

Growth, Mortality Parameters and Exploitation Ratio of Deepflounder (*Pseudorhombus elevatus* Gilby, 1912) in Northwest of Persian Gulf (Khuzestan Coastal Waters, Iran)

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Abstract: Length composition data of Deep flounder (*Pseudorhombus elevatus*) landed between April 2009 to March 2011 in Coastal Waters of Iran (Persian Gulf) were monthly used to estimate the Population biology and assessment of the stock. The growth parameters of von Bertalanffy equation were as, L_{∞} : 42 cm and K : 1 per year and t_0 : -0.14 year, Φ' : 3.24 respectively. The estimated values of total mortality, natural mortality, fishing mortality and Exploitation ratio were Z : 4.65, M : 1.5, F : 3.15, E 0.68, respectively. Relative yield per recruitment (Y'/R): 0.031, relative biomass per recruitment, (B'/R): 0.11, fishing mortality maximum sustainable yield, F_{\max} : 0.88; Exploitation ratio maximum sustainable yield, E_{\max} : 0.48; precautionary average target ($F_{\text{opt}}=0.75 \text{ year}^{-1}$) and limit ($F_{\text{limit}}=0.99 \text{ year}^{-1}$) biological reference points for deep flounder stock was calculated. The results in this study showed exploitation ratio deep flounder stock is over fishing and decreases of exploitation ratio is proposed.

Key words: *Pseudorhombus elevatus* • Exploitation ratio • Persian Gulf

INTRODUCTION

The Persian Gulf is a semi-closed water body connected to the Oman Sea through Strait of Hormuz in which is restricted to 56 km at its narrowest point. The maximum width is 640 km with the average depth of 35 m [1]. The Persian Gulf is in the subtropical zone lying almost entirely between the latitudes of 24° and 30°N and longitudes of 49° to 61° 25'E.

The Deep flounder is a member of the family Paralichthyidae and widely distributed throughout the Indo-West Pacific, from the Red Sea and East Africa to Japan and New Caledonia [2, 3]. Adults are found in shallow coastal waters and the diet of this species consists of bottom-living animals. Consequently it is exploited throughout its range with a variety of gears, including trawls [2]. This species has a gonochoristic reproductive mode and spawning occurs annually with one clear seasonal peak during April to June [4].

Many of the demersal fish populations in the Persian Gulf have been heavily exploited and fishing effort may be above optimum levels for some species [5]. The lack of appropriate data on most stocks underscores the need to assess the regions fisheries resources. Nowadays, sustainable development and sustainable yield are essential factors in all different fields dealing with "production" such as fishing and fishery industry. To attain this aim is necessary to rationally manage marine resources for long-term sustainable and successful exploitation [6]. For this to be achieved it is essential to collect biological data and monitor the resources. The present study was undertaken to estimate the key parameters of stock assessment and population dynamics of *P. elevatus* such as asymptotic length (L_{∞}), growth coefficient (K), t_0 (zero), 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 fishery development in Iran.

MATERIALS AND METHODS

Length-frequency data of *P. elevatus* were collected monthly from the commercial catches in landing sites of Abadan and Hendigan, from April 2009 to March 2011 (Fig. 1). Random sampling was done 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 2 centimeter intervals. The data were analyzed using FiSAT II (FAO-ICLARM Stock Assessment Tools) as explained in details by Gayanilo *et al.* [7].

Growth was calculated by fitting the von Bertalanffy growth function to length frequency data. The von Bertalanffy growth equation is defined as follows [8]:

$$L_t = L_\infty [1 - \exp(-K(t - t_0))]$$

where L_t is length at time t , L_∞ 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 [9].

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

The fitting of the best growth curve was based on the ELEFAN I program [10], 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 deep flounder population in terms of length growth was computed using the index of Pauly and Munro [11].

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

The annual instantaneous rate of total mortality (Z) was obtained using length converted catchcurves adapted to incorporate seasonal growth patterns [12]. Pooled length frequency samples were converted into relative age frequency distribution using parameters of the von Bertalanffy growth function.

The annual instantaneous rate of natural mortality (M) was estimated by the empirical equation derived by Pauly's empirical relationship [13].

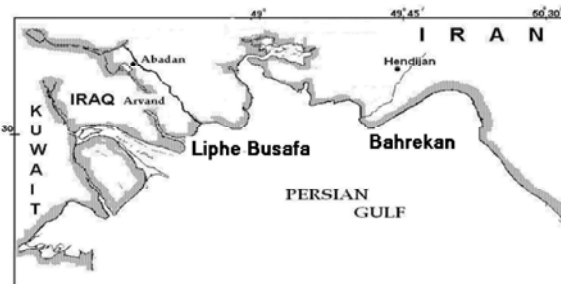


Fig. 1: Location of two landing sites of Deep flounder in Khuzestan Coastal Waters (Iran)

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

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

A selectivity curve was generated using least squares linear regression fitted to the ascending data points from a plot of the probability of capture against size, which was used to derive values of the sizes at capture at probabilities of 0.5 (L_{50}) and the size at which fish were fully recruited to the fishery (L_{100}).

