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Growth, mortality and yield per recruit of the rabbit fish *Siganus rivulatus* (Forsskål 1775) in the red sea coast of Jeddah, Saudi Arabia

Mohamed Hosny Gabr, Awadh Salem Bakaili and Ahmad Osman Mal

Abstract
The yield per recruit of *Siganus rivulatus* in Jeddah fisheries was estimated based on growth parameters and mortality coefficients investigated during the period from April 2013 to May 2014. Growth rates and von Bertallanfy growth parameters were estimated based on age determination using otoliths. The estimated growth parameters were L_∞ = 38.1 cm, K = 0.275 and t_0 = -0.24 year. The length weight relationship could be described by the equation: $W = 0.011\ L^{3.06}$. Mortality coefficients were estimated as total coefficient 'Z' = 2.04 year^{-1}, natural coefficient 'M' = 0.413 year^{-1}, and fishing coefficient 'F' = 1.627 year^{-1}. The exploitation level 'E' was estimated to be 0.8 year^{-1}. The yield per recruit estimated at the current level of fishing mortality was 66.715 gm. The maximum yield per recruit (67.8 gm) can be obtained by reducing the current level of fishing mortality to be F_{max} = 1.0 year^{-1}. These results indicated that the stock of *Siganus rivulatus* in Jeddah fisheries is currently overexploited.

Keywords: *Siganus rivulatus*, growth, mortality, yield per recruit, Jeddah fisheries

Introduction
Members of the family Siganidae (Rabbitfishes) are widely distributed throughout the tropical and subtropical waters in the Western Indo-Pacific region. They are herbivorous fishes, their distribution on the tropical reefs is more restricted than that of Acanthuridae or Scaridae [1, 2].
The marbled spinefoot rabbitfish *Siganus rivulatus*, locally known as "Sigan", is the most common among the five species of the genus *Siganus* that exist in Jeddah fisheries [3]. This species inhabits shallow sandy areas, lagoons, around rocks and coral reefs. It is one of the Lessepsian migrants [4] which invaded the Mediterranean and became one of the commercial exotic fishes there [5-9].
Due to the commercial importance of the marbled spinefoot *Siganus rivulatus* as food fish, and the growing need to fish protein, there was a lot of research about the biology of this species in its distribution area to understand how to increase its productivity in Fisheries [3, 8-19] and in mariculture [20-23].
In the Red Sea (native habitats), El-Gammal (1988) [13], El-Ganainy (2002) [44], and Mehanna and Abdallah (2002) [16] studied the growth, mortality and yield per recruit of the spinefoot. In the new (invaded) habitats of the Mediterranean, Mohammed (1991) [36], El-Okda (1998) [15], Bilecenoglu and Kaya (2002) [7], Bariche (2005) [8], and El-Far (2008) [37] studied different biological aspects including age, growth, mortality, and yield per recruit of this species.
The last recorded study on this species in Jeddah fisheries was that of Gabr and Mal [24] who studied the selectivity of trammel nets for this species. Whereas the last recorded study on the biology of this species in Jeddah fisheries was that of Amin [10, 11]. Since then, there is no published research on the fishery biology or stock assessment of the marbled spinefoot *S. rivulatus* exploited in Jeddah coral reef fisheries. Thus, the current study was carried out to determine age, growth parameters, mortalities and then do estimate the yield per recruit of *S. rivulatus* in Jeddah fisheries to evaluate the current stock status of this species.

Materials and Methods
Specimens of *Siganus rivulatus* were monthly collected from the main landing site of Jeddah Fisheries (Figure 1) during the daily auction for fresh fish catch of local artisanal fishermen.

A total of 2177 specimen were collected during the period from April 2013 to May 2014. Total fish length (TL) was measured to the nearest 0.1 cm and the total fish weight (TW) to nearest 0.1 gm was recorded.

For age determination, the largest pair of otoliths was removed from each assigned specimen, cleaned and preserved in Eppendorf vials containing water. The annual rings formed on the otoliths were counted using MEIJI Zoom Stereomicroscope. Micrometrics SE Premium software was used to capture and save pictures for recording otolith measurements. The individual back – calculated lengths at the end of each year of life of *Siganus rivulatus* in Jeddah fisheries were estimated using the Lee's equation [25] as applied in Gabr [26] and Gabr and Mal [27].

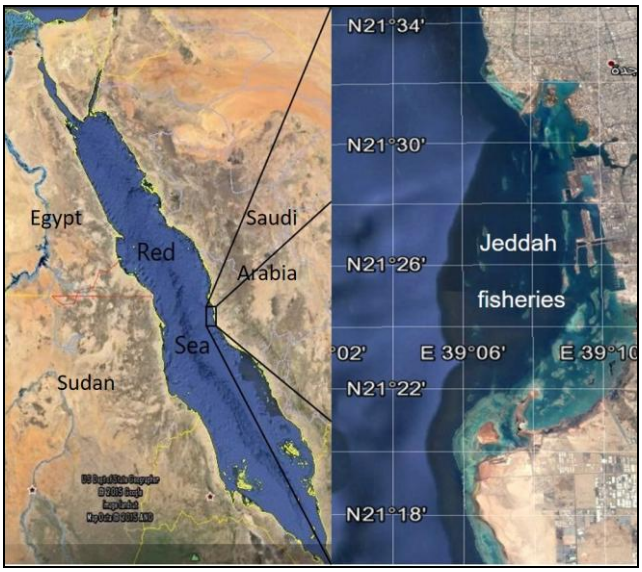

Fig 1: Map showing Jeddah fisheries in the Red Sea

The length - weight relationship was described by the power equation, $W = a L^b$, which gives a straight-line by a logarithmic transformation as follows: $Log_e W = Log_e a + b Log_e L$, where, W is the body weight in gram, L is the total fish length in centimeter, a & b are the intercept and slope of the regression line.

