

## RESEARCH ARTICLE

### **Population Dynamics and Management of Goldlined Seabream *Rhabdosargus sarba* (Sparidae) from the Oman Coast of Arabian Sea**

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# Population Dynamics and Management of Goldlined Seabream *Rhabdosargus sarba* (Sparidae) from the Oman Coast of Arabian Sea

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## Abstract

*Rhabdosargus sarba* is one of the most important coastal demersal species inhabiting Omani waters. An estimate of the age and growth of *R. sarba* ranging from 15 to 43.2 cm total length collected from the Omani waters is made by examining the growth increment of their whole otoliths. The growth rings showed that *R. sarba* rarely attain more than six years. The von Bertalanffy growth parameters were  $K = 0.33 \text{ yr}^{-1}$ ,  $L_{\infty} = 46.97 \text{ cm}$  and  $t_0 = -0.83 \text{ yr}$ . The mean total mortality coefficient "Z" estimated by two different methods was  $1.8 \text{ yr}^{-1}$ . The geometric mean of natural mortality coefficient "M" was  $0.6 \text{ yr}^{-1}$ . Exploitation rate "E" was computed as 0.67, while the length at first capture was 22.9 cm. The yield per recruit analysis showed that the stock of *R. sarba* in the Arabian Sea is overexploited and the exploitation rate should be reduced by about 47% to maintain a sufficient stock biomass for spawning and recruitment as well as the length at first capture should be raised to about 30 cm.

**Keywords:** Arabian Sea; *Rhabdosargus sarba*; age and growth; mortality and exploitation rates; yield per recruit; management.

## 1. Introduction

Sparid fishes are an important component of both artisanal and industrial fisheries in the Omani waters. The mean annual total catch during the last 10 years was about 7400 tons which constitutes 18% of the total demersal species catch and forming about 10 million Omani Riyal annually (Annual statistical books, 2010). They are represented by at least 13 species from which *Rhabdosargus sarba* is one of the most abundant species in Oman. It is a schooling species found widely throughout the Indo-Pacific including Red Sea, East Africa, Madagascar, Australia, China, and Japan [1, 2]. In Oman, it is exploited by different types of fishing gears: gillnets, lines, and traps which are used by traditional fishermen and trawlers, which are used by the industrial fleet (personal observation). This species has a high commercial importance as it is a good species for aquaculture.

In spite of the economic importance of goldlined seabream, information on its biology and dynamics are very rare and the present paper reports the first study on its age, growth, mortality rates and yield per recruit in Omani waters. These parameters will help in design a management plan for its rational exploitation in Oman.

## 2. Methods

### 2.1. Field sampling

*R. sarba* specimens were collected during the trawl surveys of the Arabian Sea that covered the area between Ras Al-Hadd in the north ( $23^{\circ}39'10''\text{N}$  and  $58^{\circ}34'03''\text{E}$ ) and the Omani Yemeni border in the south ( $16^{\circ}37'26''\text{N}$  and  $53^{\circ}17'53''\text{E}$ ) between depths of 20–250 m (Figure 1). Five seasonal surveys with an average duration of 47 days were done using RV Al Mustaqila I between September 2007 and August 2008 (Fish resources assessment survey of the Arabian Sea coast of Oman project, technical report 1) [3]. 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. RV Al Mustaqila I is 47 m length overall, has a beam of 12.5 m, horsepower of 3602 and a displacement of 1745 ton. 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.

A total of 1185 specimens were measured to the nearest mm for total length (TL), and weighed to the nearest 0.1 g for total body weight (W). The individuals were sexed by macroscopic examination of the gonads, and their sagittal otoliths were removed, cleaned, and stored dry for age determination at a later stage.

