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Population parameters of thinspine sea catfish *Plicofollis tenuispinis* (Day, 1877) (Pisces: Actinopterygii) in the north-western Persian Gulf off Khuzestan, Iran

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ABSTRACT

Length composition data of thinspine sea catfish, *Plicofollis tenuispinis* (Day, 1877), landed between April 2009 and March 2011, off Persian Gulf along the coast of Iran, were used to estimate the population parameters and to assess the stock of the species. Based on length frequency analysis, growth parameters of von Bertalanffy equation were calculated as L_∞= 58 cm; K= 0.22 yr^{-1}; t_0= -0.63 year for *P. tenuispinis*. The estimated total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate (E) were 1.97, 0.5, 1.47, and 0.75, respectively. Relative yield per recruitment (Y'/R) of 0.010, relative biomass per recruitment (B'/R) 0.1, maximum sustainable yield (MSY) 0.88, exploitation rate at maximum sustainable yield (E_{max}) 0.45, precautionary average target (F_{opt}) of 0.25 and its limit (F_{limit}) of 0.33 were estimated for the local stock of thinspine sea catfish. The results of this study indicated that the thinspine sea catfish stock is overfished and exploitation rates should be regulated.

Keywords: Assessment, Persian Gulf, Population biology, Thinspine sea catfish

Introduction

The Persian Gulf (25°-32° N; 48°-56° E) harbours some of the world's richest fishery resources (Hashemi *et al.,* 2011). For a given species, level of fishing effort should be regulated at a sustainable level where a balance between the mortality as a biomass reducing factor and reproduction as well as growth, as increasing factors is held (Jennings *et al.*, 2000). Ariid catfishes are generally marine, but some freshwater and brackishwater species are also known. They are found in shallow, temperate and tropical seas around the coastlines of North and South America, Africa, Asia and Australia and are reported to be absent from Europe and Antarctica (Nelson, 2006). The thinspine sea catfish, *Plicofollis tenuispinis* (Day, 1877) occupies coastal waters up to about 50 m depth (Fischer *et al.,* 1990). The total global catch of thinspine sea catfish has decreased dramatically since the last decade. The main objective of this study was to estimate the biological reference points and other population parameters of *P. tenuispinis* required for sustainable management of the resource.

Materials and methods

The two main fishing areas of *P. tenuispinis* in the north-west of Persian Gulf located in Liphe-Busafe and Bahrekan fishing zones between 29° 44' to 29° 07' N and 48° 45' to 49° 50' N (Fig. 1) were selected for sample collection.

During the study, a total of 439 individuals were sampled from bottom trawl/gillnet catches during April 2009 to March 2011 on a monthly basis. Individual weight and length (total length, TL) measurements were recorded for all the sampled fish and the data were then pooled from the two landing sites and subsequently grouped into classes of 4 cm intervals. The length frequency data obtained were then analysed using FiSAT II (FAO-ICLARM Stock Assessment Tools) according

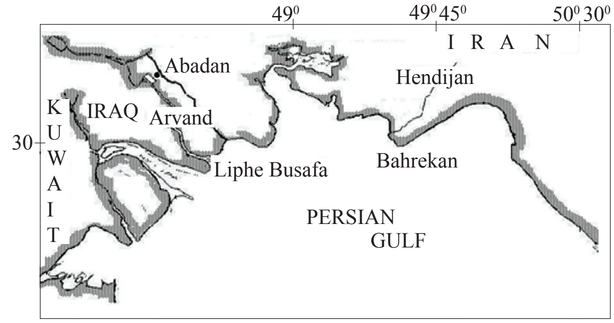

Fig. 1. Location of the two landing sites of thinspine sea catfish in the north-western Persian Gulf (Iran)

to Gayanilo *et al*. (1996) and the best fit growth curve was selected using ELEFAN I (Pauly and David, 1981) software. The growth constant (K) and asymptotic length (L_∞) were then calculated and the growth rate was formulated by fitting the von Bertalanffy growth function to length frequency data (Sparre and Venema, 1998):

$$L_t = L_\infty [(1-\exp(-K^{(t-t0)})] \quad (1)$$

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

The t_0 value was calculated using the empirical equation of Pauly (1979):

$$Log_{10}(-t_0) = -0.3922 - 0.2752\ Log_{10}(L_\infty) - 1.038\ Log_{10}(K) \quad (2)$$

The growth performance of *P. tenuispinis* population in terms of increase in total length was computed using the growth index (Φ′) of Pauly and Munro (1984):

$$(\Phi) = Log_{10} K + 2\ Log_{10}(L_\infty) \quad (3)$$

The total mortality coefficient was estimated by length converted catch curve of Pauly (1980):

$$Ln\left(\frac{N}{\Delta t}\right) = a + b \times t \quad (4)$$

Where, b = Z with the sign changed.

