

On the Biology of *Siganus rivulatus* Inhabits Bitter Lakes in Egypt

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Abstract

The present work was carried out to study the age, growth, length-weight relationships, spawning season, length at first sexual maturity and mortality of the commercial Rabbit fish, *Siganus rivulatus*, inhabits Bitter Lakes in Egypt. Fish samples which were collected during the period from January to December 2011 were selected to represent all fish size categories in the catch. Each fish specimen was measured, weighted and then dissected to detect the maturity stage of the gonads. The annual rates of total, natural and fishing mortality were calculated as 0.8840, 0.2214 and 0.6626^{yr-1} respectively. Current exploitation rate 'E' was estimated at 0.75. The length-weight relationships for males and females were estimated, respectively as:

$$W=0.01042 \times L^{3.0101} \text{ and } W=0.00952 \times L^{3.042}$$

The age data derived from the otolith readings were used to estimate the growth parameters of the von Bertalanffy growth equation. The estimated parameters were: $L_{\infty}=35.5$ cm, $K=0.0849$ and $t_0=-0.843$ for females, otherwise they were: $L_{\infty}=36.5$ cm, $K=0.0786$ and $t_0=-1.00382$ for males. It was found that, both males and females matured at a total length of about 15.4 cm. The natural spawning period of this fish species is in the summer, from May to July.

Keywords: Environment; Fishes; Phytoplankton; Fishery production

Introduction

The Siganidae form a small family of herbivorous, widely distributed fishes in the Indo-West Pacific Ocean [1]. They are of economic importance for the fishery production in several countries in the Indo Pacific and Middle East regions. *S. rivulatus* has established large populations in its new environment and can be considered as one of the most successful Lessepsian fish [2-4]. It was found in several different overgrown habitats (rocks with algae, sand with algae, and grass with algae) it is considered to be strictly herbivorous [5,6]. *Siganus rivulatus* are mainly found in shallow water, usually less than 15 meters. This shallow depth should be predictable for species that is almost entirely herbivorous where algae are the more widespread at these depths. The fishes begin their life as a phytoplankton feeder on many small diatoms, then ingest zooplankton consisting of copepods species [7]. The type and amount of food influence significant the body composition and its nutritional value [8]. Family Siganidae have a single row of flattened close-set teeth for rasping at meatier seaweeds. The mouth is specially designed to aid in the removal of algae from in between rock crevices, or coral branches. The upper jaw is fixed, with only the tip of the mouth being able to move up or down creates a nibbling action. Five species of Siganids are known in the northwestern area of Red Sea [9]. Two of which have immigrated through the Suez Canal and now are established itself successfully in the eastern Mediterranean up to the Aegean sea and along the coast of Egypt and Libya up to Tunisia in the southern Mediterranean [10]. The first species is dominant in the Egyptian waters of Mediterranean, in the coastal area off Alexandria [11] especially in Abu-Qir Bay [12]. Information about *Siganus rivulatus* age and pertinent growth rate were studied in both the Red Sea [9-15] and in the Mediterranean [16-19]. An existing data mainly concern the reproductive biology and rearing experiments [20-24] have been reported. The Rabbit fish *Siganus rivulatus* Forsskal [25] hold particular promise for marine aquaculture development by virtue of their herbivorous/omnivorous feeding habits and consequent ability to feed low on the aquatic food chain [26], their high tolerance to environmental factors, rough handling and crowding [27] fast growth and possibility to obtain their seeds from the wild or by artificial propagation [28]. Therefore, the aim of the present study

is concerned with the updating biological aspects of *Siganus rivulatus* which is one of the dominant fish species occurring in the artisanal fishery of the studying area. Such information could be employed for best planning of fishing and culturing this fish in the Egyptian waters moreover managing its stock in the area of study.

