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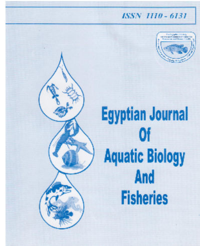

Stock assessment and management of the rabbitfish *Siganus rivulatus* from the Southern Red Sea, Egypt

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ABSTRACT

Rabbitfishes, family Siganidae, are one of the most abundant fishes inhabiting the Red Sea and now widely distributed in the Mediterranean. Age and growth of *Siganus rivulatus,* the most common species, were studied from samples collected randomly between October 2017 and October 2018 from Shalatein landing site. Otoliths of 2000 specimens were used for age determination and the maximum attained age for this species was four years. The von Bertalanffy growth parameters L_∞, K and t_o and the instantaneous annual rates of total, natural and fishing mortality were estimated and consequently the exploitation rate was determined. It is found that the current exploitation level is higher than the optimum one reflecting the intensive exploitation of *S. rivulatus* in the Southern Red Sea, Egypt. Yield per recruit analysis revealed that fishing effort should be decreased. This can be adopted through closed seasons/areas, increase of mesh size, increase of minimum landing size and setting of a total allowable catch (TAC).

INTRODUCTION

Fisheries play an important role in development, food security and providing incomes to hundreds million people, directly or indirectly worldwide. Fish is highly nutritious and serves as a valuable supplement in diets lacking essential proteins, vitamins and minerals. The main threat facing the fisheries as food resource is the ineffective management with poor conservation of habitats. To enhance the contribution of fisheries to food and livelihoods security a transition towards more people centered governance approaches is needed. Involvement of the public, civil society and private sector is required to develop incentives for sustainable ecosystem management and to ensure that the role of fisheries in reaching global food production is taken into account. Fisheries statistics, biological data and population dynamics studies are considered as a basis for assessing the fishery resources and can provide the appropriate scientific advice for their sustainable exploitation.

Rabbit fishes (family Siganidae) are widely distributed especially in the indo-Pacific regions (Woodland DJ, 1983). They are representing an important element in shallow coral reef fish communities. Recently, they received a great attention as they can be cultivated successfully with mullets and milk fish as well as they migrate through the Suez Canal and established in the eastern Mediterranean. They are represented in the Egyptian sector of the Red Sea by four species (*Siganus* *rivulatus, S. stellatus, S. argenteus, S. luridus*) of which *S. rivulatus* is the most abundant. Rabbit fishes considered as a target fishery for the artisanal fishermen in the southern Red Sea and its catch fluctuated between 1298 (2008) and 466 (2014) ton during the last 10 years with a decreasing trend in the last four years (GAFRD, 2016). However, their biological and dynamical characters are poorly investigated in the Egyptian sector of the Red Sea (El-Gammal, 1988; Mehanna and Abdallah, 2002). So a better management policy is needed in order to preserve good population structure and sustainable future fishery of the rabbit fish in the Egyptian Red Sea. This paper presents the basic parameters like growth, mortality and the critical lengths as well as evaluates the current status of this fishery with proposing some reference points for its sustainability.

MATERIALS AND METHODS

The Red Sea has a total surface area of about 458,620 km^2, of which 2.33% is protected and includes 3.8% of the world's coral reefs (Sea Around Us, 2007). The Egyptian sector of Red Sea is about 1080 km in length extending from Suez in the north to Mersa Halayeb in the south. There are many fishing grounds and landing sites along its coast from which Gulf of Suez, Hurghada, Bereneis and Shalatein are the most important ones (Fig. 1).

During the period from October 2017 to October 2018, samples of *Siganus rivulatus* were collected on a monthly basis from Shalatein fishing ground. A total sample of 2000 specimens was collected from the artisanal fleet working in this area. Total length (TL) and standard length (SL) were measured to the nearest mm, total body weight (W) to the nearest 0.01 g and the sex was determined, while otoliths were removed from the fish.

Age determination from otolith readings was performed for all individuals. Otoliths were read under a binocular stereoscope with a 25x magnification, using transmitted light. The distances from the otolith focus to the rostrum (maximum radius), and the radius (distance from the otolith focus to the opaque zone edge, in the same direction of maximum radius) of each ring were measured with an optical micrometer.

