Egypt. J. Aquat. Biol. & Fish., Vol.6, No. 1: 67- 81 (2002) ISSN 1110 – 6131

GROWTH, MORTALITY AND YIELD-PER-RECRUIT OF THE RABBIT FISH, *SIGANUS RIVULATUS*, FROM THE EASTERN SIDE OF THE GULF OF SUEZ, SINAI COAST, RED SEA

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Key words : *Siganus rivulatu,* growth, mortality, recruitment pattern, yield-per-recruit, South Sinai coast, Red Sea.

ABSTRACT

Length-based methods were used to study the growth of the rabbit fish *Siganus rivulatus,* in the eastern side of the Gulf of Suez. A total of 600 specimens were collected from the small-scale artisnal fishery landed in Al-Tur region during the period from March 2000 to February 2001. Length frequency distributions were analyzed and normal components were discriminated. The estimated von Bertalanffy growth parameters were $L_\infty = 29.409$ cm, K = 0.735 y^{-1} and t_0 = - 0.22 y. The growth performance index (Φ) was 2.803. The instantaneous total, natural and fishing mortality coefficients were 3.15, 1.431 and 1.72 respectively. The Beverton and Holt (1966) yield-per-recruit model was conducted in order to evaluate the status of the fishery. The results indicated that the *Siganus rivulatus* resource in the Gulf of Suez is slightly overexploited (E = 0.55).

INTRODUCTION

The marbled spine-foot rabbit fish (*Siganus rivulatus*) is a small-sized, short-lived (4-6 years) species. It has a wide geographical distribution in the tropical and subtropical areas. The annual total poduction of the rabbit fish in the Gulf of Suez is of considerable commercial importance. This species represents the second most abundant ones in Sinai coast, and it is caught in shallow waters (sea grass-sand habitat) by trammel nets and traps.

Despite exploitation of the rabbit fish in south Sinai coast of the Gulf of Suez, in this region of the Red Sea, information on the biology and population structure of this species are scarce. Only

Shiekh-eldin (1988) and El-Gammal (1988) studied the age and growth of this species in the Red Sea, while, Bilecenoglu & Kaya (2002) analyzed the age and growth of this species in the eastern Mediterranean Sea. The other existing data mainly concern the reproductive biology and rearing experiments (Ben-Tuvia *et al.*, 1973 and 1983; Popper and Gunderman, 1975; Lichatowich *et al.*, 1984 a and b; Amin, 1985; Hussein, 1986; Lundberg & Lipkin, 1992; Lundberg & Golani, 1995; Wassef & Abdul Hady, 1997; Diamant *et al.*, 2000 and Chiu Liaoa *et al.*, 2001).

This study is an attempt to assess the growth, mortality, recruitment and exploitation of the stock of *Siganus rivulatus* in the eastern side of the Gulf of Suez, Sinai coast based on the analysis of length frequency distributions, in order to obtain the basic information for the assessment of the stock of this species.

MATERIALS AND METHODS

Monthly samples of *Siganus rivulatus* were collected from the small-scale artisanal fishery in Al-Tur landing site in the eastern side of the Gulf of Suez, from March 2000 to February 2001.

A total of 600 specimens were obtained, where the total length to the nearest 0.5 cm, and weight to the nearest gram, of each fish was measured . After preliminary trials, lengths were pooled into one cm classes and smoothed (x 3) to reduce sampling noise (Rosenberg & Buddington, 1988). The smoothed length frequencies were analyzed using FiSAT program (Gayanilo & Pauly, 2000). In order to discriminate length components, Bhattasharya (1967) method was applied. The selection of points to distinguish normal groups in the length composition was aimed at minimizing the value of the chi-square statistic and increasing the number of degrees of freedom. Modal components were "aged" based on the general knowledge of the biology of the species, whereas plausible linkage of selected modes was made on the basis of the integrated approach (Caddy, 1986; Pauly, 1987). The growth parameters (L_∞, K and t_0) were estimated according to the von Bertalanffy (1938) growth formula. A weighed (by the reciprocal of the standard error of the modal length) non-linear, least squares technique (Prager *et al.*, 1989) was employed to fit the VBGF to the data, the mean square error was used as an index of goodness of fit.

