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Stock Characteristics and Population Dynamics of the Spiny Cheek Grouper *Epinephelus diacanthus* (Valenciennes, 1828) from the Arabian Sea, Oman

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Abstract

Based on samples of *Epinephelus diacanthus* (Family: Serranidae; subfamily: Epinephelinae) collected from the Omani coast of the Arabian Sea, age and growth, mortality and exploitation rates and yield per recruit were studied. A total of 703 fish with total lengths ranging from 16.1 to 55.6 cm were used. Age determination was carried out by examining the growth increment on both the whole otoliths and the sectioned ones. The von Bertalanffy growth parameters, the instantaneous annual rates of total, natural and fishing mortalities, length at first capture and the exploitation rate were estimated. Based on these data, a yield and biomass model was applied. The results indicated that the stock of *E. diacanthus* in the Arabian Sea is over-exploited and current management measures must be revised to sustain and optimize its yields.

Keywords: Arabian Sea*; Epinephelus diacanthus*, age and growth, population dynamics, management.

Introduction

Family Serranidae which are commonly known as groupers, rockcods and hinds, contains more than 400 species which are widely distributed in tropical and subtropical areas allover the world. The serranid subfamily Epinephelinae comprises about 159 species in 15 genera (Heemstra and Randall, 1993). The genus *Epinephelus* comprises 98 species from which 20 species are known from Omani waters (Randall, 1995).

Groupers constitute one of the important demersal resources off Oman Coast. They contributed to 11% of the demersal fish species landings with an annual average catch of about 5,000 ton during the period from 2002 to 2011 achieving more than 6 million Omani Riyal (OR ≈ 2.6 $). In Oman, groupers are exploited by both the artisanal and industrial fisheries, but the main catch comes from the artisanal one (98%) (Anonymous, 2011).

The high price of groupers and strong demand in local and export markets make them a target for an intensive fishing. The increasing fishing effort and uncontrolled exporting policy had already affected the total production of groupers and made some target species like *Epinephelus diacanthus* decreased in the catch.

Spiny cheek grouper, *E. diacanthus* is an Indian Ocean species distributed on the continental shelf of the northern Indian Ocean from the Gulf of Aden to Sri Lanka and India (Heemstra and Randall, 1993). It is a demersal species mostly found on depth range of 10-300 m and sometimes reaching 500 m (James *et al.*, 1996). *E. diacanthus* feeds on crustaceans mainly crabs and small prawns and fishes mainly *Ambassis* spp. and *Leiognathus* spp. (Zacharia *et al*., 1995a).

Although groupers are one of the most important components of the artisanal fishery and are wide spread in the area, very few authors investigated their biology in the region (McIlwain *et al*., 2003; Al-Marzouqi *et al*., 2012). On the other hand, detailed studies on the age, growth, reproduction, stock assessment and fishery are available from Indian waters (Chakraborty, 1994; Chakraborty and Vidyasagar, 1996; Chakraborty *et al*., 2005; Chen *et al*., 1980a, 1980b; Manojkumar, 2005; Rao and Krishnan, 2009; Sivakami and Seetha, 2006; Zacharia *et al*., 1995b).

The present study was undertaken to estimate the basic parameters required for assessing the status of *Epinephelus diacanthus* stock in the Arabian Sea and to provide information needed for management purposes for this valuable resource.

Materials and Methods

Collection of Samples

Fish samples of *E. diacanthus* were collected from the Oman coast of the Arabian Sea from September 2007 to September 2008 during five demersal surveys (Fish Resources Assessment Survey of the Arabian Sea Coast of Oman Project). These surveys covered the area between Ras Al-Hadd in the north and the Omani Yemeni border in the south between depths of 20 to 250 m (Figure 1). The surveys were with an average duration of 47 days and carried out using RV Al Mustaqila I. RV Al Mustaqila I is of 47 m length overall, has a beam of 12.5 m, horsepower of 3602 and a displacement of 1745 ton. All tows were carried out during daylight hours, and for each station, the trawl target distance of 2 nm at speed over the ground of 3.5 knots. The trawl net used was 35 m long headline and 38 m long ground line. The cod-end with a nominal inside mesh measurement of 40 mm and included an extension section to match with the back end of the trawl and ensure correct filtration. In untrawlable areas, fish traps were used. These traps are of Omani style with diameter of 2 m, high of 1.03 m, a single opening of 0.68 X 0.56 m and a mesh size of 98 mm. The traps are strengthened with 0.5 inch iron bars and weighed with two 5 Kg weights per trap. The total length to the nearest millimeter and total weight to the nearest 0.1 gram were measured. Sex and otoliths were taken for each specimen.