Materials and Methods

As regards to 420 specimens of Rabbit fish, *Siganus rivulatus*, were collected monthly around 2011, from the landing site at Bitter lakes. Fishes were put immediately in crushed ice and transported to the laboratory, where they were subjected investigation. Date of capture, total fish length (mm) and total fish weight (0.1 g) were recorded for each fresh specimen. Fishes were dissected to define their sex and gonad maturity stages. Guttured fish were weighed to the nearest 0.1 g and gonads were weighed to the nearest 0.001 g. Both otoliths (Sagittae) of each fish specimens were removed, cleaned in ethanol and stored for age determination after drying. The otoliths then after were treated with xylene and moistened with chamomile oil [19] to be clearly visible under reflected light microscope in order to read the annual rings. Counts of rings and measurements were always performed in the same direction, from the nucleus to the edge of the otolith. Back-calculation of total length, were obtained by Lee's equation. The growth parameters L_{∞} , k and t_0 of *Siganus rivulatus* were estimated by means of von Bertalanffy plot (Sparre and Venema [29] and application of von Bertalanffy equation von Bertalanffy [30]).

$$L_t = L_{\infty} (1 - e^{-k(t-t_0)})$$

Where L_t is the total length at time t ; k is a growth constant; L_{∞}

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is the asymptotic length; and t_0 describes the theoretical age where L_t is zero [31]. The length weight relationships were estimated from the allometric equation, $W=a L^b$ Ricker [32] where W is total body weight (g), L the total length (cm), a and b are the coefficients of the functional regression between (W) and (L) and they were obtained using the Newton algorithm from the Microsoft Excel Solver routine.

The spawning season was determined by the curvilinear average values of monthly Gonadosomatic index (GSI) for both males and females where:

$$GSI= 100 [\text{gonads weight (g)/gutted weight (g)}]$$

Total mortality rate (Z) was estimated based on the length at first capture methods evaluated by Beverton and Holt 1957 [33].

$$Z=K (L_{\infty} - L_m / L_m - L_c)$$

Where:

L_m =the average total length of the entire catch.

L_c =the length at which 50% of the fish entering the gear

Natural mortality rate (M) was estimated by using the equation derived by Ursin [34] based on the mean total length where:

$$M=W^{-1/b}$$

W =mean total length.

b =constant of length weight relationship.

Fishing mortality rates (F) were calculated as the difference between Z and M where $Z=F + M$.

The annual exploitation rate (E) was obtained according Sparre et al. where: $E=F/Z$

The total mortality coefficient " Z " was estimated using the method of Pauly [35].

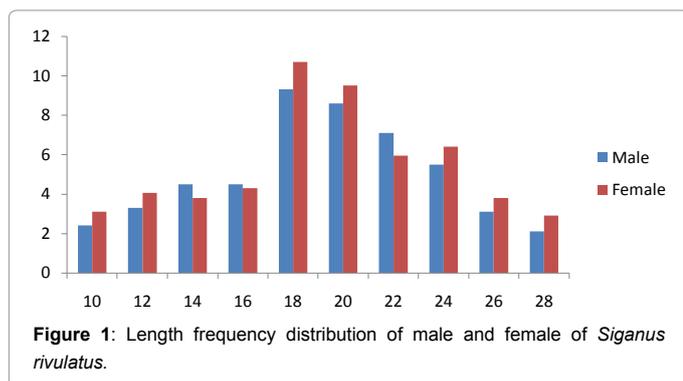
Results

Total length frequency distribution

The total length of all individuals ($n=420$) collected in the present study ranged from 9 to 28.7 cm, and the most frequent length was 18 cm as illustrated in Figure 1 and Table 1.

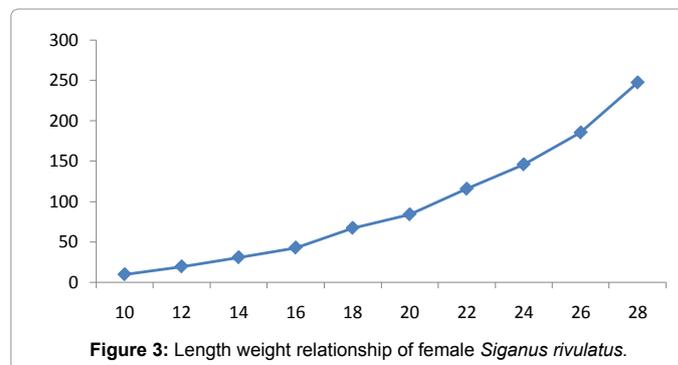
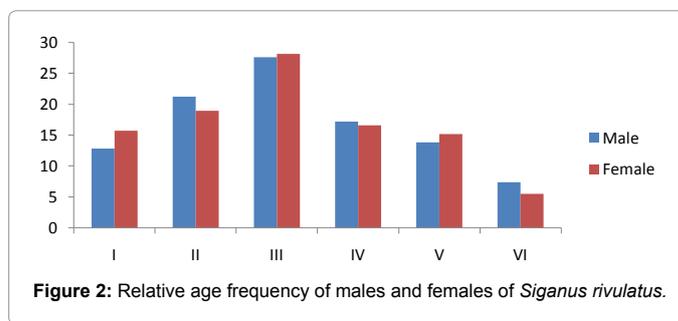
The age composition and growth