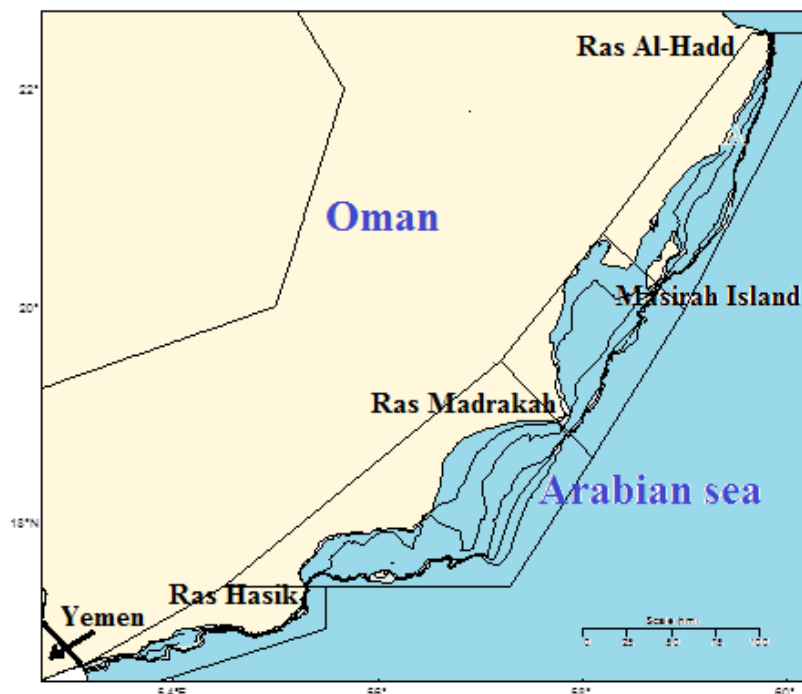


Figure 1: Oman coast of the Arabian Sea showing the surveyed area.

## 2.2. Length-weight relationship

The power equation ( $W = a L^b$ ) was applied to describe the relationship between the total length (L) and the total weight (W), a and b are constants whose values were estimated by least square method. 95% confidence interval was estimated for the slope b to see if it was statistically different from 3. ANCOVA was used to determine if there were significant differences in the length–weight relationships between the sexes.

## 2.3. Age determination

Age was determined by interpreting growth rings on the otoliths. Otoliths were immersed in a solution of alcohol and read in whole under a Zeiss research microscope at 4× and 10× magnifications using transmitted light connected to AxioCam HRC and Ziess KL 1500 LCD. The total radius of the whole otolith and the radius of each annulus were measured to the nearest 0.001 mm. The lengths at previous ages were back-calculated from otoliths' measurements using Lee's equation [4].

## 2.4. Growth parameters

The von Bertalanffy growth model [5] was applied to describe the theoretical growth of *R. sarba*. The constants of the von Bertalanffy model ( $L_\infty$  and K) were estimated using the Ford-Walford plot [6,7]. While age at time zero ( $t_0$ ) was estimated by undertaking linear regression between age (t) and  $\ln(L_\infty - L_t/L_\infty)$ , where  $L_t$  is the length at age t [8]. While the growth performance index was computed according to the formula of Pauly and Munro as  $\phi' = \text{Log } K + 2 \text{ Log } L_\infty$  [9].

## 2.5. Mortality and exploitation rates

The total mortality coefficient Z was estimated using two different methods, the Beverton and Holt formula [10] and the method of linearized length converted catch curve of Pauly [11, 12]. While the natural mortality coefficient M was computed as the geometric mean of three methods; Taylor formula [13], Rikhter and Efanov [14], and Pauly [15] equations. Accordingly, the fishing mortality coefficient F was calculated as  $F = Z - M$ .

Based on estimated  $M$  and  $F$ , the exploitation rate  $E$  was estimated using the formula of Gulland [16] as follows:  $E = F / (F+M)$ .

### 2.6. Length at first capture

The length at first capture ( $L_c$ ) was estimated by the analysis of catch curve using the method of Pauly [17].