The theoretical growth in length of *Siganus rivulatus* was described by applying the following growth model of von Bertalanffy [28] as applied in Gabr [26] and Gabr and Mal [27]: $L_t = L_\infty [1-e^{-K (t-to)}]$. The growth performance index (Ǿ) was estimated according to the formula [29]: $Ǿ = Log K + 2LogL_\infty$, where K and L_∞ are parameters of von Bertalanffy growth equation.

Based on converting lengths to their corresponding ages by applying the von Bertalanffy growth parameters, the linearized length-converted catch curve method described by Pauly [30] was used to estimate the total mortality coefficient (Z) of *S. rivulatus* in Jeddah fisheries. The equation described by Jensen [31] was used to estimate the natural mortality coefficient " M " for *Siganus rivulatus*: M = 3/2 K**,** where, K is the growth coefficient in the von Bertalanffy growth function. The fishing mortality coefficient (F) was determined by subtracting the value of the natural mortality coefficient (M) from the total mortality coefficient (Z): F = Z - M

The length at first capture 'L_c' was determined graphically by the cumulative catch curve analysis as described in Pauly [32].

The yield per recruit of *Siganus rivulatus*, collected during the period of the present study, was estimated using the following model of Beverton & Holt [33].

$$\frac{Y}{R} = F \times EXP[-M \times (t_c - t_r)] \times W_\infty \times \left[\left(\frac{1}{Z}\right) - \left(\frac{3S}{Z+K}\right) + \left(\frac{3S^2}{Z+2K}\right) - \left(\frac{S^3}{Z+3K}\right)\right]$$

where, $\frac{Y}{R}$ is yield per recruit, F is the fishing mortality coefficient, M is the natural mortality coefficient, t_c is the mean age at first capture, t_r is the mean age at recruitment, W_∞ is the theoretical maximum weight, Z is total mortality coefficient, K is growth coefficient and S equal to following equation: $S = e^{-K (tc - t0)}$. The biomass per recruit $\frac{B}{R}$ was estimated by dividing the $\frac{Y}{R}$ by the fishing mortality F. The effects of the age at first capture t_c on $\frac{Y}{R}$ were investigated by estimating the $\frac{Y}{R}$ at different levels of t_c.

Results and Discussion

Age determination

For age determination, otoliths are suitable and more satisfactory because they are formed earlier in life than scales [34, 35]. So, in the present study, age determination of *Siganus rivulatus* in Jeddah fisheries was based on the counting and interpretation of growth zones formed on the sagittal pair of otolith (as shown in Figure 2). From otolith readings of 2004 specimens of *Siganus rivulatus* collected from Jeddah fisheries, four age groups were assigned for males ranging in total length from 11.3 to 28.3 cm, and five age groups were assigned for females ranging in total length from 11.2 to 30.2 cm. For pooled data, Fishes of age groups I & II constituted the bulk of the catch and represented 83.14 % of total specimens.

However, using otoliths to determine the age of the marbled spinefoot was approved by many authors in the Red Sea and Mediterranean Sea [13, 16, 19, 36, 37]. The same maximum ages were determined for the same species in the Egyptian sector of the Red Sea by El-Gammal [13], where he used otoliths for age determination, and reported four years for males and five years for females. Also, Mehanna and Abdallah [16] used otoliths for age determination of *Siganus rivulatus* in the Egyptian sector of the Red Sea, and reported that the maximum age of this species is five years.

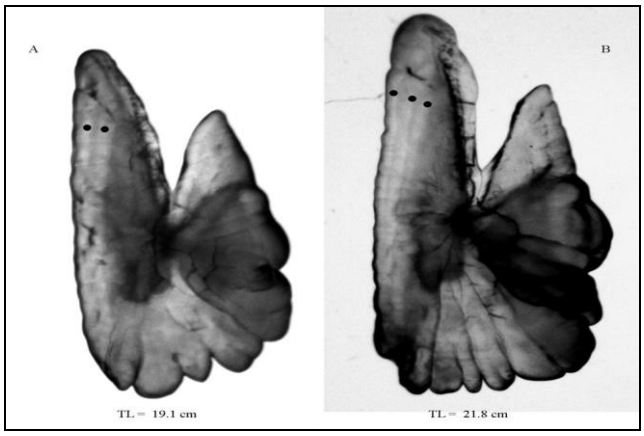

Fig 2. Otolith shape of age group II+ (A), and age group III+ (B) of S. rivulatus in Jeddah fisheries (black dots refer to the hyaline growth bands of the annuli)

Back-calculations and growth in length

In the present study, the relationship between the otolith radius (R) and the total fish length (cm) for *Siganus rivulatus* in Jeddah fisheries was found to be linear and could be described by the following equation and graphically represented in Figure 3:

L = -3.58 +14.69 R (r = 0.87, N = 2004)

The results given in Table 1 show the number of specimens assigned for each age group, the average back –calculated lengths at the end of each year of life, the growth in length and the annual increment in lengths. The growth in length and annual increment for sexes combined are graphically represented in Figure 4.