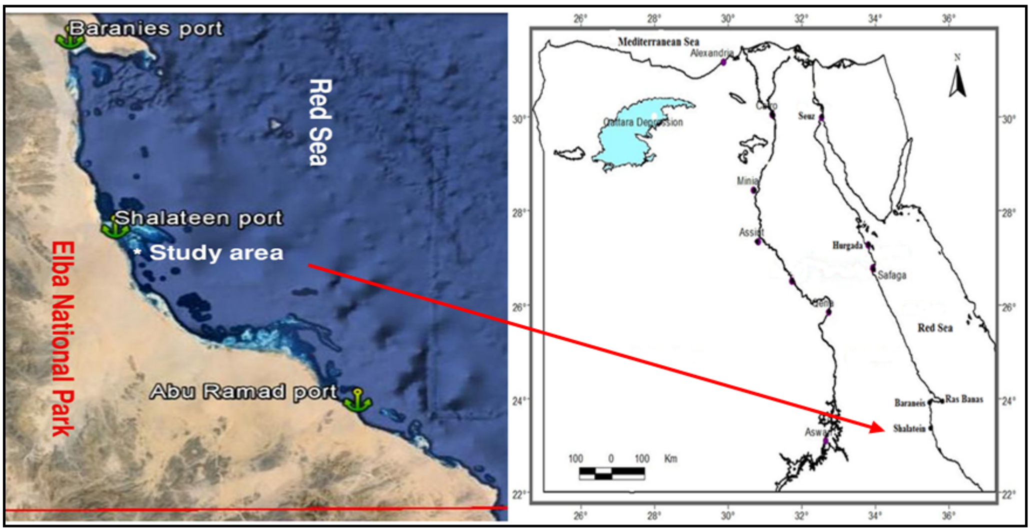

Fig. 1: Egyptian Red Sea map showing the study area

Back-calculated lengths at the estimated age of individual fish were estimated from the log transformation length-otolith radius regression. The von Bertalanffy growth equation was fitted to back-calculated length at age data using a non Linear Regression Analysis. While t_0, the hypothetical age at which length of the fish is zero (usually negative), can be estimated from the empirical equation of Pauly (1983a) as: $\log_{10}(-t_0) = -0.3922 - 0.275 \log_{10} L\infty - 1.038 \log_{10} K$.

Length-weight relationships were calculated by applying an exponential regression equation $W = aL^b$, where W is the weight (g), L is the total length (cm), and a and b are constants. The total mortality coefficient (Z) was estimated as the average of two different methods; linearized catch curve method of Pauly (1983b) and Hoenig's model (1982). While the natural mortality coefficient (M) was calculated as the geometric mean of three different methods; Ursin (1967), Rikhter and Efanov (1976) and Pauly (1980). Accordingly, the fishing mortality coefficient (F) was estimated as $F = Z - M$. The exploitation ratio (E) was estimated using the formula of Gulland (1971) as $E = F / Z$.

The length at first capture L_c was estimated by the analysis of catch curve using the method of Pauly (1984), while the length at first sexual maturity L_m was estimated using the empirical formula $\text{Log } L_m = 0.8979 \text{ Log } L_\infty - 0.0782$ (Froese and Binohlan, 2000). The model of Beverton and Holt (1966) was applied to analyze the relative yield per recruit (Y/R) of *S. rivulatus* as follows:

$$(Y/R) = E\,U\,(M/K)\,[1 - 3U/(1+m) + 3U^2/(1+2m) - U^3/(1+3m)]$$

Where: $M = 1 - E/(M/K) = K/Z$ and $U = 1 - (L_c/L_\infty)$.

Production/biomass ratio or population production (P/B)

Production/biomass or population production (specific production) is calculated using this formula $P/B = 2.64W_{mat}^{-0.35}$; where W_{mat} is fish weight at maturation (Randall and Minns, 2000).

RESULTS AND DISCUSSION

Age and growth

A total of 2000 *S. rivulatus* were collected and examined in order to determine the age and growth patterns. The total lengths and weights varied between 17.2 cm (69 g) to 30.0 cm (390 g). None of the biological characters varied between sexes ($p>0.05$). Hence, all further analyzes were carried out with sexes combined. The ages of the fish were between one and four years old (Fig. 2) and age group II was the most frequent one (60.4%). The back-calculated lengths obtained from otolith readings were 17.9, 23.1, 26.9 and 29.2 for the 1st, 2nd, 3rd and 4th years of life.

