POPULATION DYNAMICS OF THE MULLET FISH, *RHINOMUGIL CORSULA* (HAMILTON, 1822), IN THE SITAKUNDA COAST OF THE BAY OF BENGAL

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Abstract: Population dynamics of the mullet species, *Rhinomugil corsula*, was studied, using FiSAT-II program, with the length-frequency data of 2480 fish specimens. The asymptotic length (L_∞) and growth coefficient (K) of this fish were estimated to be 31.4 cm and 1.0/year, respectively. The instantaneous rate of natural mortality (M), fishing mortality (F) and total mortality (Z) were estimated to be 1.73, 1.20 and 2.93, respectively. The recruitment pattern of the species was prolonged with two peaks, major peak during June to December and a minor peak during January to April. The L_{25}, L_{50} and L_{75} were found to be 8.61, 10.42 and 12.23 cm, respectively. The relative yield per recruit (Y′/R) and biomass per recruit (B′/R) were 0.751 and 1.731, respectively. The value of exploitation (E) was found to be 0.41 which indicated that *R. corsula* was not over fished (E > 0.50) in the study area. The maximum exploitation (E_{max}) value was 0.55. The growth performance index ($\phi' = 2.99$) of *R. corsula* in the Sitakunda coast of the Bay of Bengal was found to be moderate.

Key words: Mullet fish, *Rhinomugil corsula*, population dynamics, Bay of Bengal, Sitakunda coast

INTRODUCTION

Mugilid fish*, Rhinomugil corsula*, locally known as 'Bata, Khorsula or Khalla', is a popular mullet species inhabiting the freshwater rivers as well as coastal and estuarine brackish water of Southern Asia, especially in Bangladesh, India, Nepal and Myanmar (Rahman 2005). It can tolerate wide ranges of environmental fluctuations and found in freshwater, brackish water and coastal waters at a depth range of 10 - 15 meters (Riede 2004). It is one of the most popular and commercially important fish for its high nutritive and market value (Sultana *et al.* 2013). Despite the high commercial and nutritional importance of this mugilid fish no major attention has yet been paid on its population dynamics in Bangladesh.

To manage a natural fish population for sustainable yield study on population dynamics is essential. Fish population dynamics is the fluctuation in number of fish in a population due to several factors such as reproduction,

growth, mortality, and recruitment (King 2007) for which a given population grows or shrinks. A fishery population is affected by three dynamic rate functions i.e., birth rate or recruitment, growth rate and mortality (King 2007). If these rates measured over different time intervals, the harvestable surplus of the fishery can be determined (King 2007).

In Bangladesh population dynamics of several fishes have been done by many authors such as Mustafa and Khan (1988), Azadi *et al.* (1995, 1996, 1997), Azadi and Quddus (1995), Azadi and Barua (1999), Mustafa and Azadi (1995), Azadi (2000), Azadi and Mamun (2009), and Sarkar *et al.* (2017). However, studies on population dynamics of mullets, especially of *Rhinomugil corsula*, has not been done yet in Bangladesh. Fatima (1991) studied the age growth of *R. corsula* of Yamuna River of India by scale method.

Nedreaas (1990) stated that determination of age and growth by employing direct methods, such as scale method, are perhaps the most complicated and controversial in fish biology and also very expensive, especially for tropical fish. Dutt (1969) and Qasim (1973) pointed out that the growth checks of the hard parts of the tropical fishes, though formed, do not show a yearly regular pattern; as the environmental conditions of summer and winter is not so extreme in the tropical region as it is in the temperate region.

Therefore, to overcome the collection of costly hard parts (such as otolith and other body parts) and to use the easily available length frequency data for the study of fish population dynamics, several computer based programs are made and used, such as Length-based Fish stock Assessment (LFSA) (Sparre 1987), MULTIFAN (Fournier *et al.* 1990) and FiSAT (Gayanilo and Pauly 1997). In the present study, the population dynamics (growth parameters, mortality, selection pattern, exploitation rate, recruitment pattern and yield) of *R. corsula* were investigated from length frequency data analysis using FiSAT II (FAO ICLARM Stock Assessment Tools) (Gayanilo *et al.* 1996). It is resulted from the merging of LFSA (Length based Fish Stock Assessment) developed by FAO (Sparre 1987) and the Complete ELEFAN (Electronic Length Frequency Analysis) package (Gayanilo *et al.* 1989).