Table 1: Growth in length & annual increment of *Siganus rivulatus* (Sexes combined) collected from Jeddah fisheries

Age group	Number	Back - calculated length at the end of each year of life					growth in length (cm)	Annual increment (cm/year)
		1	2	3	4	5		
I	520	10.7					10.70	10.70
II	1146	10.9	17.3				17.30	6.60
III	308	11.1	17.7	22.0			22.00	4.70
IV	23	10.9	17.2	22.0	26.8		26.80	4.90
V	4	10.40	16.95	22.40	26.65	28.97	28.97	2.12

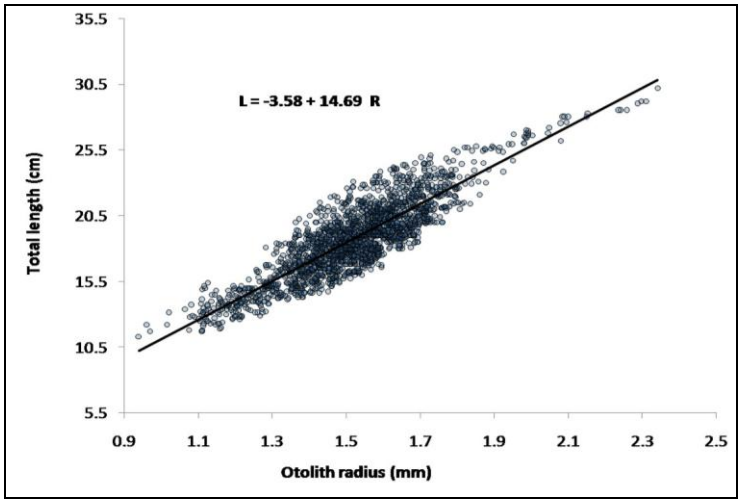

Fig 3: Total length-Otolith radius relationship of Siganus rivulatus (sexes combined) collected from Jeddah fisheries

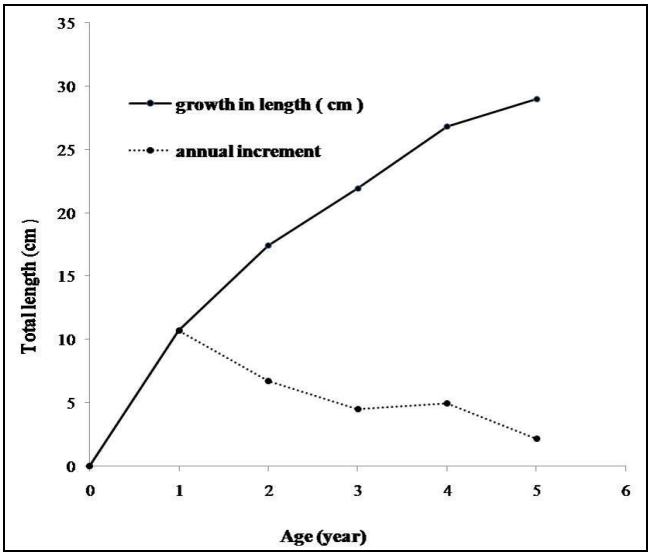

Fig 4: Growth in length & annual increment of *Siganus rivulatus* (Sexes Combined) collected from Jeddah fisheries.

The results indicated that the highest growth rate was attained by the end of the first year of life (10.7 cm), whereas the least growth was found during the fifth year of life (2.12 cm). Comparative results estimated by different authors at various locations in the Red Sea and Mediterranean Sea are given in Table 2. There are variable differences in the number of age groups and the calculated lengths at ages which may be related to differences in size ranges of collected samples, the method and parts used for age determination and measurements [8]. However, all authors obtained the same conclusion that the maximum growth in length of the marbled spinefoot was attained during the first year of life.

Length – weight relationship

The analysis of the relationship between fish length and fish weight of *Siganus rivulatus* was based on total length and body weight measurements of 1082 males and 1094 females. The total length of males ranged from 11.3 to 28.3 cm and the total weight ranged from 21.2 to 268 g. For females, the total length ranged from 11.0 to 30.2 cm and the total weight ranged from 20.5 to 336 g. The length-weight relationship for pooled data (sexes combined) could be described by the following power equations and graphically represented in Figure 5: $W = 0.011\ L^{3.06}$ ($r^2 = 0.96$, N = 2176)

Table 2: Calculated lengths at ages of Siganus rivulatus estimated by different authors at different locations in Red Sea and Mediterranean.