Age Determination

Both whole and sectioned otoliths were used for age determination of *E. diacanthus*. Annual rings on the whole otolith were identified and counted using optical system consisting of Zeiss research microscope at 4× and 10× magnifications connected to AxioCam HRC and Ziess KL 1500 LCD using transmitted light. For otolith sectioning, the left otolith was embedded in clear epoxy resin and sectioned using a Buehler Isomet low-speed saw containing a diamond wafering blade which cuts a thin section (300 µm) through the nucleus. A grinding wheel fitted with silicon carbide paper with different grit sizes (400 to 1200 grit) flushed with water was used to remove excess resin on the face of the sections and to provide a polished face for viewing. The section is then mounted on a glass slide and read under a Zeiss compound microscope equipped with zoom lens and (magnification up to 60×) using transmitted light.

The total otolith radius and the radius of each annulus were measured to the nearest 0.001 mm. The total radius of each otolith was plotted against the total fish length to determine the body length-otolith radius relationship. The total lengths of the previous ages were back-calculated using Lee's (1920) equation.

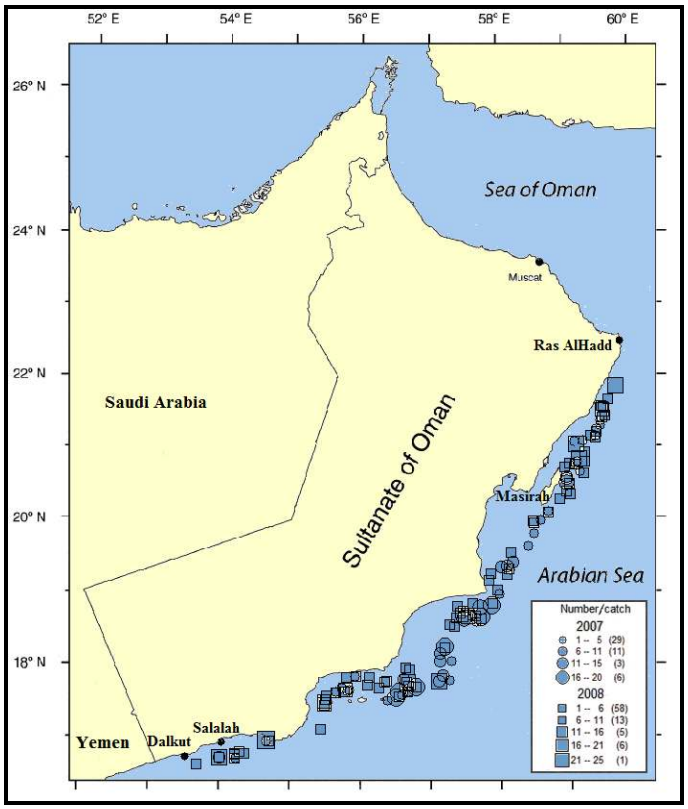

Figure 1. Distribution of *Epinephelus diacanthus* in the Arabian Sea during the survey Age determination.

Growth Parameters

The back-calculated lengths were applied to a Ford (1933) and Walford (1946) plot to estimate the von Bertalanffy growth parameters (L_∞ and K). While the growth performance index (ø') was estimated using the formula of Pauly and Munro (1984) as

$$ø' = \log K + 2 \log L_\infty.$$

Mortality and Exploitation Rates

The total mortality coefficient (Z) was estimated using the Linearized catch curve of Pauly (1983). Natural mortality coefficient (M) was estimated as the geometric mean for three methods; Ursin (1967) method which is expressed as $M = W^{-1/3}$ where W is the total weight of fish, Pauly's (1980) formula and Hoenig's (1983) equation as Ln (M) = 1.44-0.982*Ln (t_{max}) where t_{max} is the maximum observed age.

Fishing mortality coefficient (F) was estimated as Z-M while the exploitation ratio (E) was computed using the formula of Gulland (1971) as E = F/Z.

Length at First Capture

The length at first capture (L_c) was estimated by the analysis of catch curve using the method of Pauly (1984).