### 2.7. Relative Yield per Recruit "Y'/R"

The relative yield per recruit  $Y'/R$  and relative biomass per recruit  $B'/R$  were estimated using the model of Beverton and Holt [18] as modified by Pauly and Soriano [19] as follows:

$$Y'/R = EU^{M/K} \left[ 1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m} \right]$$

$$B'/R = \frac{Y'/R}{F}$$

where

$$m = \frac{1-E}{M/K} = K/Z$$

$$U = 1 - \frac{L_c}{L_{\infty}}$$

## 3. Results and Discussion

Lassen and Medley stated that the purpose of fish stock assessment is to provide estimates of the state of the stock. The state of the stock is defined by its abundance at a specific time, together with the mortality and growth that control its development. These estimates consequently were used to fisheries management advice for reviewing different fishing options [20].

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 were used in assessing the status of the exploited fish stocks and consequently managing of these resources. The present study is the first attempt to estimate the population parameters needed for management purposes of *R. sarba* in the Oman coast of Arabian Sea.

### 3.1. Length–weight relationship

The measurements of total length and total weight of 1185 specimens of *R. sarba* were used to estimate the length–weight relationship (Figure 2). The total length ranged between 15 and 43.2 cm while the total weight varied from 90 and 1700 g. The obtained equations were:

$$\text{Males: } W = 0.0373 L^{2.8444} \quad (r = 0.944)$$

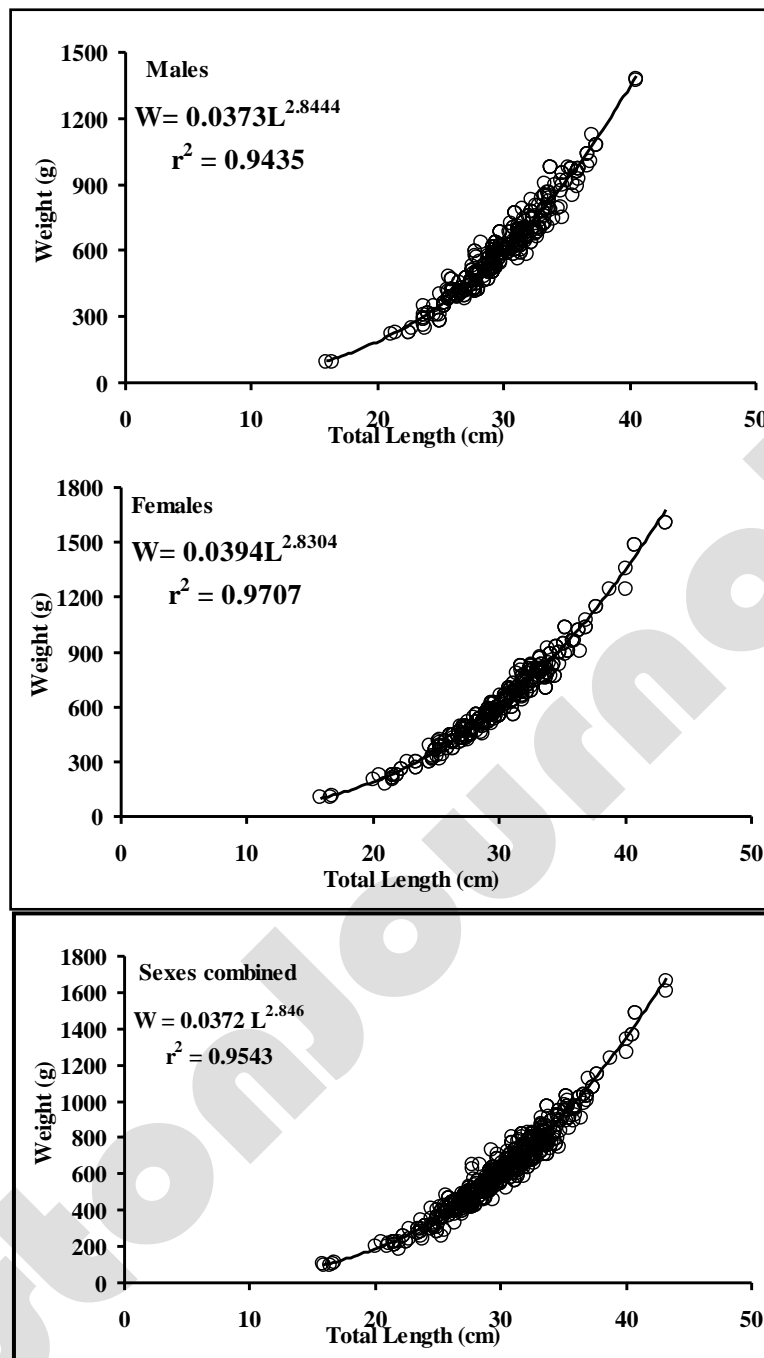
$$\text{Females: } W = 0.0394 L^{2.8304} \quad (r = 0.971)$$