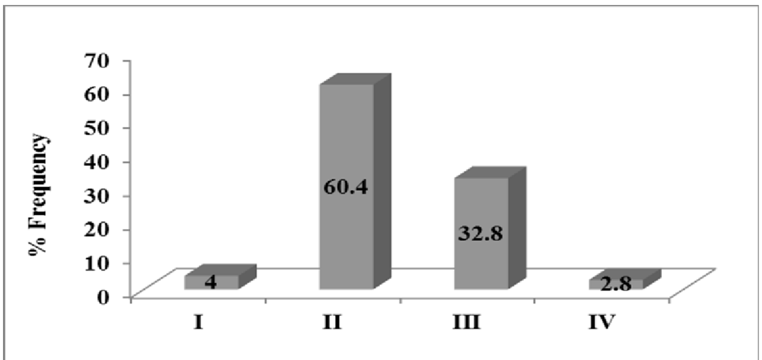

Fig. 2: Age composition of *Siganus rivulatus* from Shalateen, Red Sea

The only available previous works dealing with age and growth for *S. rivulatus* in the Egyptian Red Sea are those of El-Gammal (1988) and Mehanna and Abdallah (2002).

El-Gammal (1988) estimated the longevity of *S. rivulatus* to be four years for males and five years for females. He estimated the back-calculated lengths as 13.32, 20.50, 24.61 and 27.53 cm at the end of the 1st, 2nd, 3rd and 4th year of life, respectively for males and 13.15, 20.86, 25.00, 28.15 and 30.65 cm at the end of the 1st, 2nd, 3rd, 4th and 5th year of life, respectively for females. Mehanna and Abdallah (2002) determined the age of *S. rivulatus* as five years for combined sexes and they gave back-calculated lengths as 13.86, 21.30, 26.84, 29.98 and 32.30 cm at the end of the 1st, 2nd, 3rd, 4th and 5th year of life, respectively.

The length-weight relationship in fish is affected by a number of factors including gonad maturity, sex, diet, stomach fullness, differences in the observed length ranges of the caught specimen and health as well as season and habitat (Froese, 2006). Also, values of exponent b provide information on fish growth type; isometric (b=3), positive allometric (b>3) or negative allometric (b<3). In the present study, the b value for *Siganus rivulatus* (3.166) was significantly different from 3 (P<0.05) indicating positive allometric growth (Fig. 3). The length-weight relationship equation was $W = 0.0077 L^{3.166}$ ($r^2 = 0.90$; SE(a) = 0.109; SE(b) = 0.079; CI(b) at 95% = 3.0106 - 3.3213).

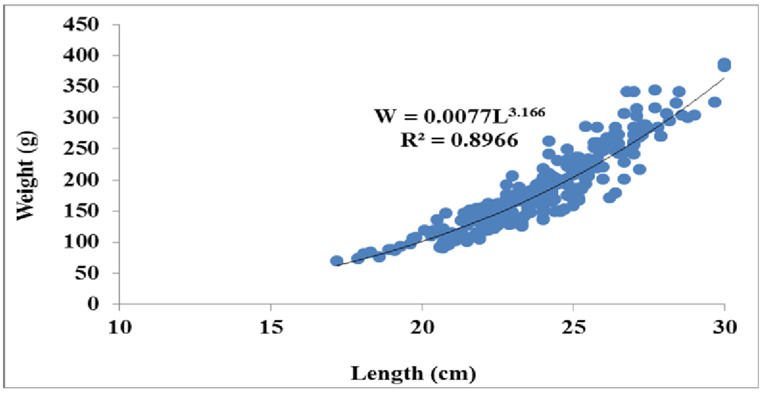

Fig. 3: Length-Weight relationship of *Siganus rivulatus* from Shalatein, Red Sea

The Von Bertalanffy growth parameters of *S. rivulatus* were calculated as: $L_t = 34.44\,[1 - e^{-0.38(t+0.41)}]$ for growth in length and $W_t = 565.94\,[1- e^{-0.38(t+0.41)}]^{3.166}$ for growth in weight. The von Bertalanffy growth parameters of the rabbitfish in Shalatein fishing area compared with those estimated in the previous studies were given in Table (1).

Table 1: Growth parameter estimates of *Siganus rivulatus* in different localities.