In order to compare the present the estimates with thos derived from other geographical areas, the growth performance inde Φ (Munro & Pauly, 1983) was computed.

The instantaneous total mortality coefficient (Z) wa estimated by applying two methods, the length converted catch curv (Pauly, 1987) and the method of Ault and Ehrhardt (1991). Th VBGF parameters (L_∞ and K) along with the mean annual wate temperature of the investigated area (26.5 °C) were used to comput the instantaneous natural mortality coefficient (M) from the empirica equation derived by Pauly (1980). The instantaneous fishing mortality coefficient (F) was calculated from $F = Z - M$ and the exploitation ratio ($E = F/Z$) then computed.

The length at which 50% of the catch retains in the net (L_c) was obtained by plotting the curve for probability of capture by length (Pauly, 1984).

A recruitment pattern was obtained by projection on the length axis of the available length frequency data.

The length class that generates highest yield (L_{opt}), where the number of survivors multiplied with their average weight reaching a maximum, was calculated according to the relationship between L_{opt} and the von Bertalanffy growth function as: $L_{opt} = L\ (3/(3 + M/K))$ (Beverton, 1992).

The relative yield-per-recruit and relative biomass-per-recruit model were derived by Beverton and Holt (1966) as incorporated in the FiSAT soft ware and used to assess the present status of the stock of *Siganus rivulatus* and to forecast the effects of the changes in fishing pattern.

RESULTS AND DISCUSSION

Age and Growth

The smoothed length-frequency distributions of *Siganus rivulatus* from the Gulf of Suez were analyzed by Bhattasharya method (1967). Modal decomposition was carried out monthly as well as for the pooled data. The estimated monthly normal components resulting from the modal progression analysis are given in Table (1). Up to four groups were identified from the pooled data with mean modal lengths of 15.8, 19.3, 22.3 and 24.0 cm. These are almost well discriminated according to the values of the separation index, which must be over 2 to allow an objective separation of the adjacent groups (Rosenberg & Beddington, 1988). The statistical analysis showed that the estimated length frequency compositions were not significantly different from the observed ones with a degree of freedom = 9 for the pooled data. A plausible age of one year was assigned to 15.5 cm of length. Thus allowing generating ages for the successive modal lengths.

The available age and growth studies from the Red Sea (Shiekh-Eldin, 1988 and El-Gammal, 1988) showed that the data are consistent with a life span of 4-6 years. The back-calculated lengths from scale reading recorded by Shiekh-Eldin (1988) for *S. rivulatus* were 12.99, 19.21, 23.95, 28.21, 30.82 and 32.1cm for the 1^{st} to the 6^{th} years old respectively, while El-Gammal (1988) studied the age and growth of this species in the same area for separated sexes and he recorded 4 years life span for males and 5 years for females with back-calculated lengths from otolith reading as:

	1	2	3	4	5
Males	13.32	20.60	24.61	27.53	
Females	13.15	20.86	25.00	28.15	30.65

These records differ from the results of the present study, but the maximum observed length in the present work is 26.5 cm, which is much lower than the length of the last age group recorded by both authors. On the other hand, Bilecenoglu & Kaya (2002) suggested that *S. rivulatus* from the eastern Mediterranean is long-lived species with maximum observed age of 8 years from the scale reading.

The assigned modal lengths were used for fitting the growth curve (Fig. 1) and estimating the von Bertalanffy growth parameters by nonlinear least square fitting (Prager *et al.*, 1989). The resulting VBGF parameters were L_∞ = 29.409 cm, K = 0.735 y^{-1} and t_0 = - 0.22y. The calculated growth parameters from previous studies are given in Table (2). The highest asymptotic size (42.0 cm.) recorded by Ben Tuvia *et al.* (1973) was based on data of *S. rivulatus* reared in cages with high growth rate.

The obtained growth performance index (Φ = 2.803) was lower than that reported in the Mediterranean Sea for *S.rivulatus* reared in cages (Φ = 3.25) by Ben Tuvia *et al.* (1973) and it was higher than that reported for the same species from the Red Sea (Φ =

2.627, Shiekh-Eldin, 1988 and Φ = 2.702, El-Gammal, 1988). It was also higher than that recorded by Bilecenoglu and Kaya (2002) from the eastern Mediterranean (Φ = 2.182 for males and Φ = 2.133 for females). Such differences may be attributed partially from the different techniques used, but more likely reflect slight environmental differences such as food availability, salinity and temperature.