MATERIAL AND METHODS

For this study, a total of 2480 samples of *Rhinomugil corsula*, ranging from 3.3 to 29.5 cm length and 0.4 to 235.34 g weight, were collected from the Sitakunda coast of Bay of Bengal monthly for two-year period (February, 2016 to January, 2018) from the fishermen, caught by enclosure net. Monthly collected

length frequency data of two years were merged together to facilitate the calculation and analysis.

FiSAT II (Gayanilo *et al.* 1996) was used to find the asymptotic length (L_∞), growth co-efficient (K), total mortality (Z), Fishing mortality (F), natural mortality (M), exploitation rate, recruitment pattern, selection pattern, relative yield-per-recruit and biomass-per-recruit. Length frequency data were then analysed by electronic length frequency analysis using the correct routines in FiSAT II package (Pauly and David 1981, Pauly 1984, 1986, 1987, Gayanilo *et al.* 1996). In this method the growth parameters, asymptotic length (L_∞) and growth coefficient (K) were estimated following the von Bertalanffy growth equation (von Bertalanffy 1938): $L_t = L_\infty (1\text{-exp}^{-K(t-t_0)})$.

Where, L_t is the length at age t, L_∞ the asymptotic length, K the growth coefficient and t_0 age at which fish would have had zero length. Parameters of L_∞ and K were computed from the ELEFAN I. The growth performance index (ϕ) for *R. corsula* was computed using the following equation (Pauly and Munro 1984). $\phi' = \log_{10}K + 2 \log_{10}L_\infty$

Additional estimates of L_∞ and total mortality/growth constant (Z/K) were obtained through the Powell-Wetherall Plot (Wetherall 1986 as modified by Pauly 1986). These initial estimates were fed into ELEFAN I in order to the optimized values for L_∞ and K. The most optimized L_∞ and K values were obtained by ELEFAN I automatic search routine and the restructured length frequency histograms were also obtained.

The total mortality coefficient (Z) was estimated using the length converted catch curve analysis in the FiSAT II program using the input parameters L_∞, K and t $^\circ$C (Pauly 1984). The theoretical equation used in this analysis is, In $(N_i/\Delta t_i) = a + b \times t_i$

where, N_i = The number of fish in length class i, Δt_i = The time needed for the fish to grow through length class i, t_i = The age corresponding to the mid length of class i, and b = The estimate of Z (with sign changed).

The natural mortality (M) was estimated using the empirical relationship derived by Pauly (1980) where the mean annual temperature (T) was set at 27°C. $\text{InM} = -0.0152 - 0.279 \ln L_\infty + 0.06543 \ln K + 0.463 \ln T$

where, M is the natural mortality, L_∞ is in cm, K is annual and T is the mean annual temperature (in $^\circ$C). Fishing mortality (F) was calculated using the formula, F = Z – M.

Probability of capture can be estimated by backward projection of the number that would be expected if no selectivity had taken place.

Equation: $N_{i-1} = N_i' \times \text{EXP} (Z\Delta t_i)$.

Where, N_i = Terminal population, N' = Number of fish under the length groups that not recruited under gear, Δt_i = The time needed for the fish to grow

through length class i, $Z = (Z_i+Z_{i+1})/2, Z_i = M + F_i, F_{i-1} = F_i - X$, $X = F/$(No. of classes below P_1+1), and P = The first length group with a probability of capture equal to 1.0 and whose lower limit is an estimate of L'.

The extrapolation points will be used to approximate the probability of capture.

The recruitment pattern was derived using the program of Gyanilo *et al.* (1989).

The exploitation ratio, E was estimated as: $E = F/Z = F/(F+M)$. Length at first capture (L_c or L_{50}) was estimated following Pauly (1984).

The probabilities of capture by length (Pauly 1984) were estimated by calculating the ration between the points of extrapolated descending arm and the corresponding ascending arm of the length converted catch curve. Relative yield-per-recruit (Y/R) and biomass-per-recruit (B/R) were obtained from the estimated growth parameters and probabilities of capture by length (Pauly and Soriano 1986). The relative yield per recruit (Y'/R) **was predicted by considering Y'/R as a function of U, E and M/K by employing Beverton and Holt Y'/R** analysis (knife edge) in the FiSAT II package. The relative yield per recruit equation which gives a quantity proportional to Y'/R was derived from the method of Beverton and Holt (1956, 1957, 1966) through a number of algebraic manipulations. The predicted values were obtained by substituting the input parameters of $Lc/L\infty$ (Lc is the minimum length captured; obtained from the extrapolation of length converted catch curve) and M/K in the FiSAT II package, and according to the model.