The age distribution of samples ranged from I to VI years for *S. rivulatus*, based on the results of otolith reading (Figure 2). The age group III was dominant (27.6%) for male followed by age groups II



Age group	Mean number	Observed Length (mm)	Back calculated lengths in mm					
			1	2	3	4	5	6
I	34	11.0	10.46					
II	41	15.5	10.69	14.15				
III	61	18.9	11.50	15.20	17.68			
IV	36	21.7	11.35	15.37	16.98	20.19		
V	33	23.9	10.81	15.85	18.81	20.90	23.44	
VI	12	26.4	10.75	15.34	19.52	22.02	23.69	25.36
Average total	217		10.92	15.18	18.95	21.44	23.57	25.36
Increment of length			10.92	4.26	3.77	2.49	2.13	1.79
% of annual Increment			43.1	16.88	14.87	9.82	8.40	7.06

Table 1: Average back-calculated lengths (cm) of male *Siganus rivulatus* from the Bitter lakes, Egypt.



(21.2%), IV (17.2%), V (13.8), I (12.8) and VI (7.4%), While the age group III was dominant (28.1%) for female followed by age groups II (18.9%), IV (16.6%), I (15.7%), V (15.2%) and VI (5.5%). The growth of the studied fish was described by the von Bertalanffy model based on the back-calculated length at age data (Figure 3). The estimated growth functions were:

$$L_t=36.5 \text{ cm } (1 - e^{-0.0786(t+1.0038)}) \text{ for males and}$$

$$L_t=35.5 \text{ cm } (1 - e^{-0.0849(t+0.8430)}) \text{ for females}$$

Growth in both sexes is almost similar ($K=0.0786$ for males and $K=0.0849$ for females). However, the maximum theoretical length were 36.5 cm and 35.5 cm for males and females, respectively.

Growth in length

The otolith radius-total length relationship of males and females are described by the following equations:

$$L=5.3227 + 4.0465 S \text{ for males } (r^2=0.998) \text{ and}$$

$$L=4.8465 + 4.01173 S \text{ for females } (r^2=0.995)$$

Where: L is the total length in centimeters, S is the otolith radius in millimeters and r is the correlation coefficient.

Back-calculations

The following formula was derived to obtain the back-calculated total length at the end of each year of life for males and females respectively.

$$L_n=(L - 5.3227) S_n / S + 5.3227$$

$$L_n=(L - 4.8465) S_n / S + 4.8465$$

Where: L_n is the length at the end of n^{th} year, S_n is the radius of the otolith to n^{th} annulus, S is the total radius of the otolith and L is the total length at capture. From the data given in Tables 1 and 2, it is obvious that, *S. rivulatus* attains its highest growth rate in terms of length during the first year of life, after which a gradual decrease in growth increments was noticed with further increase in age.

Length-weight relationship

The total length of *S. rivulatus* varied from 9.0 to 28.5 cm and 9.0 to 28.9 cm for males and females respectively, while the total weights ranged between 10.83 to 246.7 g. for males and 10.68 to 248.3 g for females. The equations were extracted for describing the relationship between weight and length for both sexes as follows:

$$W=0.00952 * L^{3.042} \text{ (} r^2=0.98 \text{) or } \text{Log } W=- 2.02136 + 3.0424 \text{ Log } L \text{ for female and } W=0.01042 * L^{3.010} \text{ (} r^2=0.98 \text{) or } \text{Log } W=- 1.9821 + 3.010 \text{ Log } L \text{ for male}$$

Where:

W is the total weight (gm)

L is the total length (cm)

R is the correlation coefficient.