The natural mortality rate (M) was calculated using 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_∞ is expressed in cm and T is the mean annual seawater temperature (~26°C)

Fishing mortality (F) was calculated by subtracting M from total mortality (Z) and exploitation rate (E) was obtained by dividing F by Z.

Relative yield per recruit (Y/R) and relative biomass per recruit (B/R) values (as a function of exploitation rate) were determined from the estimated growth parameters and probability of capture by length (Pauly and Soriano, 1986).

The backwards extrapolation routine of the length converted catch curve was used to estimate probability of capture. A selectivity curve was then 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 50% capture probability (L_{50}) and the size at which fish were fully recruited to the fishery (L_{100}). The annual instantaneous rate of total mortality was also estimated using the length converted catch curve method of Pauly (1983). Pooled length frequency samples were converted into relative age frequency distributions using parameters of the von Bertalanffy growth function. Relative yield and biomass–per-recruit analyses were conducted using growth and mortality parameters and selectivity of gear derived from probability of capture data. The Beverton and Holt (1966) yield per recruit (YPR) model modified by 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 maximised (L_{max}). Fishing mortality rates associated with the point on the YPR curve, where the marginal increase in relative yield per recruit was maximum yield (F_{max}) were derived from the YPR model for the various mean sizes at first capture (L_{50} and L_{max}). Evaluations of resource status were made using estimates of exploitation rates associated with a marginal increase of relative yield per recruit which is of its value at maximum sustainable yield (E_{max}). Precautionary target and limit biological reference points were set to F_{opt} = 0.5 and F_{limit} = 2/3 M, respectively (Patterson, 1992).

Results

During the study, 439 thinspine sea catfish (*P. tenuispinis*) comprising 42 males, 96 females and 301 immature fishes were analysed and their total length (TL) and weight were measured. The estimated mean, maximum and minimum total length (TL) were 231±79 mm, 470 mm and 79 mm, respectively. The estimated mean, maximum and minimum total weight were 173±133 g, 1385 g and 14 g, respectively.

Growth studies

Using the best fit given by ELEFAN I, population parameters for *P. tenuispinis* were calculated as: L_∞= 58 cm; K= 0.22 yr^{-1}; t_0= -0.63 (Fig. 2).

Considering the value of growth performance index (Φ') = 2.86, the von Bertalanffy growth equation for this species was formulated as: L_t= 58(1- exp (-0.22 $^{(t+0.63)}$).

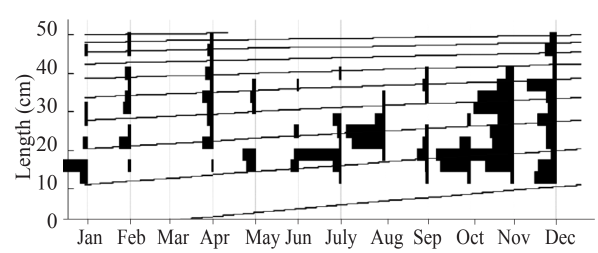

Fig. 2. Growth curve of thinspine sea catfish off north-western Perrsian Gulf, by ELEFAN I superimposed on the restructured length frequency diagram (L_∞ = 58 cm; K = 0.22 yr^{-1}).

Mortality estimates, relative yield, relative biomass per recruit

The estimated value of total mortality, natural mortality, fishing mortality and exploitation rate (males and females combined) were Z = 1.97, M= 0.5, F = 1.47, and E = 0.75 respectively (Fig. 3).

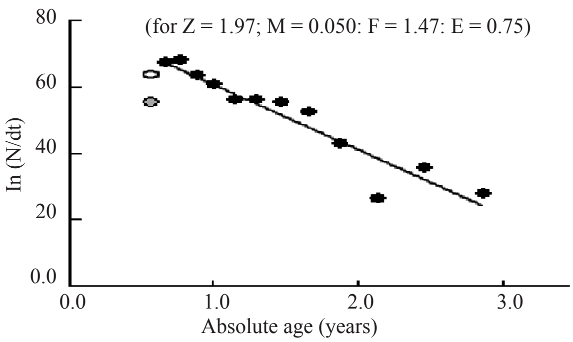

Fig. 3. Length converted catch curve of thinspine sea catfish off north-western Perrsian Gulf during 2009-11.