RESULTS AND DISCUSSION

Asymptotic length ($L\infty$) and growth coefficient (K): The growth parameters asymptotic length or $L\infty$ and growth coefficient or K of von Bertalanffy growth formula was estimated to be 31.4 cm and 1.0/year, respectively (Fig. 1). The estimated (through ELEFAN-I) correlation co-efficient (R^2) (ESP/ASP) was 0.171. The computed growth curves produced for *R. corsula* with those parameters are shown over its restructured length distribution in Fig. 1. The corresponding estimates of $L\infty$ and Z/K for this fish were 31.99 and 3.714, respectively using Powell-Wetherall Plot (Fig. 2). For regression, the r^2 was 0.99, a and b values were 6.79 and −0.212 respectively. This additional estimate of $L\infty$ was found to be slightly higher than the $L\infty$ estimated by ELEFAN I. The growth performance index ($\phi' = 2.99$) of *R. corsula* in the Sitakunda coast of the Bay of Bengal was found to be moderate.

No study on the VBGF growth parameters of *R. corsula*, based on ELEFAN, was found. But Fatima (1991) determined the VBGF growth parameters of

R. corsula by scale method and estimated asymptotic length (L$_\infty$) as 33.125 cm and growth coefficient (K) as 0.5547/year. The asymptotic length (33.125 cm) recorded by Fatima (1991) was found to be a little bit higher than that of the present study (31.40 cm), however the K value was far less than that of the present study. For other mugil species like *Mugil cephalus*, Murugan *et al.* (2014) recorded L$_\infty$ as 51 cm (male) and 57 cm (female), and K values as 0.096/year (male) and 0.082/year (female) from Southern coast of India. For two different Mugil species of Egyptian water, *Liza carinata* and *L. aurata*, L$_\infty$ values were estimated to be 23.51 and 32.4 cm, respectively; whereas K values were 0.6 year^{-1} and 0.63/year, respectively (Mehanna 2004). Relatively high K and low L$_\infty$ values, typical of short-lived tropical fishes, was obtained for *R. corsula*. In this regard the studied fish (*R. corsula*) was a small sized fish (max. length 31.4 cm) thus K value (1.0/year) fitted well.
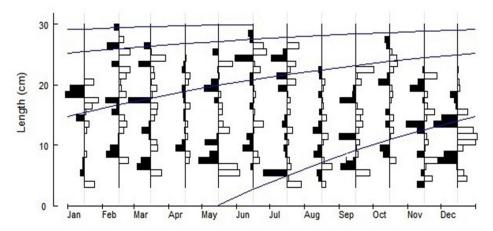

Fig. 1. Restructured length frequency histogram for *R. corsula* of the Sitakunda coast. L$_\infty$ = 31.4 cm, growth co-efficient (K) = 1.0, R^2 = 0.171, peak spawning during May, SS = 7, SL = 5.0 cm, May, Age 3$^+$ years.

Mortality: Natural mortality (M), fishing mortality (F) and total mortality (Z) were estimated to be 1.73, 1.20 and 2.93, respectively for *R. corsula*. Fig. 3 shows the length converted catch curve utilized in the estimation of Z. The dark circles represent the points used in calculating Z through least square linear regression. The blank circles represent points either not fully recruited or nearing to L$_\infty$ hence discarded from calculation. Good fit to the descending right hand limits of the catch curve was considered. For regression, the r^2 was 0.995, a and b values were 8.815 and −2.934, respectively (Fig. 3). In mugil species, *L. carinata* the M, F and Z values were found to be 0.96, 3.24 and 4.2 and in *L. aurata* 0.96, 1.95 and 2.91, respectively; whereas the M, F and Z values in *L. ramada* were recorded as 0.16, 1.06 and 1.22, respectively from Egypt (Mehanna