Locality	L∞	K	t_o	Author
Mediterranean	42.00			Pauly, 1978
Egypt (Red Sea)	--	1.016	--	El-Gammal, 1988
Males	31.54	0.55	-0.09	
Female	34.22	0.397	-0.10	
Egypt (Red Sea)	37.07	0.397	-0.19	Mehanna and Abdallah, 2002
Egypt (Red Sea)	34.44	0.38	-0.41	Present study

Mortality and exploitation rates

The obtained mean value of total mortality coefficient (Z) for rabbitfish in Shalatein fishing ground was 2.46 year^{-1}, while that of natural mortality coefficient "M" was estimated at 0.64 year^{-1}. Accordingly, the fishing mortality coefficient "F" was found to be 1.82 year^{-1}. Based on mortality estimates, the exploitation ratio was estimated at 0.74 (The optimum E for any fishery resource is 0.5). Based on the mortality data, the percentages of non-survivors were: From natural causes = $1 - e^{-M}$ = 47.3% From fishing = $1- e^{-F}$ = 83.8%. From the above results the rabbitfish collected from Shalatein fishing ground, shows that the contribution of natural mortality to total mortality is very small compared to the role of fishing mortality. This means that the activity of catching the rabbitfish population in Shalatein is quite high. If such fishing activities remain intensive and continuing to meet fishermen and consumer desires in the absence of resources management plan, the rabbitfish stocks will decline drastically within a certain time.

Length at first capture and at first sexual maturity

The length at first capture of the fish individuals of *S. rivulatus* was 18.8 cm TL. In the present study, the length at first capture was smaller than the length of first sexual maturation (L_m = 20 cm). This situation, of harvesting pre- spawning fishes, may cause a greater reduction in the catch in near future. To maintain the rabbitfish population, it is of great importance to give each fish the chance to reproduce at least once in its lifespan to replenish the stock, and therefore the length at first capture should be bigger than the length at first sexual maturity.

Yield per recruit

Y/R in this study estimated using Beverton and Holt equation (1966) showed that the value of Y/R of rabbitfish was 0.045 g at the current rate of exploitation (E = 0.74). Based on the calculation of the relationship between the rate of exploitation (E) and yield per recruitment (Y/R) as shown in Figure 4, some management regulations for rabbitfish resources should be implemented. As the ability recruiting rabbitfish populations are very small (0.045 g per recruitment), the population recovered ability not too big, so it is necessary to increase the population recruitment capabilities. Ability recruit rabbitfish populations can be enhanced through the enrichment of the stock (stock enhancement) such as improvement of water quality, restrictions on the size of the captured fish, setting the total allowable catch TAC, restocking, etc. Also, reducing the rate of current exploitation (E = 0.74) to the exploitation rate ($E_{0.5}$ = 0.37) which maintain 50% of the spawning stock biomass is an urgent action. If the rate of exploitation is maintained at current levels without any effort to increase the recruitment of the population, the rabbitfish population in Shalatein fishing area could be suffer from both growth and recruitment over fishing, and in the end this will affect the resource sustainability.

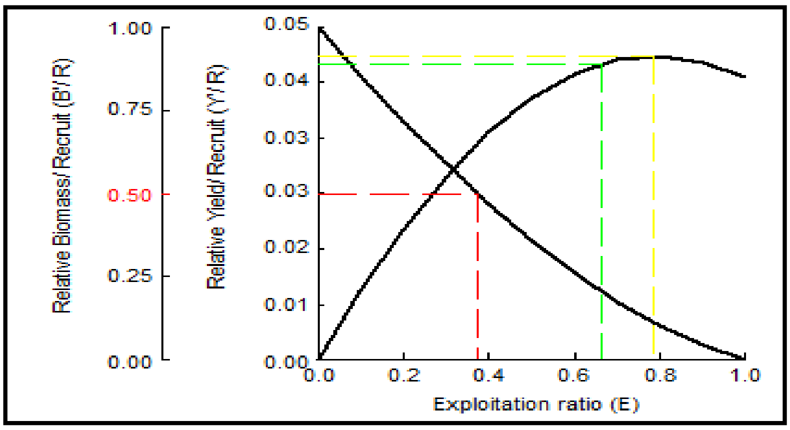

Fig. 4: Relative yield per recruit Y/R for *Siganus rivulatus* from Shalateen, Red Sea.

Production/biomass ratio or population production (P/B)

The ability to predict population P/B ratios is important, as this would allow the estimation of production from biomass data. Annual production/biomass of rabbitfish population production (specific production) in Shalatein fishing ground is calculated at 0.52 and the P/B was related to fish size with a slope of -0.35, and the intercept was population dependent. The observed decline in P/B with fish size is consistent with physiological scaling, but other population factors especially the habitat factors may influence the slope as well.

In conclusion, the population of rabbitfish in Shalatein fishing ground, Red Sea consists of four age groups, and population grow slowly as $K \leq 0.5$. Also, the death of individuals in the population because of the fishing activities was very high and the rate of exploitation of rabbitfish is greatly higher than the optimum value as well as the recruitment process was not optimum and can interrupt the rabbitfish sustainability.

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