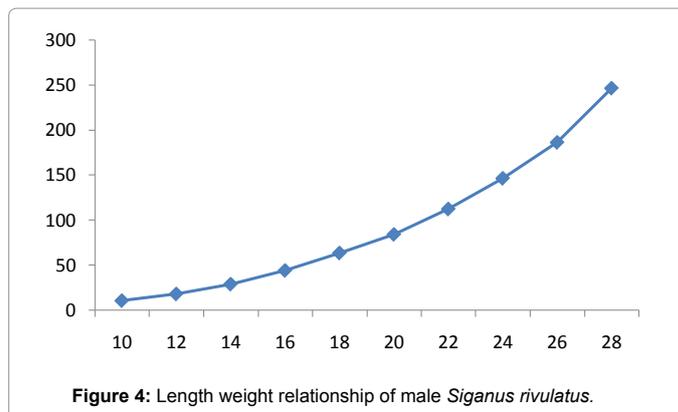
The high values of r^2 indicate a good measure for the strength of these equations and closeness of observed and calculated values of fish weight. The length and weight measurements of the analyzed specimens used to describe the length-weight relationship are given in Figures 3 and 4.

Condition factor

The present results of condition factor revealed that the (Kn) values fluctuated between 0.98-1.04 with an average of 0.999 for males and

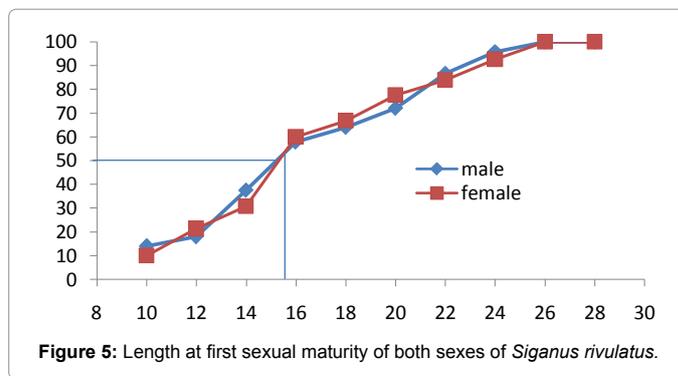
Age group	Mean number	Observed length (mm)	Back calculated lengths in mm						
			1	2	3	4	5	6	
I	26	10.8	10.32						
II	43	15.3	10.93	15.50					
III	56	18.5	11.24	16.18	20.35				
IV	35	21.4	10.86	15.28	19.50	21.89			
V	28	24.7	10.92	15.80	19.22	21.26	23.12		
VI	15	26.2	11.08	16.03	19.53	22.01	23.68	24.97	
Average total	203		10.89	15.76	19.65	21.72	23.40	24.97	
Increment of length			10.89	4.87	3.89	3.07	1.68	1.57	
% of annual Increment			43.6	19.50	15.58	8.29	6.73	6.29	

Table 2: Average back-calculated lengths (cm) of female *Siganus rivulatus* from the Bitter lakes, Egypt.



Age group	Mean number	Back calculated weights in (g)					
		1	2	3	4	5	6
I	34	11.55					
II	41	13.76	39.82				
III	61	14.98	45.38	91.16			
IV	36	13.49	38.13	80.06	113.82		
V	33	13.72	42.21	76.62	104.14	134.41	
VI	12	14.34	44.11	80.44	115.73	144.56	168.44
Average total	217	13.64	41.93	82.07	111.23	139.49	168.44
Increment of weight		13.64	28.29	40.14	29.16	28.26	28.95

Table 3: Calculated weights (g) of male *Siganus rivulatus* from the Bitter lakes, Egypt.



between 0.92-1.07 with an average of 1.00 for females (Table 3).

Length at first maturity

To determine the length at first maturity, males and females were grouped into 10 mm size groups and the percentage occurrence of fish at the different maturity stages in each size group was calculated. Examination of the male and female maturity stages indicated that males and females of *S. rivulatus* matured at about 15.5 cm total length (2 year old) (Figure 5).

Gonadosomatic Index (GSI)

The monthly changes in GSI values of individuals of both sexes are given in Figure 6. It was observed that the GSI values of males and females were low during February, March, and April 2011. Index values began to increase after April to reached maximum values in July, and then began to decrease indicating that its breeding season is in July.