Per-Recruit Analysis

Relative yield per recruit Y'/R and relative biomass per recruit B'/R were estimated using the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986).

Results and Discussion

Age and Growth

Age and growth of fishes are of vital importance in the field of fisheries management. Information on age, growth parameters and mortality rates are the basic input data into the analytical models which used in assessing the status of the exploited fish stocks and consequently managing of these resources.

Otoliths were found to be a reliable and valid method for ageing *E. diacanthus* from Omani coast of the Arabian Sea (Figure 2). Body length-otolith radius relationship showed a strong correlation between the body length and otolith radius (Figure 3). Also, back-calculated lengths are in accordance with the observed lengths for the different age groups. On the other hand, whole otolith readings were 92% in agreement with sectioned otoliths readings and the number of annuli counted for each individual was similar for the two readings and there was a high congruence (93%) between the age estimations from the two methods.

The oldest fish of *E. diacanthus* examined was 9

Figure 2. Section and whole otolith for *Epinephelus diacanthus* of 47.6 cm TL.

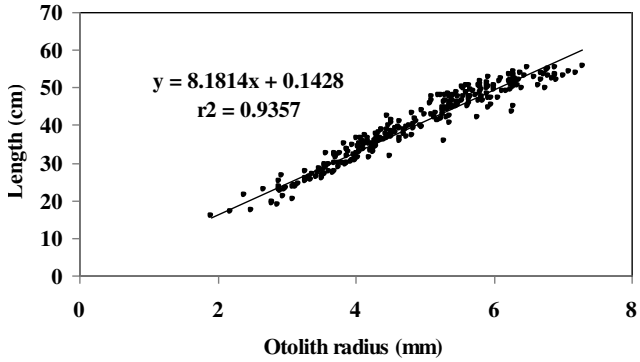

Figure 3. Total length-otolith radius relationship for *Epinephelus diacanthus.*

years old. The back-calculated lengths at the end of each year of life were 21.52, 28.86, 35.09, 41.15, 45.42, 48.83, 50.84, 52.54 and 54.09 cm TL for age groups from 1 to 9 respectively.

Age readings indicated that *E. diacanthus* attains its highest growth rate in length during the first year of life, after which a gradual decrease in growth increment was observed with further increase in age. From age-length data, it was found the most frequent age groups in the catch the age group I and II where they contributed by 21 and 24% respectively.

The present age and length data are lower than those reported in the previous studies on the age and growth of *E. diacanthus*. Chakraborty (1994) stated that this species in Bombay waters grows to 22.9, 35.4, 42.1, 45.8 and 47.8 cm at the end of I-V years. The largest specimen observed by him from Bombay waters was 47.8 cm. Manojkumar (2005) gave higher values for length by age as 24.4, 37.2, 43.9, 47.4 and 49.2 cm at the completion of 1 to 5 years respectively. The difference here may be due to the method used, while they used length frequency analysis we used the otolith readings and back-calculated lengths.

Growth Parameters

The von Bertalanffy (Figure 4) growth parameters estimated using the back-calculations from otolith reading method were L_∞ = 61.0 cm, W_∞ = 3183.8 g, K= 0.22 year^{-1} and t_o = -0.99 year. These values of growth parameters more or less similar to those estimated for the same species in different areas (Table 1).

Growth Performance Index

The growth performance index (ø') of *E. diacanthus* from the Arabian Sea was estimated as 2.87. The ø' value obtained was consistent with other estimates (Table 1). The difference in growth parameters and growth performance index between the different localities can be attributed to the difference in size-composition among species and to the method of analysis.

Mortality and Exploitation Rates

The values estimated for total, natural and fishing mortality coefficients were 0. 86, 0.37 and 0.49 year^{-1}, respectively. Exploitation ratio "E" was computed as 0.57 per year which was higher than the optimum one (0.5 as in Gulland, 1971 and 0.4 as in Pauly, 1987). This high value indicates that the stock of *E. diacanthus* in the Arabian Sea is overexploited.