Fishery assessment

The relative yield per recruit (Y'/R) and biomass per recruit (B'/R) were determined as a function of L_c/L_∞ and M/K. With computed L_c values of 11.5 cm, the resultant L_c/L_∞ and M/K values were 0.13 and 2.27, respectively. Relative yield per recruitment (Y'/R) of 0.01, and relative biomass per recruit (B'/R) of 0.10 were obtained for thinspine sea catfish stock (Fig. 4). The size at which yield per recruit would be maximised (L_{max} = 16.1 cm) approximated the mean size of the fish that were 0.32 years old which was considerably greater than the mean size at first capture. The yield per recruit function predicted that an increase in the size at first capture to L_{max} would be associated with a substantial increase in yield at the current level of exploitation, despite the high level of fishing mortality. The relative biomass per recruit at the current exploitation rate was less than 13% of the theoretical unexploited level. An increase in the mean size at first capture to that which would maximise yield per recruit was predicted to be associated with a small increase in biomass per recruit. Maximum sustainable yield (MSY) of 0.88, exploitation rate at maximum sustainable yield (E_{max}) of 0.45, precautionary average target (F_{opt}) of 0.25 and limit (F_{limit}) of 0.33 were set as biological reference points for *P. tenuispinis* stock.

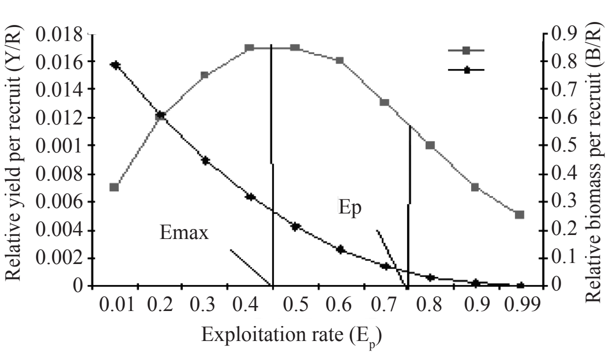

Fig. 4. Relative yield per recruit and relative biomass per recruit showing the existing exploitation rate (E_p) and exploitation rate at maximum sustainable yield (E_{max}) for thinspine sea catfish during 2009-11.

Discussion

In general, our results can be considered as mean annual values for the species since the fish samples were collected during different seasons throughout the sampling period, and the data do not represent a particular season or time of the year. Talwar and Jhingran (1989) estimated L_∞ and growth coefficient of thinspine sea catfish as 82 cm and 0.21 yr^{-1} in the Indian Ocean. L_∞ and K values of thinspine sea catfish estimated in the present study are comparatively lower. Unfortunately, no references from other studies for L_∞ and K are available for this species. Parsamanesh *et al.* (1996) estimated L_∞ and K as 91 cm and 0.11 yr^{-1} for *Arius thalassinus* in north-west of Persian Gulf (Khuzestan Coastal Waters, Iran). Observed differences in our comparisons may be due to the different sampling methods (bottom trawls and gillnets *vs.* traps), seasonal variability of the environment, food availability, sampling size or habitat suitability (Nieto-Navarro *et al.,* 2010). This difference is perhaps a manifestation of the observation that similar species experience different growth rates in different habitats (Merron and Bruton, 1988). Age at zero length (t_0) was calculated as -0.18 for this species in Indian waters (Talwar and Jhingran, 1989). 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 (King, 2007).

Value of Φ' reported for *P. tenuispinis* in Indian waters was 3.51 (Talwar and Jhingran, 1989). The estimate obtained in our study was 2.87. A method of validating growth parameters involves the comparison of growth performance indices (Φ') in terms of growth in length with other estimates obtained for the same or a similar species (Gayanilo and Pauly, 1997).

The estimated mean exploitation rates from the length cohort analysis (LCA) for this species is greater than 0.5, which suggests that the stocks are over-exploited. It is possible that the Z for this species might have been underestimated by the length converted catch curve, which would then result in higher E estimates. Moreover, several other factors that can affect Z are variation in lengths of fish of the same cohort, gear selectivity, emigration and immigration of the species when they meet stationary nets (Gabache and Hockey, 1995), which were not accounted for in this study.

The current fishing mortality rate (1.47) is greater than that which would maximise yield per recruit (F_{max} = 0.88) at the existing size at first capture, which clearly demonstrates that growth overfishing is occurring for this species. The fishing mortality rate of 1.47 was substantially greater than both the target (F_{opt} = 0.25) and limit (F_{limit} = 0.33) biological reference points. The results of our study clearly indicates that the resource is overexploited and management options including mesh size regulations and substantial reduction in fishing effort need to be implemented.

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