Mortalities and exploitation ratio:

The length-converted catch curve (Pauly, 1983) produced a (Z) value of 3.15 y^{-1} with a confidence interval of 3.65-2.65 and r^2 = 0.9891. Figure (2) represents the Catch Curve utilized in the estimation, the black dots represent the used points through least square linear regression, while open dots represent the points either not fully recruited or close to L_∞ and hence discarded from the calculation. The Ault and Ehrhardt (1991) method yielded a total mortality coefficient (Z) equals 3.18 y^{-1}. It is clear that the two values are highly comparable.

The von Bertalanffy growth parameters (L_∞ = 29.409 and K = 0.735y^{-1}) and the mean annual water temperature of the study area (T = 26.5°C recorded by Ahmed, 1999) were used in Pauly empirical equation (1980) and the resultant natural mortality coefficient was M = 1.431 y^{-1}. Then the fishing mortality coefficient was calculated directly as F = 1.72 y^{-1} and the exploitation rate (E) was computed as E = 0.55. According to Gulland (1971) the present estimated value of (E) refers to a slight overexploitation of this species in the eastern side of Gulf of Suez.

Concerning mortality estimates, comparison is difficult because of the scarcity of data. The only estimate that found in literature was that of El-Gammal (1988), who computed the total mortality coefficient of *S. rivulatus* in the Red Sea as Z = 0.817y^{-1} for males and Z = 0.712 y^{-1} for females. These values are lower than those estimated in the present study. However, the total mortality coefficient is not a species-specific parameter, but an area specific parameter.

Selection pattern:

Estimates of the length-at-first capture (L_C) or the selection length were derived from probabilities of capture generated from the catch curve analysis. Fig. (3) shows the selection curve which provided an estimate of L_c = 12.81 cm.

Recruitment pattern:

The annual recruitment pattern was produced following Moreau and Cuende (1991), through reverse projection of the restructured data onto the time axis. The resultant recruitment pattern (Fig. 4) suggested that recruitment had one annual peak, which in agreement with the results of Ahmed in press (2002) who found that *S. rivulatus* in the same investigated area spawns once a year with a peak in summer.

Optimum length (L_{opt}):

A fishery would obtain the maximum possible yield if it were to catch only fish of the optimum size (Beverton, 1992). The derived estimate of this optimum length for *S. rivulatus* in the eastern side of the Gulf of Suez was 17.8 cm. It was used with the length at first maturity (L_m = 17.4 as derived from the empirical equation of Froese & Binoblan, 2000) to evaluate the length frequency diagram (Fig. 5) for signs of growth overfishing. The figure indicates with a little extent growth and recruitment overfishing.

Yield per recruit and biomass per recruit:

Relative yield-per-recruit and relative biomass-per-recruit of *S. rivulatus* were determined as a functions of L_c/L_∞ and M/K respectively. Figure (6) shows the relative yield-per-recruit (Y`/R) and relative biomass-per-recruit (B`/R) values at various levels of exploitation rate (E). As might be seen, the maximum Y`/R occurs at a value of exploitation rate E_{max} = 0.686 which is higher than the current exploitation rate E_{cur} = 0.55. However, the value of the present exploitation rate equals to the value of the optimum exploitation rate of *S. rivulatus* which corresponds to a point on the yield per recruit curve where the slop is $1/10^{th}$ of the value at the origin of the curve, this provides an estimate of E_{opt} which is lower than E_{msy} but generates the economic yield-per-recruit.

Conclusion :

The marbled spine foot rabbit fish is an important commercial species in the eastern side of the Gulf of Suez. The results of the present study indicate that the resource of *S. rivulatus* in the eastern side of the Gulf of Suez is slightly overexploited. The fisheries strategy at this region should be planned to reduce the fishing effort and consequently the exploitation rate by about 10% of their current values. For the proper management of the multi-species resource in this area, further studies must be undertaken on the other species inhabiting the present investigated region .

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Table (1) Results of the modal progression analysis on *Siganus rivulatus* length frequency distribution.