$$\text{Sexes combined: } W = 0.0372 L^{2.846} \quad (r = 0.954)$$

There is no significant difference between male and female length–weight relationship. Isometric growth was observed for goldlined seabream, as the value of (b) was not deviated significantly from the value 3 (95% Confidence Interval = 2.806-2.887). ANCOVA showed no significant differences between length–weight relationships of sexes ( $P > 0.05$ ).

### Age determination

Reliable age determinations are essential for almost all aspects of fishery research but especially for studies of growth, production, population structure, and dynamics. Age determination of *R. sarba* from Omani coast of Arabian Sea, was done by comparing the growth increment readings on the whole sagittal otoliths and their sections. It was found that the number of annuli counted for each individual was similar for the two readings and there was a high congruence (95%) between the age estimations from the two readings.



**Figure 2:** Length–weight relationship of *Rhabdosargus sarba* from Arabian Sea, Oman.

The results revealed that the maximum life span for *R. sarba* was six years and age group two was the most frequent group in the catch that constituted 48% while the age group six was the least age group constituted 0.8% of the catch (Figure 3). These results differ from those of the previous ones. This may be due to the great difference in the maximum length recorded in those studies and the different habitats. El-Agamy [21] based on scales readings, found that the oldest fish of *Sparus sarba* from Arabian Gulf had a length of 30 cm TL and was 8 years old. Kuitert [22] reported maximum length of 45 cm from Australia, while Radebe *et al.* [23] estimated the age of *R. sarba* from South Africa as 0–16 yr for length ranging 8.2–68 cm FL (78.2 cm TL). They also found that the tagged-recaptured *R. sarba* showed a growth rate of 0.18 and 0.10 mm per day for fish of 32.2 and 57 cm TL respectively, which is close to the growth curve for fish of this study (0.15 mm per day for fish of 33.5 cm TL). Hesp *et al.* [24] determined the age of *R. sarba* from three different habitats in Australia as 7, 11, and 13 years old.

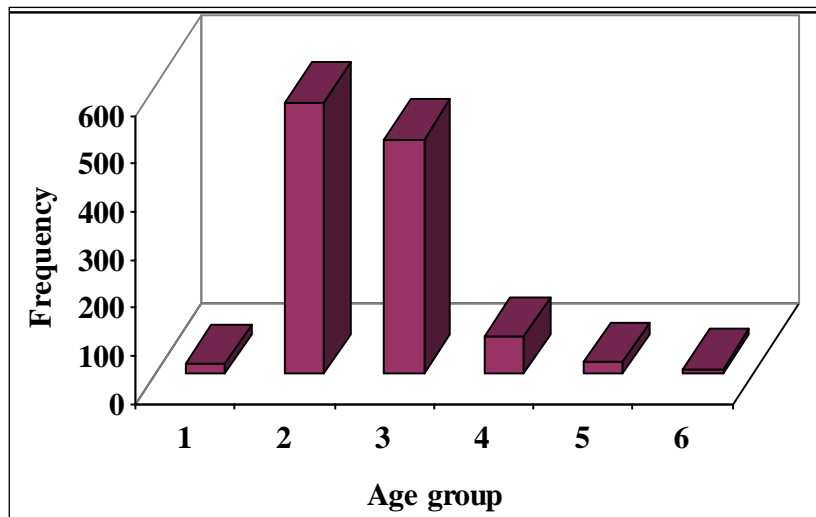


Figure 3: Age composition of *Rhabdosargus sarba* from Arabian Sea, Oman.