Growth in weight

The calculated weights at the end of each year of life of *S. rivulatus* were estimated by applying the corresponding length-weight equation to the back calculated lengths. The resulting values are given in Tables 3 and 4. The obtained results for males and females indicated that the growth rate in weight was slow during the first year of life. Then the annual growth increment in weight increased with further increase in age until it reached its maximum value at the end of the third year of life, after which a decrease in the growth increment was observed.

Age group	Mean number	Back calculated weights in (g)					
		1	2	3	4	5	6
I	34	12.21					
II	41	13.04	30.32				
III	61	16.24	37.61	81.83			
IV	36	15.61	38.89	72.91	105.16		
V	33	13.48	42.66	83.47	112.89	138.51	
VI	12	13.26	38.66	77.89	114.76	143.00	169.37
Average total	217	13.97	37.63	79.03	110.94	140.76	169.37
Increment of weight		13.97	23.66	41.40	31.91	29.82	28.61

Table 4: Calculated weights of female *Siganus rivulatus* from the Bitter lakes, Egypt.

Sex ratio

As presented in Table 6, the percentage of females to males (sex ratio) of *Siganus rivulatus*, in Bitter lakes is fluctuated around the year. It was obvious that sex-ratio deviate significantly from 1:1 among the size classes. However, the overall sex ratio (Males: Females) of this species during the year was 1: 1.079 and did not differ significantly from 1:1. It ranged between 48.4 in June as a minimum value to 55.8 in December, maximum one. However, the number of both sexes is equal with percentage 50.0% in May. But in July (spawning period) the males somewhat predominated females (percentage of sex ratio is 48.5%).

Mortality rates

By using the cumulative curve of *S. rivulatus* (Figure 7) illustrating length at first capture at 50 % and applying the method of Sparre et al. the total mortality coefficient (Z) was estimated. This coefficient was found to be 0.8840 year⁻¹. But the Natural mortality coefficient "M" which obtained from the mean total length was 0.2214 year⁻¹. Using the estimated (M) and (Z) the fishing mortality (F) was obtained (0.6626 year⁻¹), where Z=M + F.

Exploitation rate (E)

According to Gulland [36] who suggested that the optimum exploitation rate in an exploited stock should equal approximately 0.50.

Author	Location	Year	sex	L _∞ (cm)	K (year ⁻¹)	to (year)
El-Gammal [13]	Red Sea (Egypt)	1988	M	31.5	0.501	-0.09373
			F	34.2	0.434	-0.1002
EL-Okda [23]	Red Sea (Egypt)	1991	M	30.6	0.513	-0.07638
			F	31.2	0.499	-0.04007
			C	30.9	0.505	-0.05562
EL-Okda [23]	Mediterranean(Egypt)	1998	C	32.0	0.299	-0.09786
Bilecenoglu and Kaya [18]	Med. (Turkey)	2002	M	21.1	0.345	-0.537
			F	22.6	0.267	-0.473
			C	22.3	0.279	-0.503
El-Ganainy and Ahmed [15]	Red (Egypt)	2002	C	29.4	0.735	-0.220
Mehanna and Abdallah [39]	Red (Egypt)	2002	C	37.1	0.397	-0.186
Bariche [43]	Mediterr. (Lebanon)	2005	C	31.9	0.225	-1.307
Present study	Bitter Lakes Egypt	2011	M	36.5	0.0786	-1.0038
			F	35.5	0.0849	-0.843

Table 5: Von Bertalanffy parameters from the literature and the present study for male (M), female (F) and combined sex (C) of *Siganus rivulatus*.