Month	group	Mean length	Separation index	Standard diviation
March	1	18.903	--	0.9076
d.f.=12	2	20.000	0.9393	1.4286
	3	22.000	2.5276	1.1985
	4	24.000	2.3850	1.6895
May	1	15.714	--	0.9874
d.f.=16	2	19.199	4.3338	0.6208
Jun	1	17.225	--	1.2888
	2	18.763	2.1263	1.4432
Sep	1	16.902	--	0.9367
Oct	1	16.298	--	0.8253
	2	17.844	2.523	1.2055
Nov	1	17.273	--	1.2090
d.f. =10	2	19.000	2.5008	1.0928
	3	21.000	2.6025	1.4033
Dec	1	17.690	--	0.7597
Jan	1	17.082	--	1.4557
d.f. =14	2	19.000	2.4227	1.2405
	3	22.034	4.0218	0.2681
Feb	1	14.750	--	0.6006
d.f. =16	2	18.102	4.8478	0.7824
Total	1	15.800	--	0.9865
d.f. 9	2	19.301	2.4583	1.2458
	3	22.300	2.5894	0.8987
	4	24.000	2.8581	0.9965

f.d.: degrees of freedom

Table (2) Estimated growth parameters of *Siganus rivulatus* by different authors

Author		L_∞	K	t_0	Φ	Area
Ben Tuvia (1973)		42.00	1.016		3.25	Mediterranean Sea
El-Gammal (1988)	M	31.54	0.506	-0.094	2.698	Red Sea
	F	34.22	0.434	-0.100	2.706	
Shiekh-Eldin (1988)		38.041	0.293	-0.427	2.627	Red Sea
Bilecenoglu and Kaya (2002)	M	21.06	0.343	-0.540	2.182	Mediterranean Sea
	F	22.55	0.267	-0.470	2.133	
Present study		29.409	0.735	-0.220	2.803	Gulf of Suez

Fig (1) Theoretical growth curve of *Siganus rivulatus* from the eastern side of the Gulf of Suez

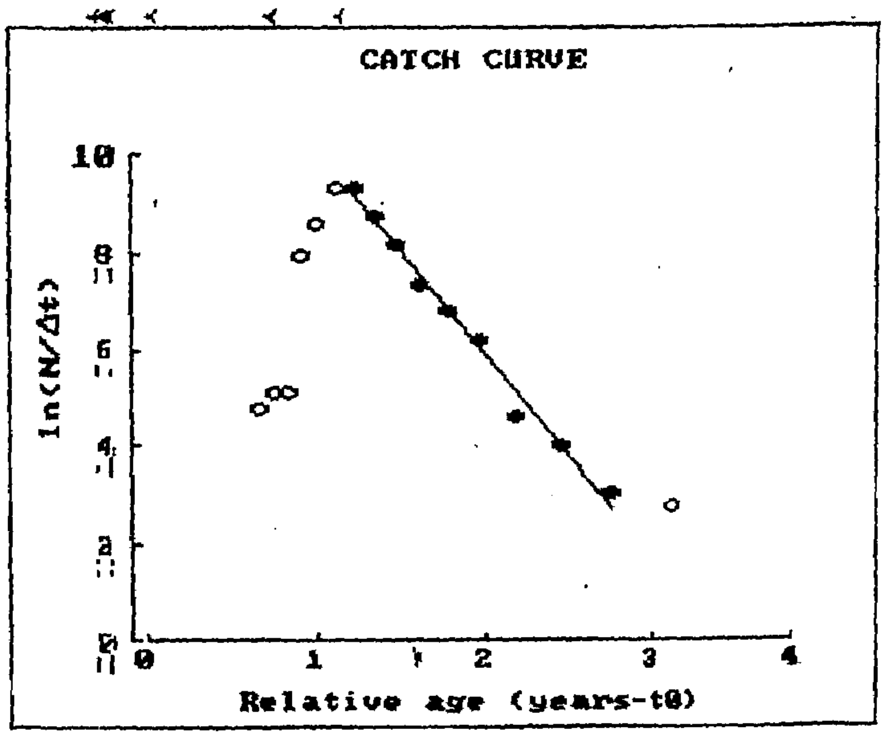

Fig (2) Length converted catch curve of *Siganus rivulatus* from the Gulf of Suez, Sinai coast.