Pauly and Soriano [14] 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 (L_{max}). Evaluations of resource status were made using estimates of exploitation rates associated with: (i) a marginal increase of relative yield per recruit which is 0.1 of its value at $E=0$ ($E_{0.1}$) (ii) maximum sustainable yield (E_{msy}). Fishing mortality rates associated with the point on the YPR curve where the marginal increase in relative yield per recruit was 0.1 of its value at the origin ($F_{0.1}$), and maximum yield (F_{max}) were derived from the YPR model for the various mean sizes at first capture (L_{50}), and 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 $F_{limit} = 2/3M$, respectively [15]. 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 [8].

RESULTS

Length Frequency Distribution: The total lengths of 369 fish were in 110 to 410mm range size (Table 1), using a meter scale ($2 \pm \text{mm}$). Major and minor range

Table 1: Average values (\pm SD) of size corresponding of Deep flounder in Khuzestan Coastal Waters (2009-2011)

Month	N	MeanW		MeanTL	
		\pm S.D (g)	Min-max	\pm S.D (mm)	Min- max
January	44	183 \pm 135	41-518	245 \pm 54	165-370
February	26	224 \pm 133	73-507	260 \pm 41	198-335
March	46	201 \pm 132	42-827	256 \pm 41	171-396
April	25	338 \pm 141	112-629	306 \pm 40	225-380
May	23	315 \pm 169	128-581	300 \pm 54	222-375
July	63	287 \pm 135	110-693	285 \pm 39	205-375
August	35	96 \pm 60	14-785	180 \pm 63	115-415
September	9	250 \pm 88	162-378	272 \pm 26	245-312
October	31	310 \pm 151	77-532	293 \pm 56	190-380
November	27	237 \pm 86	93-345	273 \pm 31	210-305
December	33	208 \pm 128	85-479	258 \pm 44	202-342
Average	-	150 \pm 238	14-827	57 \pm 264	115-415

length fishery was supporting in the 250-270 and 390-410mm range respectively. Length frequency percentage groups of *P. elevatus* during April 2009 to March 2011 are presented in Fig. 2.

Growth Studies: Growth parameters of von Bertalanffy growth formula for *P. elevatus* were as follows: $L_8 = 42$ cm and $K = 1 \text{ yr}^{-1}$ (Fig. 2). For these estimates through ELEFAN I the response surface (R_n) was 0.178 for the curve. The growth curves produced with those parameters are shown over its restructured length distribution in Fig. 3. The Φ' and t_0 was found to be 3.24 and -0.14 year respectively.

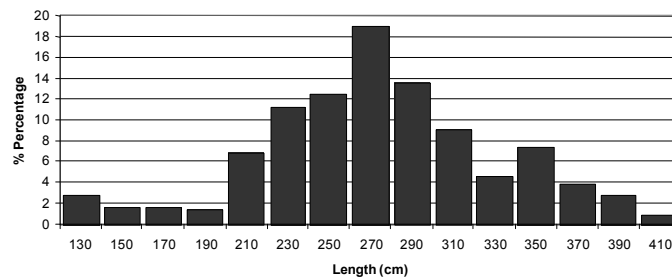


Fig. 2: Percentage frequency length of *P. elevatus* in Coastal Waters of Iran during 2009-2011

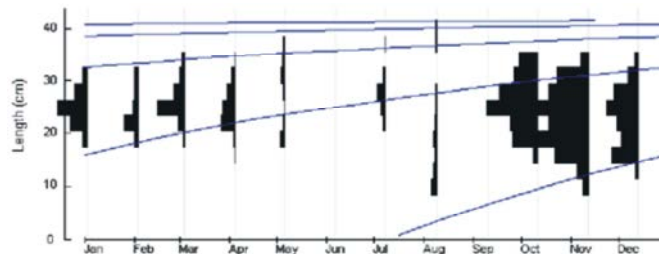


Fig. 3: Growth curve of *P. elevatus* from Iran by ELEFAN I superimposed on the restructured length-frequency diagram ($L_8 = 42$ cm and $K = 1 \text{ yr}^{-1}$)

Mortality Estimate: The mortality rates M and Z computed were 1.5 and 4.65 respectively. Fig. 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_8 . 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 3.15 yr^{-1} .

Exploitation Rate: The rate of exploitation (E) was estimated at 0.68. The higher value of E is indicated over fishing during that period. 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 21.30 and 28.5 cm (TL), respectively. Fish were recruited to the fishery at a mean size of $L_{50} = 21.30$ cm.