### 3.2. Back-calculations and growth in length

The modal lengths corresponding to the various ages of *R. sarba* are given in Table 1. It is obvious that the observed (empirical) lengths were consistently higher than the back-calculated lengths-at age for individual age groups, which indicated that seasonal growth had occurred since formation of a new annulus. Differences between back-calculated lengths-at-age and observed lengths are in the range of observed seasonal growth. Greatest incremental growth in TL occurred during the first year of life and then declined rapidly thereafter. This is in agreement of the previous studies [23–25].

Table 1: Mean back-calculated lengths (cm) of *Rhabdosargus sarba*.

Age group	No. of fish	Empirical length (cm TL)	Back-calculated lengths at the end of each year of life (cm)					
			1	2	3	4	5	6
I	19	22.7	21.10					
II	566	29.5	21.05	28.2				
III	489	34.1	20.86	28.13	33.5			
IV	77	38.1	20.74	28.06	33.39	37.6		
V	24	40.6	20.71	27.91	33.30	37.48	39.9	
VI	10	42.5	20.59	27.82	33.22	37.35	39.81	41.9
Increment			21.1	7.1	5.3	4.1	2.3	2.0

### 3.3. Growth parameters

A likelihood ratio test (LRT) showed no significant difference between males and females von Bertalanffy growth curves. Back-calculated lengths of pooled data (Figure 4) were applied according to Ford-Walford plot to estimate the growth parameters ( $L_{\infty}$  and  $K$ ). The obtained equations were:

$$\text{For growth in length, } L_t = 46.97 (1 - e^{-0.33(t+0.83)})$$

$$\text{For growth in weight, } W_t = 2130.81 (1 - e^{-0.33(t+0.83)})^{2.846}$$

The calculated growth performance index ( $\phi'$ ) was 2.86. El-Agamy [21] studied the age and growth of *Sparus sarba* from the Arabian Gulf based on scales readings. He estimated the growth parameters as  $L_{\infty} = 37.5$  cm TL and  $K = 0.16 \text{ year}^{-1}$ , the  $K$ -value suggests that Arabian Gulf population has a lower growth rate but attains a smaller maximum size and larger age. While Radebe *et al.* [23] gave these values:  $L_{\infty} = 71.5$  cm FL,  $K = 0.16 \text{ year}^{-1}$  and  $t_0 = -0.996$  year for *R. sarba* in South Africa. Although, the  $K$ -values were the same in both studies, the maximum lengths were greatly different. Hughes *et al.* [26] found that for both sexes of *R. sarba* in south-eastern Australia the von Bertalanffy growth parameters were:  $L_{\infty} = 26.40 \pm 0.40$  cm FL,  $K = 0.39 \pm 0.02 \text{ year}^{-1}$  and  $t_0 = -0.56 \pm 0.09$  years.

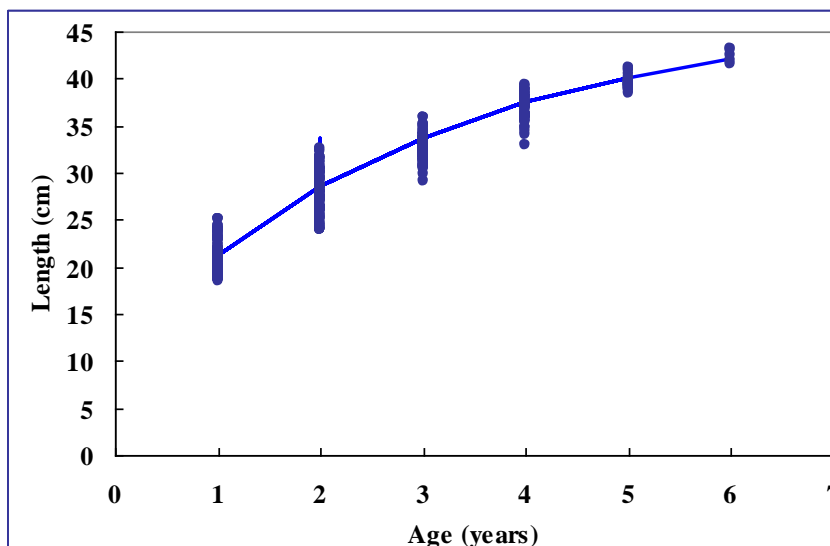


Figure 4: Von Bertalanffy growth model of *Rhabdosargus sarba* from Arabian Sea, Oman.