2006). In *M. cephalus* from northarn Siani of Egypt M, F and Z values were recorded as 0.66, 1.07 and 1.73, respectively (Mehanna and Hegazi 2013). All the estimated M, F, and Z values were recorded for different mugil species, so comparison was not possible. However, in the present study natural mortality was found to be a little bit higher than that of the fishing mortality, which disagreed with the findings of different Egyptian mugil species where fishing mortality was always higher than the natural mortality. It might be due to under fishing or sustainable fishing (E = 0.41) in case of *M. corsula* in the coastal water of Bangladesh and over fishing in case of different mugil species in Egyptian waters. It indicated that *R. corsula* might not be overfished in the Sitakunda coast of the Bay of Bengal but the above mentioned mugil species from Egyptian waters might be overfished.
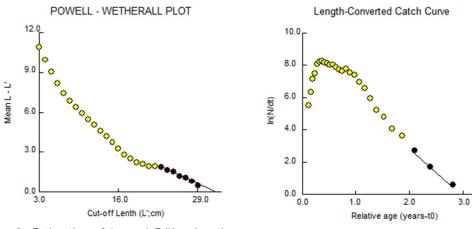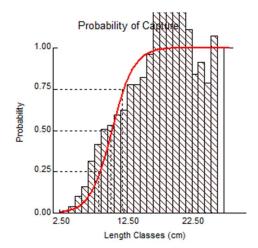

Fig. 2. Estimation of L_∞ and Z/K using the method of Powell-Wetherall (R^2 = 0.99, a= 6.79, b= −0.212).

Fig. 3. Length converted catch curve of *R. corsula* for all length groups. Z = 2.93, M =1.73, F =1.20 and E = 0.41.

Selection pattern/probability of capture: From selection pattern, L_{25}, L_{50} and L_{75} were found to be 8.61, 10.42 and 12.23 cm, respectively (Fig. 4). The length at first capture (L_c) was found to be 10.42 cm, which was reasonable harvestable size for this fish in the study area. L_c values of *L. carinata* and *L. aurata* (in two different mugil species) from Egyptian waters were found to be 13.6 and 18.28 cm, respectively (Mehanna 2004). The L_c values in different mugil species from different parts of Egypt were found to be 18.45 cm for *L. ramada* (Mehanna 2006) and 28 cm for *M. cephalus* (Mehanna and Hegazi 2013). As no works on *R. corsula* was found so comparison was not possible.

Recruitment pattern: Through the ELEFAN II analysis (Pauly and David 1981), with the separation of the normal distribution of the peaks by means of the NORMSEP program the recruitment pattern was determined which showed

two recruitment peaks (Fig. 5). The major peak occurred during June to December, whereas the minor or lean peak occurs during January to April (Fig. 5). Mehanna (2004) found one recruitment pulse for *L. aurata* and *L. carinata* in
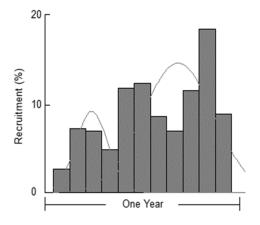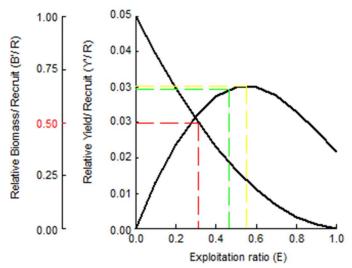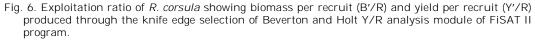

Fig. 4. Selection pattern (probability of capture) of *R. corsula* produced through length converted catch curve module. Selection patterns were L_{25} = 8.61 cm, L_{50} = 10.42 cm, L_{75} = 12.23 m.

Fig. 5. Recruitment pattern of *R. corsula* produced through recruitment pattern module of FiSAT II program.

Fig. 6. Exploitation ratio of *R. corsula* showing biomass per recruit (B′/R) and yield per recruit (Y′/R) produced through the knife edge selection of Beverton and Holt Y/R analysis module of FiSAT II program.

Egyptian waters. This pattern agrees with the findings of Fatema (1991) as she pointed out this fish as a prolonged breeder; but disagrees with the findings of Mehanna (2004) for different species of mugils in Egypt.

Exploitation ratio: The relative yield-per-recruit and biomass-per-recruit were determined as a function of Lc/L$_\infty$ and M/K, which were 0.751 and 1.731, respectively. The E$_{10}$ and E$_{50}$ and E-max were found to be 0.462, 0.321 and 0.55, respectively (Fig. 6) which showed that the present exploitation rate, E = 0.41 which does not exceed the E-max (0.55), indicated the fish was not over fished in the Sitakunda coast of Bay of Bengal as Gulland (1971) stated that E value above 0.5 indicates over fishing of a species in an area.

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