltd., for FAO, 255p, revised edition of FAO Fisheries Technical paper, (97):425p.

Hile, R. 1936. Age and growth of sisco Leucichthys artedi (Lesueur) in the lake of three northern highlands, Wisconsin. Bulletin of the United States Bureau of Fisheries, 48: 209 – 317.

Islam, M.S. 2003. Perspectives of the coastal and marine fisheries of the Bay of Bengal, Bangladesh. Ocean and Coastal Management 46: 763–796.

Islam, M.S., Khan, M.G., Quayum, S.A., Sada, M.N. and Chowdhury, Z.A. 1993. The estuarine set bag net fishery. In: Studies of interactive marine fisheries of Bangladesh, Working Paper no. 89, Bay of Bengal Program, Madras, India, p 19 – 50.

Jones, R. and VanZalinge, N.P. 1981. Estimations of mortality rate and population size for shrimp in Kuwait waters. Kuwait Bulletin of Marine Sciences, 2: 273-288.

Kader, M.A., Bhuiyan, A.L. and Khuda, Ar.R.M.M. 1988. The reproductive biology of Gobiodis rubicundus (Hamilton – Buchanon) in the Karnaphuly river estuary, Chittagong. Indian Journal of Fisheries, 35(4): 239 – 250.

Kamal, M. (ed.). 2000. Assistance to Fisheries Research Institute. Dhaka, Bangladesh: Bangla Academy.

King, M. 1995. Fisheries biology, assessment and management. Oxford, UK: Blackwell Science.

King, R.P. 1996. Length-weight relationship of Nigeria coastal water fishes. NAGA, 19(4): 53-58.

LeCren, E.D. 1951. The Length-weight relationship and seasonal cycle in gonad weight and condition in perch (Perca fluviatilis). Journal of animal Ecology, 20: 201-219.

Nabi, M.R., Hoque, M.A., Rahman, R.A., Mustafa, S. and Kader, M.A. 2007. Population dynamics of Polynemus paradiseus from estuarine set bag net fishery of Bangladesh. Chiang Mai Journal of Science, 34 (3): 355 – 365.

Nabi, M.R., Rahman, R.A., Hoque, M.A., Mustafa, S. and Kader, M.A. 2006. Population dynamics of Harpadon nehereus from estuarine set bag net fishery of Chittagong region, Bangladesh, Paper presented at the International Conference on "Coastal Oceanography and Sustainable Marine Aquaculture, Confluence& Synergy" 2-4 May 2006, Kota Kinabalu, Sabah –Malaysia, 246 – 255.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks, ICES Journal of Marine Science, 39(2): 175–192.

Pauly, D. 1984. Fish population dynamics in tropical waters: A manual for use with programmable calculators. Studies and Review No. 8, International Center for Living Aquatic Resource Management, Manila, The Philippines.

Pauly, D. and Morgan, G.R. (eds.). 1987. Length based methods in fisheries research, Conference Proceedings No. 13, International Centre for Living Aquatic Resource Management, Manila, The Philippines.

Rahman M.M., Chowdhury, Z.A and Sada, M.N.U. 2003. Coastal resources management, policy and planning in Bangladesh, p. 689 - 756. In G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A.V. Santos, C. Luna, L. Lachica-Aliño, V. Christensen, D. Pauly and P. Munro (eds.), Assessment, Management and future directions for coastal fisheries in Asian countries. WorldFish Center Conference Proceeding 67, 000 p.

Ricker, W.E. 1963. Big effects from small caused: two examples from fish population dynamics. Journal of Fisheries Research Board of Canada, 20: 257-264pp.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, 191:1-382.

Rounsefell, G.A. and Everhart, W.H. 1953. Fishery science, its methods and applications. John Wiley and Sons New York, USA.

Silvestre G.T. and Garces L.R. 2004. Population parameters and exploitation rate of demersal fishes in Brunei Darussalam (1989 – 1990). Fisheries Research, 69: 73–90.

Silvestre, G.T. and Matdanan, H.J.H. 1992. Brunei Darussalam capture fisheries: A review of resources, exploitation and management. In: Silvestre, G.T., Matdanan, H.J.H., Sharifuddin, P.H.Y., DeSilva, M.W.R.N. and Chua, T.E. (eds.). The Coastal Resources of Brunei Darussalam: Status, Utilization and Management. Conference Proceedings No. 34, International Centre for Living Aquatic Resource Management, Manila, The Philippines.

Silvestre, G.T., Garces, L.R., Stobutzki, I., Ahmed, M., Santos, R.A.V., Luna, C.Z. and Zhou, W. 2003. South and South-East Asian coastal fisheries: Their status and directions for improved management; Conference Synopsis and Recommendations. In: Silvestre, G.T., Garces, L.R., Stobutzki, I., Ahmed, M., Santos, R.A.V., Luna, C.Z., Lachica-Aliño, L., Christensen, V., Pauly, D. and Munro, P., (eds.). Assessment, management and future directions for coastal fisheries in Asian countries. Conference Proceedings No. 67, International Centre for Living Aquatic Resource Management, Manila, The Philippines.

VonBertalanffy, L. 1938. A quantitative theory of organic growth. Human Biology, 10:181–213.

Wetherall, J.A., Polovina, J.J. and Ralston, S. 1987. Estimating growth and mortality in steady-state fish stocks from length–frequency data. In: Pauly, D. and Morgan, G.R. (eds.). Length-based methods in fisheries research, Conference Proceedings No. 13, International Centre for Living Aquatic Resource Management, Manila, The Philippines.

White, T.F. and Khan, M.G. 1985. Marine fisheries resources survey; Demersal trawling survey cruise Report 1. Chittagong, Bangladesh: Department of Fisheries.

Whitehead, P.J.P. 1985. FAO species catalogue. Vol. 7. Clupeid fishes of the world (suborder Clupeioidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. Part 1 - Chirocentridae, Clupeidae and Pristigasteridae. FAO Fisheries Synopsis, 125(7/1):1-303.