Author (year)	Location	Method	Sex	I	II	III	IV	V	VI
Present study	Red Sea (Saudi Arabia)	Otolith	M	10.7	17.3	21.5	25.8	-	-
			F	10.7	17.3	22.0	26.9	28.9	-
			C	10.7	17.3	22.0	26.8	28.97	-
El-Gammal [13]	Red Sea (Egypt)	Otolith	M	13.05	20.39	24.52	27.53		-
			F	13.22	20.55	25	28.17	30.65	-
Mehanna and Abdulla [16]	Red Sea (Egypt)	Otolith	C	13.86	21.3	26.84	29.98	32.30	-
Hashem [3]	Red Sea (Saudi Arabia)	Length frequency	C	8	15	20	24.5	27	29.5
El-Ganainy and Ahmed [44]	Red Sea (Egypt)	Length frequency	C	15.8	19.3	22.3	24.0	-	-
Hussein [12]	Mediterranean (Egypt)	Scales	C	10.1	16.1	19.9	22.98	25.7	-
El-Far [37]	Mediterranean (Egypt)	Otolith	M	10.47	14.56	17.44	19.95	21.90	-
			F	10.53	14.59	17.64	19.98	21.91	-
			C	10.47	14.57	17.55	19.96	21.90	-
Shakman *et al.* [9]	Mediterranean (Libyan coast)	Otolith	C	10	13	16	20	23	24
Bariche [8]	Mediterranean (Lebanon)	Otolith	C	12	16	20	22	25	27
El-Drawany [19]	Bitter Lakes (Egypt)	Otolith	M	10.92	15.18	18.95	21.44	23.57	25.36
			F	10.89	15.76	19.65	21.72	23.40	24.97

However, there are many published results of the length-weight relationship for the marbled spinefoot in the Red sea and Mediterranean Sea; the parameters of these relationships are listed in Table 3. The estimated values of the exponent "b" varied between 2.84 and 3.07 for populations in the Red sea, and 2.59 and 3.32 for populations in the Mediterranean Sea. This range of b values coincides well with that reported by Froese [38] and suggested by Carlander [39] that the exponent b should be between 2.5 and 3.5. As mentioned by many authors [8, 40, 41], variations in the b values of the length weight relationship may be due to many factors including seasonal, regional, water temperature, sex, food availability, and the length range of the specimens used in the regression analysis.

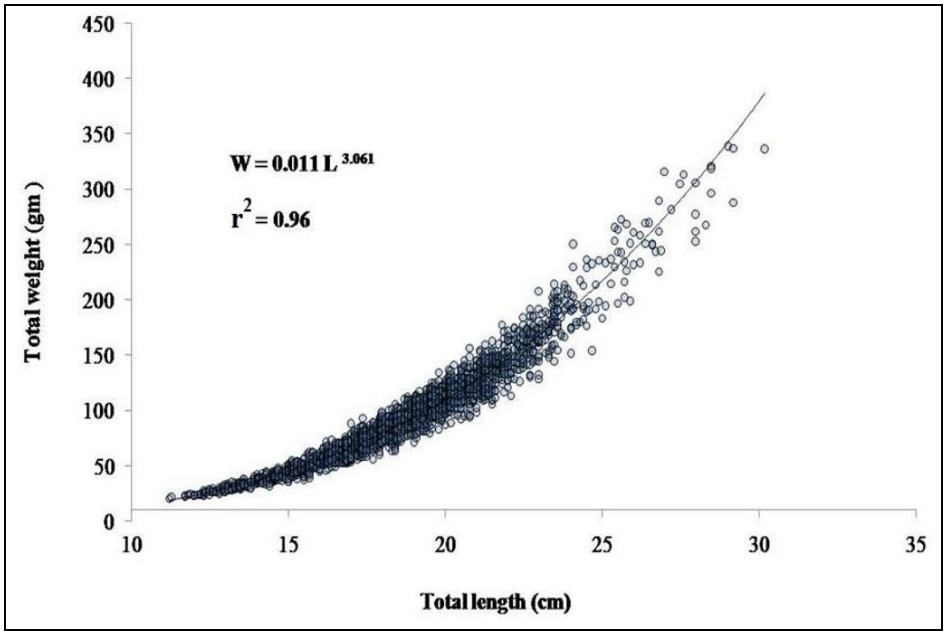

Fig 5: Length weight relationship of *Siganus rivulatus* (Sexes combined) collected from Jeddah fisheries.

Table 3: Parameters of the length weight-relationship of *S. rivulatus* at different locations in Red Sea and Mediterranean.