Authors	Location	year	sex	a	b	r
Hashem [9]	Red Sea (Saudi Arab.)	1983	combined	0.021	3.071	-
El-Gammal [13]	Red Sea (Egypt)	1988	Male	0.012	2.838	0.99
			Female	0.011	2.841	0.99
Mohamed [17]	Mediterranean Sea (Egypt)	1991	Male	0.018	2.830	0.99
			Female	0.017	2.866	0.99
			Combined	0.012	2.934	0.99
EL-Okda [23]	Mediterranean Sea (Egypt)	1998	Combined	0.016	2.872	-
Taskavak and Bilecenoglu [18]	Mediterranean Sea (Turkey)	2001	Combined	0.047	3.203	0.98
Mehanna and Abdallah [39]	Mediterranean Sea (Egypt)	2002	Combined	0.022	2.820	0.93
Bilecenoglu and Kaya [18]	Mediterranean Sea (Turkey)	2002	Male	0.075	3.135	0.95
			Female	0.064	3.221	0.95
			Combined	0.071	3.179	0.95
Mehanna and Abdallah [39]	Red Sea (Egypt)	2002	Combined	0.012	3.020	-
Tharwat and Al-Owafeir	Red Sea (Saudi Arb.)	2003	Combined	0.013	2.990	0.99
Bariche et al. [43]	Mediterranean Sea (Lebanon)	2005	Male	0.020	3.323	0.95
			Female	0.010	3.011	0.96
			Combined	0.010	3.037	0.99
Present study	Bitter Lakes (Egypt)	2011	Male	0.0104	3.010	0.98
			Female	0.0095	3.042	0.98

Table 6: Estimated parameters of *S. rivulatus* recorded by some other authors in different regions.

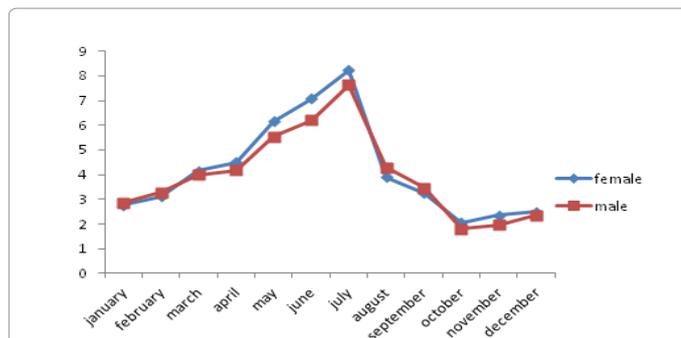


Figure 6: Monthly changes in the Gonadosomatic Index of both sexes of *S. rivulatus*.

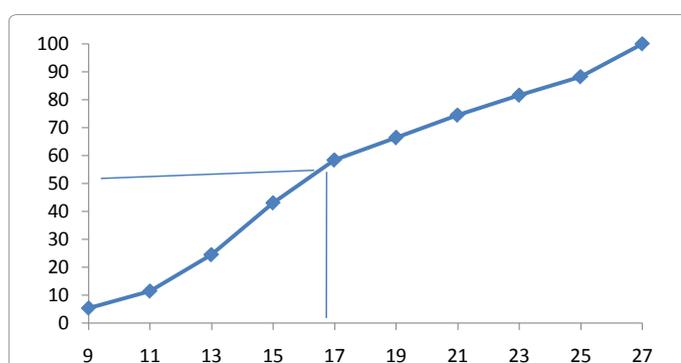


Figure 7: Cumulative curve from which length at first capture was determined.

The current exploitation rate "E" was estimated at 0.75. Accordingly, the high value of the current exploitation rate indicates that the stock of *S. rivulatus* in the Red Sea is subjected to overfishing.

Length at first capture (Lc)

The length at first capture L50% (the length at which 50% of the fish are first exposed to capture) was estimated as a component of the length converted catch curve analysis (FiSAT), was found to be 16.4 cm which corresponds to an age of 2.37 years.

Discussion

The most abundant size class (18 cm) for both sexes of *S. rivulatus*, is composed of individuals that have already reproduced (15.5 cm). This observation is closed to that reported for the same species at Libyan coast [25]. The same authors stated that, the age is necessary to assess population dynamics and the state of exploited resources. The opaque zone on the Otoliths of *S. rivulatus* corresponds to a rapid growth but the translucent zone to a slow growth of the fish. This phenomenon is observed in a large number of fish species living in subtropical and temperate regions in tropical regions Brothers, [37] and in other Lessepsian species [38]. The maximum ages for males and females of *Siganus rivulatus* were observed at six years in the present study. However, Mohamed stated that, the maximal age of both males and females of *Siganus rivulatus* were four years in Alexandria region, while Bariche estimated it to be six years in Batrun, Lebanon. On the other hand, in Red Sea, El-Gammal estimated the maximal age to be four and five years for males and females respectively whereas Mehanna and Abdallah [39] estimated five years for combined sex for the same fish species using the same method. Otherwise, Hashem estimated six years in Mediterranean and Red Sea respectively for *Siganus rivulatus* using the Peterson (length frequency) method. Hussein recorded six years