### 3.4. Mortality and exploitation rates

Total mortality coefficient “Z” was estimated by two different methods, and the obtained results were as follows:

$Z = 1.87 \text{ year}^{-1}$  Beverton and Holt, 1957

$Z = 1.73 \text{ year}^{-1}$  Pauly, 1983 (Figure 5)

The obtained results indicated that both the values of Z are very close to each other. The mean annual natural mortality coefficient M estimated by three different methods was  $0.6 \text{ year}^{-1}$ . Accordingly, the fishing mortality coefficient “F” was computed as  $1.2 \text{ year}^{-1}$ .

The exploitation rate “E” of *R. sarba* was found to be 0.67. This value is high indicating that the stock of *R. sarba* is overexploited. Gulland [16] suggested that the optimum exploitation rate for any exploited fish stock is about 0.5, at  $F_{\text{opt}} = M$ . More recent report by Pauly [27] who proposed a lower optimum F that equals to 0.4 M. In the present study, F was higher than the two values of  $F_{\text{opt}}$  given by Gulland [16] and Pauly [27] indicating that the stock of *R. sarba* in Arabian Sea may be overexploited.

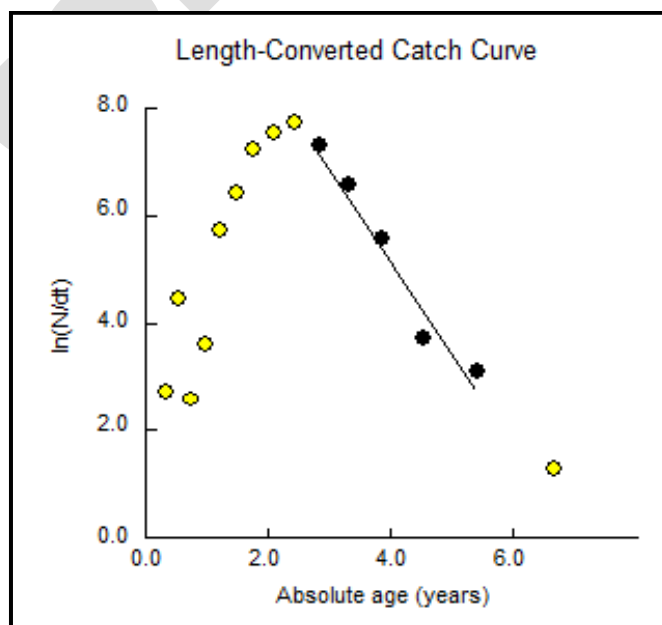


Figure 5: Length converted catch curve of *Rhabdosargus sarba* from Arabian Sea, Oman.

### 3.5. Length at first capture $L_c$

The length at first capture (the length at which 50% of the fish at that size are vulnerable to capture) was estimated as 22.9 cm TL cm (Figure 6), this value is equivalent to an age of 1.2 years. Both the estimated  $L_c$  and the observed lengths of fish captured indicated growth and recruitment overfishing as the length at first sexual maturity was estimated as 28.9 cm TL by Mehanna *et al.* [28]. In the light of these results, a minimum size limit should be implemented for *R. sarba* in Omani waters of the Arabian Sea.