Authors	Area	Sex	a	b	r	N	Size range (cm)
Present study	Red Sea (Saudi Arabia)	M	0.12	3.049	0.98	1000	11.3 – 28.3
		F	0.0123	3.029	0.99	1004	11.2 – 30.2
		C	0.0114	3.061	0.98	2004	11.2 – 30.2
Hashem [3]	Red Sea (Saudi Arabia)	C	0.021	3.071	-	898	11.0 – 30.0
El-Gammal [13]	Red Sea (Egypt)	M	0.012	2.838	0.99	114	-
		F	0.011	2.841	0.99	137	-
Mehanna and Abdulla [16]	Red Sea (Egypt)	C	0.012	3.02	-	425	-
Tharwat and Al- Owafair [18]	Red Sea (Saudi Arabia)	C	0.013	2.99	0.96	200	15.0 – 27.0
Mohammed [36]	Mediterranean (Egypt)	M	0.018	2.83	0.99	-	-
		F	0.017	2.866	0.99	-	-
		C	0.012	2.934	0.99	-	-
El-Okda [14]	Mediterranean (Egypt)	C	0.016	2.872	-	1126	11.0 – 28.0
Taskavak & Bilecenoglu [45]	Mediterranean (Turkey)	C	0.047	3.203	0.96	355	10.7 – 24.1
Bilecenoglu and Kaya [7]	Mediterranean (Turkey)	M	0.075	3.135	0.95	229	7.1 – 20.6
		F	0.064	3.221	0.95	292	7.0 – 21.5
		C	0.071	3.179	0.95	521	7.0 – 21.5
Bariche [8]	Mediterranean (Lebanon)	M	0.02	3.323	0.95	98	12.7 – 23.2
		F	0.01	3.011	0.96	93	12.6 – 26.7
		C	0.01	3.037	0.99	781	12.4 – 26.7
El–Far [37]	Mediterranean (Egypt)	M	0.039	2.594	0.97	586	10.9 – 25.9
		F	0.017	2.906	0.98	617	9.7 – 22.9
		C	0.023	2.783	0.93	1217	8.6 – 25.9

Growth in weight

The average back-calculated lengths at the end of each year of life of *S. rivulatus* were converted to their corresponding weights by applying the corresponding length-weight equation for pooled data. The average back-calculated weights, the growth in weight and annual increment were estimated and the results are given in Table 4. The growth in weight and annual increment in weight are graphically represented in Figure 6. Unlike the growth increment in length, the growth rate in weight was slow during the first year of life (16 gm), then the annual growth increment in weight increased with further increase in age until it reached its maximum value at the end of the fourth year of life (123.2 gm) and was greatly reduced to 70.7 gm in the fifth year. Based on the back-calculated lengths given in Table 2 and the length weight relationship parameters given in Table 3, it can be concluded that the growth rate in weight for the marbled spinefoot, at the various locations, is the lowest during the first year of life.

Table 4: Growth in weight and annual increment of Siganus rivulatus (Sexes combined) collected Jeddah fisheries.

Age group	N	Back - calculated weight at the end of each year of life					Growth in weight (gm)	Annual increment (gm/year)
		1	2	3	4	5		
I	520	16.0					16.0	16.0
II	1146	17.3	70.7				70.7	54.7
III	308	18.0	75.9	146.4			146.4	75.7
IV	23	17.3	69.4	147.4	269.6		269.6	123.2
V	4	14.8	66.0	154.9	263.6	340.3	340.3	70.7

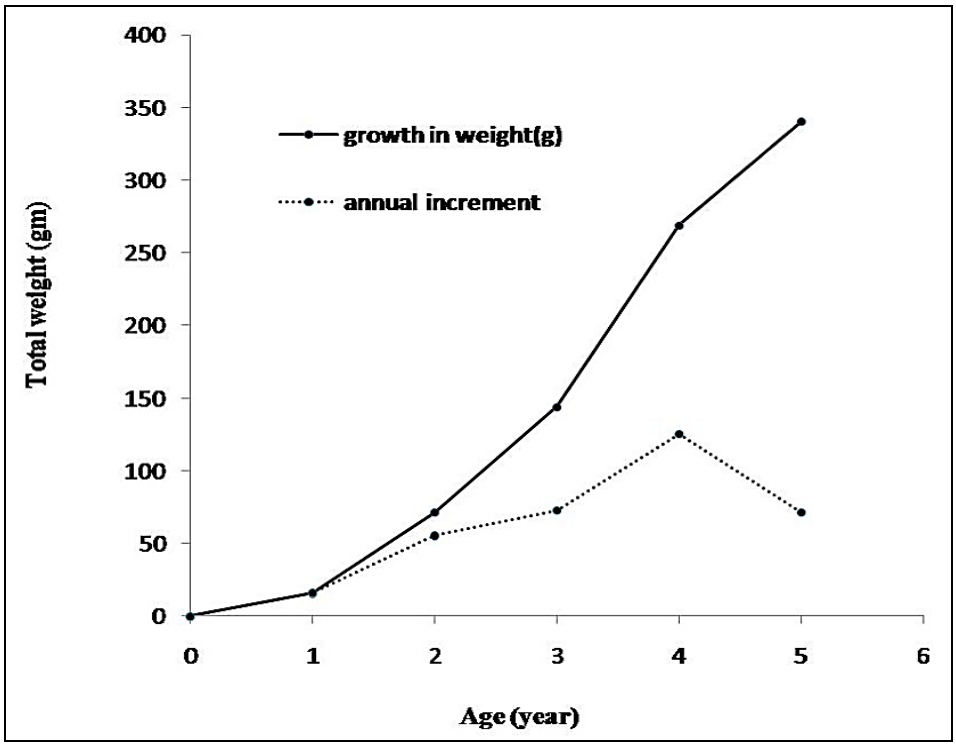

Fig 6: Growth in weight and annual increment of Siganus rivulatus (Sexes Combined) Collected from Jeddah fisheries.