while Bilecenoglu and Kaya determined eight years of Mediterranean Sea for the same fish using posterior body scale reading. Also, Shiekh-eidin recorded six years in the Red Sea, using the same method and El-Okda determined four years as maximum age using the vertebrae. These differences between the age groups may be returned to the way of samples collection and its length range or the method used in age determination [19]. The maximum theoretical length is found to be slightly higher but in accordance with those available in the literature for *S. rivulatus*, except for those calculated by Mehanna and Abdallah (Table 5). The differences between parameters of the von Bertalanffy growth equation in different locations (Mediterranean and Red Sea) found in Table 5 may be resulted from different factors such as sampling, ageing method used or even geographical differences of habitats and fish condition. Von Bertalanffy parameters from the literature and the present study for male (M), female (F) and combined sex (C) of *Siganus rivulatus* (Table 6). The sex ratio of females to males for all individuals of *S. rivulatus* was about 1.079: 1. However this ratio varied in different length groups. These changes in percentage of females to males were most probably due to spawning and feeding migration [40]. The increase in ratio of females in February to April and the decrease of such ratio in September and October may be due to feeding migrations. In the other hand, the relatively equal percentage in May, June and July, which is accepted as spawning period, all population members come together and form sex ratio of about 1 : 1 (spawning migrations). The spawning season of *S. rivulatus* in Bitter Lakes extended from May to July (i.e. three months). These observation is closed to that reported for the same species at Turkey [41], at Israel [42] and at Lebanon [43] and slightly differed from that mentioned in the Mediterranean coast of Turkey by Torcu [44] and Yeldan and Avsar [40] from April to August and of Alexandria by Hussein from July to August as well Mohamed [17] and El-Okda [23] from May to August. In the other hand, the spawning season of *Siganus rivulatus* in Red Sea begins earlier than in Mediterranean as reported by Popper et al. [45] at the Gulf of Aqaba, also Hashem [9] from March to April and by Amin [20] from February to April at Jeddah region of the Red Sea. The value of total mortality obtained from the present study ($Z=0.884 \text{ year}^{-1}$) is agree with that reported by El-Gammal [13] in the Red Sea at Ghardaqa region where $Z=0.82 \text{ year}^{-1}$. Nonetheless, it is lower than that estimated by Mehanna and Abdallah [39] in the Egyptian sector of the Red Sea ($Z=1.270 \text{ year}^{-1}$), and El-Gainay and Ahmed in the eastern side of Suez Gulf ($Z=3.15 \text{ year}^{-1}$). On the other hand, the natural and fishing mortalities ($M=0.2214$ and $F=0.6626 \text{ year}^{-1}$) in the present study are lower than that obtained by El-Gainay and Ahmed [15] in the eastern side of Suez Gulf ($M=1.43$ and $F=1.72$) and nearly equal to that reported by Mehanna and Abdallah [39] ($M=0.26$ and $F=1.01 \text{ year}^{-1}$). Concerning mortality estimates, comparison is so difficult due to shortage of data and the total mortality coefficient is not a species-specific parameter, but an area specific parameter.

The exploitation rate of *Siganus rivulatus* in the present study ($E=0.75$) is higher than 0.50. of Gulland suggested that as a rule of thumb a fish stock is optimally exploited at a level of fishing mortality that generates $E=0.50$ where optimum fishing mortality equal the natural mortality ($F=M$). However, Pauly [35] proposed a lower optimum fishing mortality ($F=0.40$). Therefore, the stock of rabbit fish (*Siganus rivulatus*) from the Bitter lakes is being seriously over-exploited by the nylon trammel nets used, such observation noted also in Egyptian sector of the Red Sea by Mehanna and Abdallah where $E=0.80$, and the eastern side of Suez Gulf by El-Gainay and Ahmed [15] where $E=0.55$. It can be concluded that the *S. rivulatus* stock in the Egyptian Bitter Lakes is in a circumstances of overexploitation and to maintain

this valuable fisheries resource some management measures, including reduction of the present level of fishing mortality and increase in the length at first capture should be applied.

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