Value L_c/L_8 and M/K were 0.51 and 1.5 respectively (Fig. 5). Relative yield per recruitment (Y'/R): 0.031, relative biomass per recruitment, (B'/R): 0.11, fishing mortality maximum sustainable yield, F_{max} : 0.88; Exploitation ratio maximum sustainable yield, E_{max} : 0.48; precautionary average target ($F_{opt} = 0.75 \text{ year}^{-1}$) and limit ($F_{limit} = 0.99 \text{ year}^{-1}$) biological reference points for deep flounder stock was calculated.

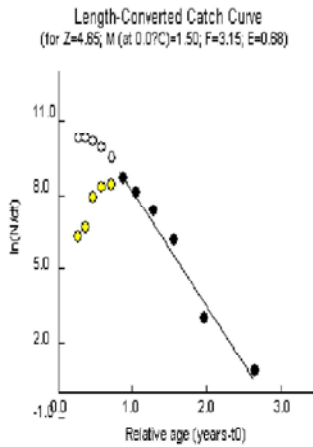


Fig. 4: Length converted catch curve of *P. elevatus* during 2009-2011

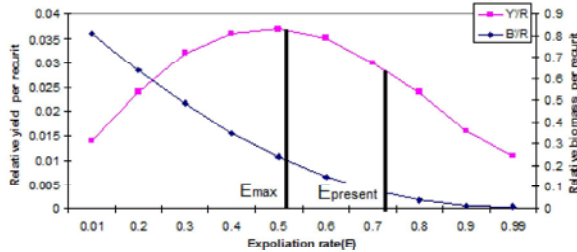


Fig. 5: Relative yield-per-recruit and Relative biomass-per-recruit showing the existing exploitation rate (E) *P. elevatus* during 2009-2011

DISCUSSION

The values of L_8 and K were calculated as 42cm and 1 (year^{-1}). L_8 and K of deep flounder were calculated in Kuwait waters for both male and female, L_8 (44) and K (0.16). These parameters reported in Khuzestan by Mohamadi and Khodadadi [16] (41.9,0.2) for *Euryglossaorientalis*.

Differences between L_8 and K is influenced by ecological characteristics, population size and gene frequency of species considering their habitat and regarding natural selection, appear different adaptation patterns were seen their life [17]. L_8 and K amounts have reverse correlation and with decrement L_8 , amount of K increases and vice versa [8]. Differences in growth rates between regions indicated a stock separation which has, in some cases, supported a genetic difference [18].

Φ' was estimated 3.24 and 2.49 reported in others researches in Kuwait waters. In general, the correlated parametric values adjust themselves to provide a similar growth pattern represented by Φ' [8]. Age at zero length (t_0) was as -0.14 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 [8].

In this study exploitation coefficient was more than 0.5 and fishing mortality was more than natural mortality. The fishing mortality rate of 3.15 year^{-1} was substantially greater than both the target ($F_{\text{opt}} = 0.75 \text{ year}^{-1}$) and limit ($F_{\text{limit}} = 0.99 \text{ year}^{-1}$) biological reference points. In Khuzestan area (Iran) for *Euryglossaorientalis* M , F and Z were 0.67, 0.58 and 1.19 respectively [19]. This result clearly indicates growth over fishing for both species and, in combination with the results of the yield-per-recruit analyses, demonstrates that effort reductions are also required in the fishery because target reference points cannot be achieved by modification of the gear-selectivity characteristics alone.

Reliable estimate of M can only be obtained for an unexploited stock [20]. Errors in estimates of the natural mortality rates (M) from the empirically derived formula of Pauly [13] may have occurred as the relationship has tended to overestimate M , especially for slow growing species [21].

The relative biomass per recruit of *P. elevatus* at the estimated fishing mortality rates was particularly low at less than 30% of unexploited levels. If the critical spawning stock biomass is between 20% and 50% of the unexploited levels, as suggested by King [22], recruitment over fishing is likely to be occurring for this species.

Because the size at first capture was smaller than the size at which yield per recruit would be maximized (21.3 cm) and mean size at first sexual maturity (237 mm) for *P. Elevatus* [23], an increase in the mesh size for the trap fishery should be considered by management authorities especially given the high rate of juvenile retention for this species.

At the existing exploitation rate and size at first capture Deep flounder, is being growth over-fished, where the fishing mortality is in excess of that which is required to maximize the yield per recruit. An increase in the mean size at first capture to that which would maximize yield per recruit was predicted to increase yields and the standing stock biomass by an order of magnitude. Furthermore, because of the increase in sustainable yields at this mean size at first capture, the stock would not be growth over-fished at the existing rate of fishing mortality.

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 [15] 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.

Life history characteristics can be used to classify the vulnerability of a species to fishing pressure and the level of productivity within a population [24]. The growth, mortality estimates derived here suggest that P. elevatus has a high resilience to exploitation.

CONCLUSIONS

Considering E, Y/R and B/R values it can be concluded that catch rate and fishing mortality are more than maximum sustainable yield of Deep flounder. 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 impose immediate fishing regulation on the stock and this can be done by gradual 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 and spawning time.

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