Growth Parameters

The von Bertalanffy growth parameters were estimated by the method of Ford [42] -Walford [43], and the von Bertalanffy growth equation for the theoretical description of growth in length of *Siganus rivulatus* in Jeddah fisheries could be written as follows:

$L_t = 38.1\ [1- e^{-0.275\ (t + 0.24)}]$

The theoretical description of growth in length of *S. rivulatus* is graphically represented in Figure 7. Based on values of the estimated growth parameters, the growth performance index for *S. rivulatus* (Ǿ) was estimated to be: Ǿ = Log 0.275 + 2 Log 38.06 = 2.60

In general, results in Table 5 show that the maximum theoretical length 'L_∞' of *Siganus rivulatus* in the Red Sea fisheries (ranging between 31.5 and 38.16 cm) is larger than that in the Mediterranean Sea (ranging between 21.1 and 32 cm). Moreover, the growth performance index (Ǿ) of this species in the Red Sea fisheries (ranging between 2.58 and 2.74 cm) is higher than that in the Mediterranean Sea (ranging between 2.13 and 2.49 cm). These results indicate that the new environment in the Mediterranean Sea, invaded by the marbled spinefoot through the Suez Canal, may have adverse conditions for the growth of this species compared to that in the Red Sea.

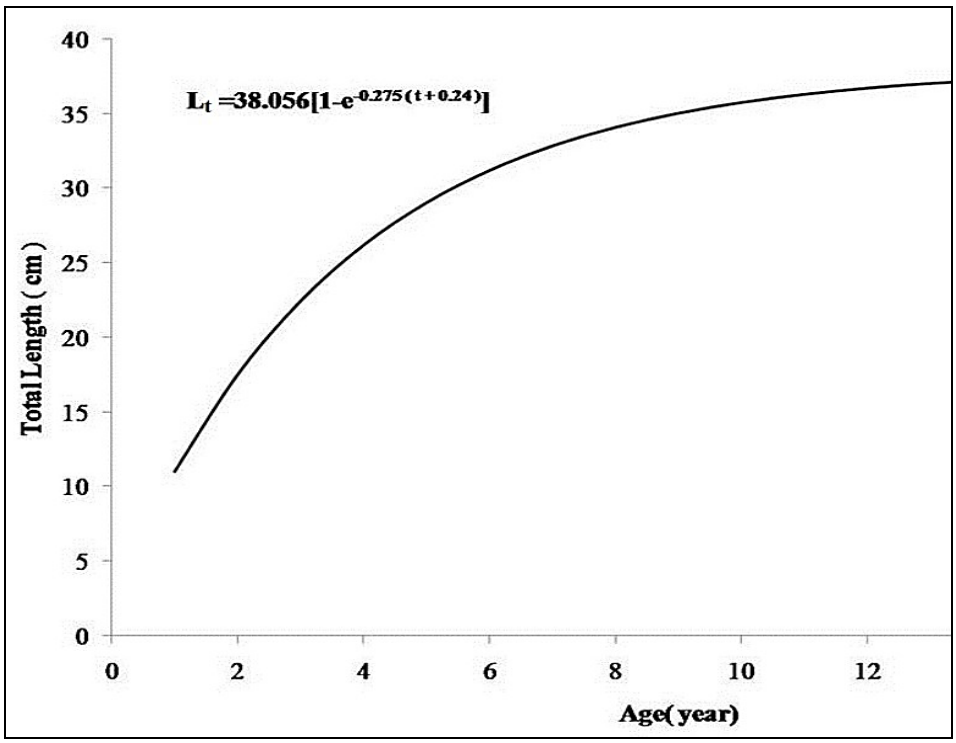

Fig 7: Theoretical growth in length of *Siganus rivulatus* (Sexes Combined) collected from Jeddah fisheries

Table 5: von Bertalanffy growth parameters and Growth performance index (Ǿ) of *Siganus rivulatus* at different locations in the Red Sea and Mediterranean.

Author	Location	Sex	L_∞(cm)	W_∞ (gm)	K (year^{-1})	t_0 (year)	Ǿ
The present study	Red sea (Saudi Arabia)	M	37.89	742.23	0.268	-0.24	2.580
		F	38.16	799.13	0.27	-0.27	2.590
		C	38.06	784.65	0.275	-0.24	2.600
El-Gammal [13]	Red Sea (Egypt)	M	31.5	273.91	0.501	-0.0937	2.702
		F	34.2	436.11	0.434	-0.1002	
Mehanna and Abdullah [16]	Red Sea (Egypt)	C	37.1	665.69	0.397	-0.186	*2.738
EL-Okda [14]	Mediterranean (Egypt)	C	32	329.73	0.299	-0.09786	*2.486
Bilecenoglu and Kaya [7]	Mediterranean (Turkey)	M	21.1	112.06	0.343	-0.537	2.182
		F	22.6	146.81	0.267	-0.473	2.133
		C	22.3	137.87	0.279	-0.503	*2.142
Bariche [8]	Mediterranean (Lebanon)	C	31.9	318.2	0.225	-1.307	*2.360
El- Far [37]	Mediterranean (Egypt)	M	29.6	256.88	0.248	-0.8667	2.327
		F	28.2	269.41	0.264	-0.8155	2.313
		C	29.3	280.37	0.257	-0.8377	2.313