Length at First Capture

The length at first capture (the length at which 50% of the fish is retained by the gear and 50% escape) was estimated as 21. 8 cm which is

Figure 4. von Bertalanffy plot for *Epinephelus diacanthus.*

Table 1. Growth parameters (L_∞ and K) and growth performance index (ø') of *Epinephelus diacanthus* from different localities

Locality	L_∞	K	Ø'	Author
Yemen	57.0	0.21	2.83	Edwards and Shaher, 1991
Bombay, India	50.2	0.61	3.19*	Chakraborty, 1994
Bombay, India	49.4	0.59	3.16*	Chakraborty and Vidyasagar, 1996
India	55.8	0.60	3.29	Chakraborty *et al*., 2005
India	51.2	0.65	3.23*	Manojkumar, 2005
Arabian Sea, Oman	61.0	0.22	2.91	The present study

*The Ø' value was estimated by the present authors

corresponded to an age of one year (Figure 5). Also, $L_{75\%}$ (the length at which 75% of the fish is retained in the gear) was estimated as 26.04 cm (1.8 year).

The length at first capture was smaller than length at first maturity for this species as recorded in Fishbase (28.1 cm TL). Therefore, the mesh sizes used should be increased to catch fish of about at least 30 cm length. This means that the exploited *E. diacanthus* must be protected till in order to share at least once in the spawning activity.

Per-Recruit Analysis

The relative yield-per-recruit Y'/R and relative biomass-per-recruit B'/R of *E. diacanthus* from the Arabian Sea were estimated (Figure 6). The results show that the maximum Y'/R was obtained at E= 0.57 which equals the present value. As the exploitation rate increases beyond this value, Y'/R decreased. Also $E_{0.5}$, the exploitation level which maintains the spawning stock biomass at 50% of the virgin spawning biomass was estimated. The $E_{0.5}$ estimate was 0.32 which was greatly lower than the current one.

Conclusion

The grouper catch in the Arabian Sea coast of Oman showed a decreasing trend in the last three years and some serranid species became rare in the catch from them the *E. diacanthus* (personal observation in the landing sites). The results proved that the stock of *E. diacanthus* from Arabian Sea was overexploited and may not be reproductively resilient enough to recover from declined populations. For its management, the current exploitation rate must be reduced from 0.57 to 0.32 (43.8%) to maintain a sufficient spawning biomass as well as the length at first capture should be raised from 21.8 to about 30 cm (> recorded length at first maturity) to give each

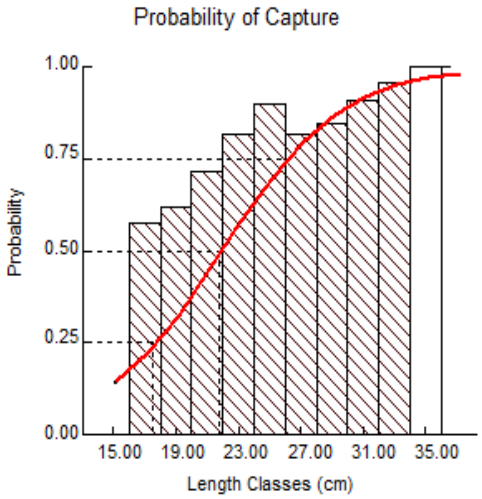

Figure 5. Probability of capture curve for *Epinephelus diacanthus.*

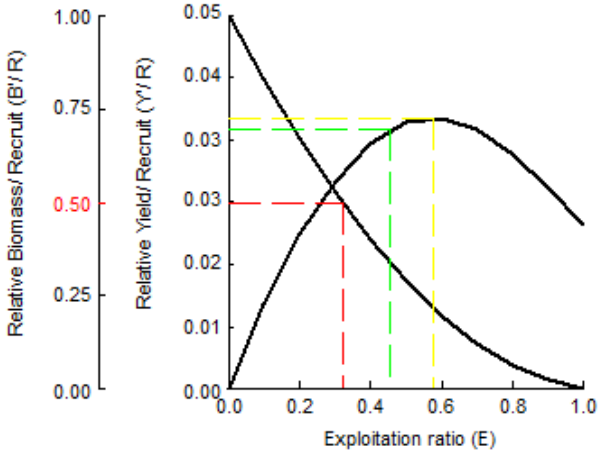

Figure 6. Relative yield per recruit analysis for *Epinephelus diacanthus.*

fish the chance to reproduce at least once in its life span. Also, there is a need to identify and protect the nursery grounds through establishing Marine Protected Areas (MPAs). Besides, it is of great importance to improve the fishery statistics recording system to involve the catch by species especially for those species that have economic importance to Oman.

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