### 3.6. Per recruit analysis

The effect of fishing pattern on the abundance of *R. sarba* stock in Omani coast of Arabian Sea was studied through the regulation of catch—length composition by applying the model of Beverton and Holt [18]. The relative yield per recruit  $Y'/R$  and relative biomass per recruit  $B'/R$  of *R. sarba* were estimated (Figure 7). The results showed that the present level of exploitation rate of *R. sarba* ( $E = 0.67$ ) was very close to that produces the maximum relative yield per recruit ( $E_{max} = 0.69$ ). Also the present level of exploitation rate was higher than the exploitation rate ( $E_{0.5} = 0.35$ ) which maintains 50% of the stock biomass as spawning stock. To insure that at least 50% of the individuals can be maintained for spawning and recruitment, the present level of exploitation rate should be reduced from 0.67 to 0.35 (47%).

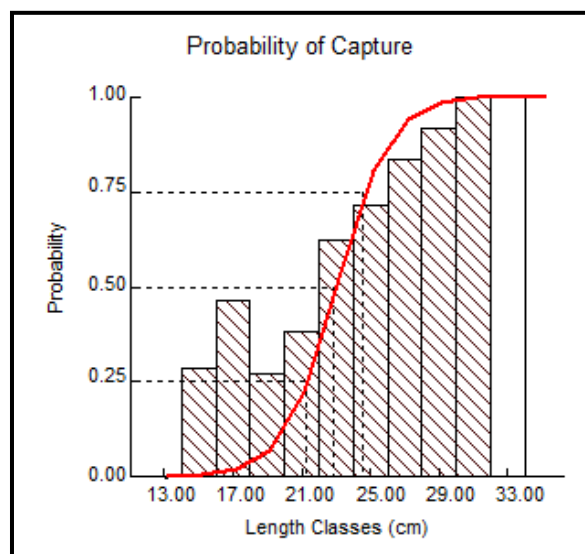


Figure 6: Length at first capture of *Rhabdosargus sarba* from Arabian Sea, Oman.

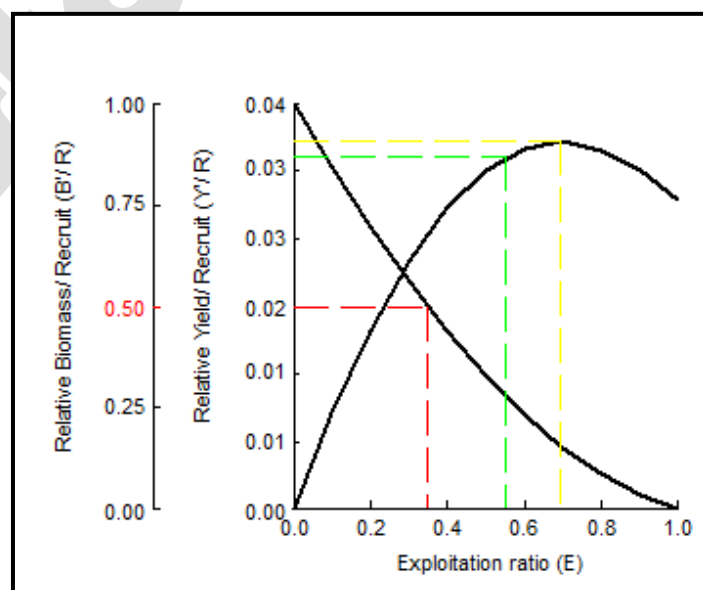


Figure 7: Relative yield per recruit analysis of *Rhabdosargus sarba* from Arabian Sea, Oman.



It could be concluded that the stock of *R. sarba* in the Omani coast of Arabian Sea seems to be highly exploited as the current  $E$  is higher than the defined values of reference points  $E_{0.1}$  and  $E_{0.5}$  (0.55 and 0.35 respectively). For rational exploitation of this fishery resource, the present fishing pressure should be decreased especially fishing of spawners and juveniles. This can be achieved by reducing the number of fishing days or the number of fishing trips or proposing a closure period. It was also necessary to limit the size of nets used to allow the escapement of young fishes and to conserve the reproducible part of the population. At the same time, it is important to analyze the economic factors affecting the fishery before establishing any management measures. Finally, it is important to establish some form of cooperation among fishers, scientists, and government agencies for implementing sustainable management programs.

#### Competing Interests

Authors have no competing interests.

#### Authors' Contributions

All authors contributed equally to this work.

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