Mortality and Exploitation

The total mortality coefficient 'Z' of *Siganus rivulatus* in Jeddah fisheries, estimated using the linearized length converted catch curve graphically represented in Figure 8, was found to be 2.04 year^{-1}. The natural mortality coefficient 'M' estimated by the equation described by Jensen [31] was 0.413 year^{-1}. The fishing mortality coefficient 'F' was equal to 1.627 year^{-1} which is the difference between the total 'Z' and the natural 'M' mortality coefficients. Hence, the exploitation rate of both sexes combined was estimated to be E = 0.8 year^{-1}. However, similar exploitation rates were observed in the Egyptian sector of the Red Sea by Mehanna and Abdallah [16] (E = 0.80 year^{-1}), and in the Mediterranean Sea by El- Far [37] (E = 0.81 year^{-1}).

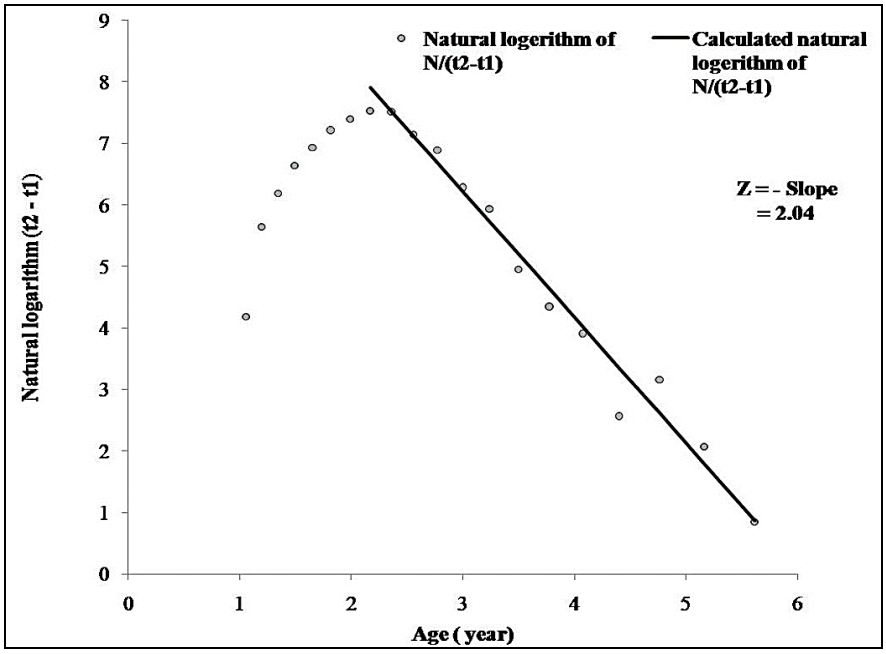

Fig 8: Linearized length converted catch curve based on length composition of *Siganus rivulatus* (Sexes Combined) collected from Jeddah Fisheries.

Length at first capture (L_c)

Figure 9 shows the cumulative length frequency distribution and the length at first capture of *S. rivulatus* collected from Jeddah fisheries during the period from April 2013 to May 2014. The length at first capture was found to be 18.35 cm. The age corresponding to this length was estimated by applying the von bertalanffy equation and found to be 2.23 years.

The estimated length at first capture in the present study is larger than that determined for the same species in the Egyptian sector of the Red Sea by Mehanna and Abdallah [16] (L_c =17.04 cm), and in the Mediterranean Sea by El- Far [37] (L_c =15.6 cm).

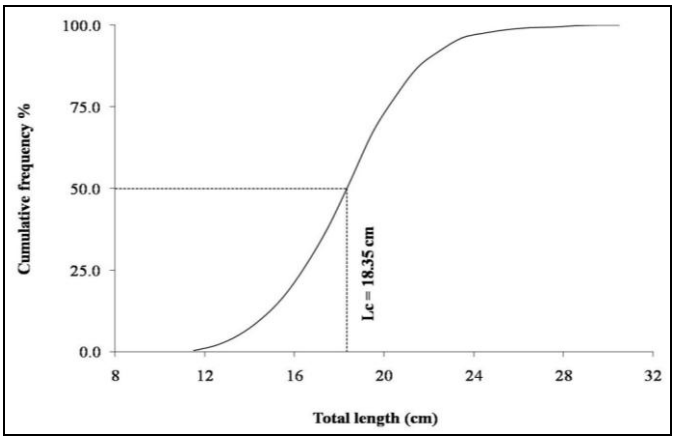

Fig 9: Cumulative length frequency distribution and the length at first capture of *Siganus rivulatus* collected from Jeddah fisheries.

Yield per Recruit

The results of the yield per recruit (Y/R) of *S. rivulatus* in Jeddah fisheries calculated as a function of the fishing mortality " F " are given in Table 6 and graphically represented in Figure 10. From the obtained results, it can be concluded that at the present level of natural mortality " M = 0.41 year^{-1}", age at first capture "t_c = 2.23 year" and fishing mortality "F = 1.627 year^{-1}", the yield per recruit of *S. rivulatus* in Jeddah fisheries was found to be 66.72 gm.