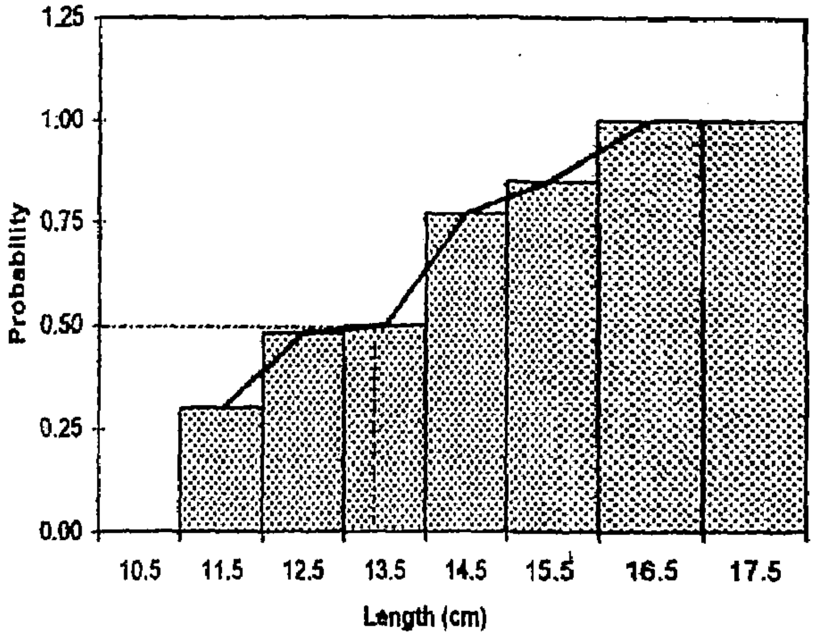

Fig (3) Selection pattern of *Siganus rivulatus* from the eastern side of the Gulf of Suez.

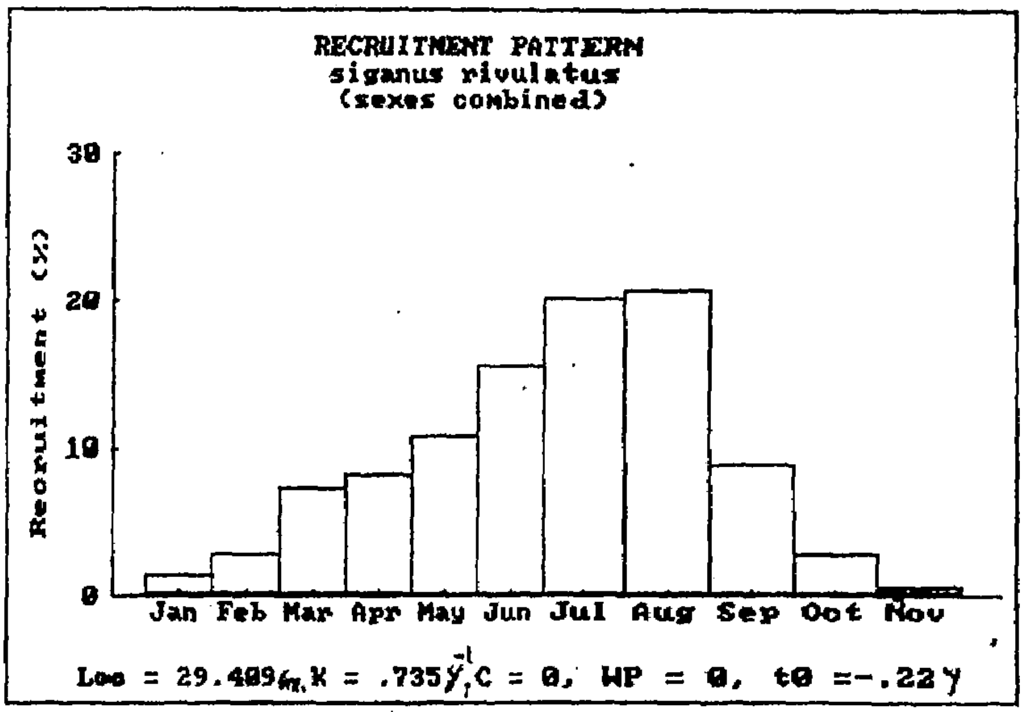

Fig (4) Recruitment pattern of *Siganus rivulatus* from the Gulf of Suez, Sinai coast.