Table 6: Yield Per Recruit (gm) of *S. rivulatus* as a function of fishing mortality (F) and different ages (in years) at first capture (tc)

F	t_c = 2	t_c= 2.23	t_c = 2.5
0.1	31.595	31.063	30.252
0.2	47.458	47.127	46.376
0.3	55.895	55.998	55.605
0.4	60.517	61.101	61.154
0.5	63.053	64.103	64.606
0.635	64.399	65.875	66.801
0.7	65.044	66.901	68.213
0.8	**65.266**	67.461	69.120
0.9	65.233	67.727	69.696
1	65.043	**67.802**	70.049
1.1	64.761	67.754	70.249
1.2	64.426	67.627	70.345
1.3	64.062	67.450	**70.367**
1.4	63.687	67.241	70.339
1.5	63.310	67.015	70.276
1.627	**62.840**	**66.715**	**70.162**
1.7	62.577	66.541	70.085
1.8	62.228	66.303	69.970
1.9	61.892	66.069	69.849
2	61.570	65.840	69.724
2.1	61.262	65.618	69.597
2.2	60.968	65.403	69.470
2.3	60.688	65.195	69.345
2.4	60.421	64.996	69.221
2.5	60.167	64.804	69.100

Since the maximum sustainable yield per recruit (67.80 gm) can be obtained at lower fishing mortality F_{max} = 1.0 year^{-1}, this means that the current stock status of *S. rivulatus* in Jeddah fisheries is over-exploited, where both the limit reference point F_{max}=1.0 year^{-1} and the target reference point $F_{0.1}$=0.635 year^{-1} are lower than F_{cur} = 1.627 year^{-1}. Although similar situation of over-exploitation was found for the same species in the Mediterranean Sea by El-Far [37], the maximum yield per recruit of *S. rivulatus* in Jeddah fisheries (67.80 gm) was found to be higher than that estimated for the same species in the Mediterranean Sea (40.45 gm). These results indicated that the stock of *Siganus rivulatus* in Jeddah fisheries is currently overexploited. It is recommended that the current fishing level be reduced to the level of the target reference point $F_{0.1}$ = 0.635 year^{-1}.

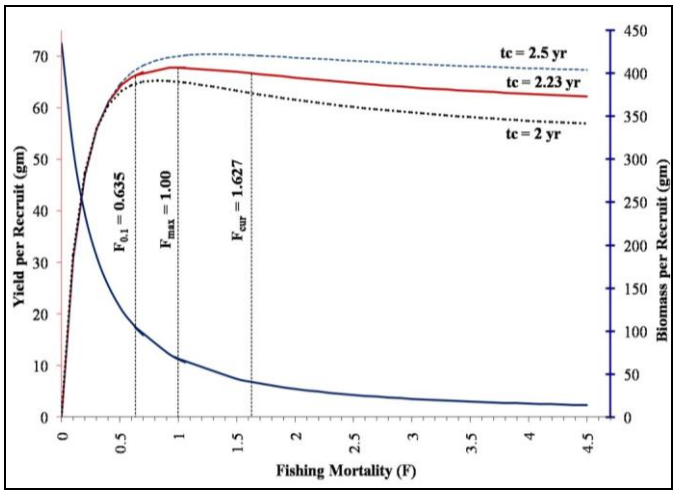

Fig 10: Yield Per Recruit (gm) of *S. rivulatus* as a function of fishing mortality (F) and different ages at first capture (t_c) collected from Jeddah fisheries

The effect of the age at first capture "t_c" on the yield per recruit was assessed through estimating the yield per recruit as a function of fishing mortality coefficient and different values of age at first capture. As given in Table 6 and represented in Figure 11, it is clear that, at present level of fishing mortality, the increase in the age at first capture from the current value (t_c = 2.23 year) to 2.5 year will increase the yield per recruit from 66.715 to 70.162 gm. In contrast, the decrease of age at first capture from current value to 1.96 year will be associated with a decrease in the yield per recruit from 66.715 to 62.840 gm.

Conclusions

From the results obtained in the present study we can conclude that the maximum recorded age of *Siganus rivulatus* in Jeddah fisheries is four years for males and five years for females. The maximum growth in length was attained at the end of the first year of life for both males and females (10.7 cm). The maximum theoretical length was estimated to be 38.05 cm corresponding to a maximum theoretical weight of 785 gm. The length-weight relationship reveals that the growth of *Siganus rivulatus* in Jeddah fisheries is isometric where the value of the slope "b" is not significantly different from its value "3" in the cubic law. The stock of the marbled spinefoot in Jeddah fisheries is currently over-exploited, where the current exploitation is 0.8 year^{-1}. This level is higher than both the limit biological reference point (F_{max}=0.71 year^{-1}), required to get the maximum yield per recruit, and the target biological reference point ($F_{0.1}$=0.635 year^{-1}) required to get the optimum yield per recruit. Increasing the age at first capture, which is related to the mesh size of the fishing gear, results in an increase in the yield per recruit and vice versa. It is recommended that the current fishing level be reduced to the target reference point $F_{0.1}$ = 0.635 year^{-1}.

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