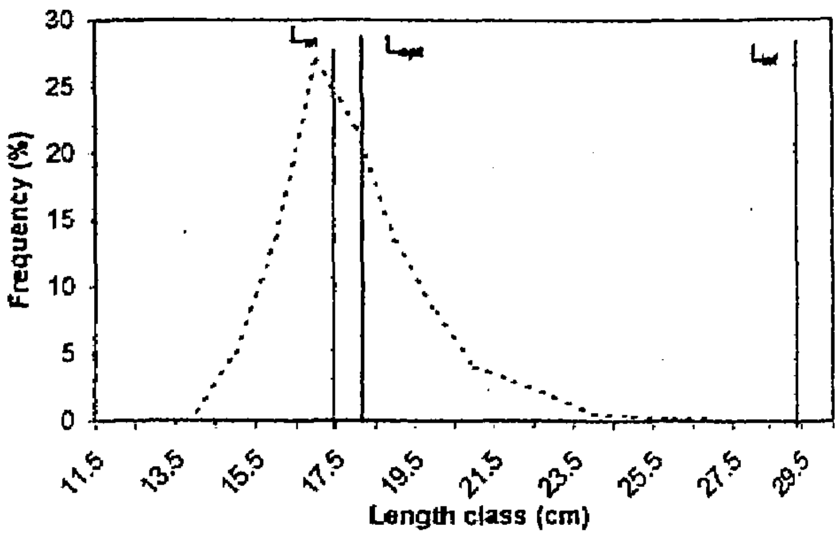

Fig (5) Length frequency data of *Siganus rivulatus* from the Gulf of Suez, indicating L_{inf}, L_m and L_{opt}

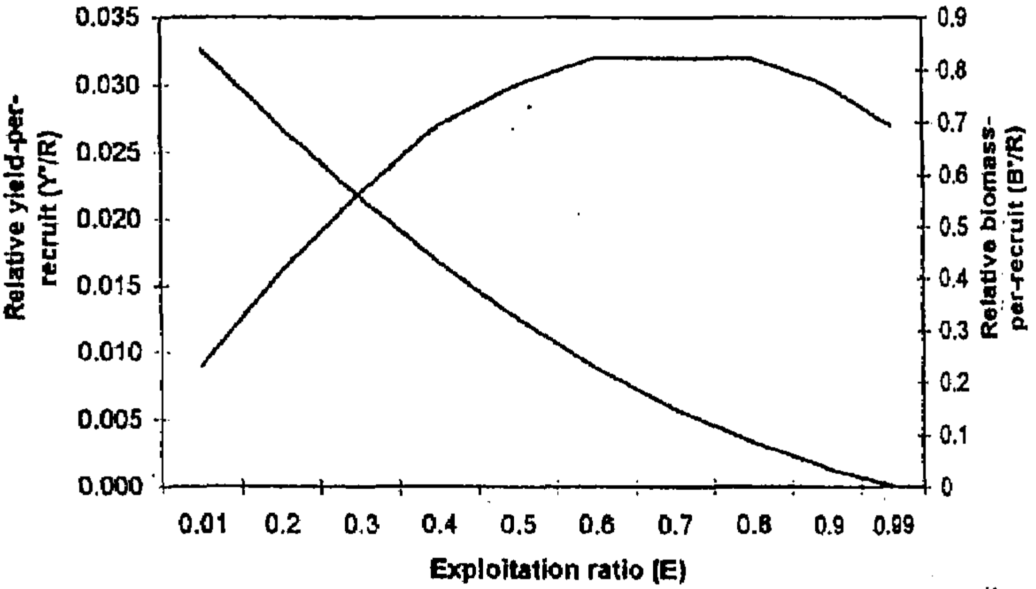

Fig (6) Relative yield-per-recruit and relative biomass-per-recruit of *Siganus rivulatus* from the the Gulf of Suez, Sinai coast.