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Population Dynamics and Stock Assessment of Two Lizardfish Species in the Southern Red Sea Coasts, Foul Bay, Egypt

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ABSTRACT
Lizard fishes are the most abundant demersal fishes inhabiting the Egyptian coasts of the Red Sea. They constitute 30% of the total trawl catch in the northern part (Gulf of Suez) and 26.9% of the total trawl catch in the southern (Foul Bay) part. Stock assessment was done for the pseudocohort of two lizardfish species from the Foul Bay. Random samples were collected between October 2013 and November 2021. A total of 1553, and 1320 *Saurida undosquamis* and *S. tumbil* specimens were collected, respectively, from the Foul Bay. Otoliths were used for age determination and differentiation between the species and sexes. The von Bertalanffy growth parameters ($L\infty$, K and t_0) were estimated for males, females and the whole population of each species. The instantaneous annual rates of total and fishing mortality and subsequently the exploitation rates were estimated and the yield per recruit was analyzed. Stock assessment revealed an over exploitation situation for lizardfish fisheries in the Foul Bay. The relationship between length and weight indicates an isometric growth for *S. undosquamis* and a positive allometric growth for *S. tumbil*.

INTRODUCTION

The Egyptian sector of the Red Sea is about 1080km from Suez in the north to Mersa Halayab in the south, and has three main fishing grounds: the Gulf of Suez, Foul Bay and the Gulf of Aqaba. In the past, the Gulf of Suez was the most productive area along the Egyptian Red Sea, with about 64% of the total fish production from the Egyptian Red Sea, followed by the Foul Bay (about 33%), while the Gulf of Aqaba remained an unexploited fishing ground (Mehanna, 2021). In the recent years and with the decline of fish stocks in the Gulf of Suez due to overfishing and illegal fishing methods, the Gulf of Suez contribution declined to only 37% of the Red Sea catch.

Foul Bay (Fig. 1) lies in the west side of the Red Sea near our boundaries with Sudan and enclosed between Ras Banas (23^0 55’ N, 35^0 47’ E) in the north and Abo Dara in the South (22^0 41’ N, 36^0 11’ E). Its length is about 150km, and its width varied between 20 and 65km, with depth of about 200m (El-Sharkawy, 1984). Three main fishing methods are operated in the Bay; namely, trawl purse-seine and artisanal fisheries, especially long and hand lines. There are five landing sites along the bay, including Ras

Banas, Berenice, Mersa Hemaira, Shalatein and Abo Ramad from which Berenice is the most productive fishing ground.

Family Synodontidae consists of four genera (77 species), viz. Harpadon, Saurida, Trachinocephalus and Synodus **(FishBase, 2022)**. Members of this family are commonly referred to as lizardfishes. They are the most abundant fish among trawl fisheries landings, contributing about 30% of the total trawl fishery in the northern Red Sea (Gulf of Suez) and a percentage of about 26.9 in the southern Red Sea (Foul Bay) (General Authority for Fish Resources Development). The brush-tooth lizard fish *Saurida undosquamis* is the most abundant species and the most commercially important fish species in the Egyptian Red Sea, as well as, the most studied species. Unfortunately, all previous studies focused on the Gulf of Suez fisheries **(Shenouda, 1976; Sanders & Kadidi, 1984; Sanders *et al*., 1984)**. The greater lizardfish *S. tumbil* is the second important species in the Synodontidae family from the bottom trawl fishery of the Egyptian Red Sea, and very few studies were conducted on this species **(Mehanna *et al*., 2006)**.

Because of the declined resources in the Egyptian waters, the importance of the two species has increased. The present work was organized to study the age and growth rate of two lizardfish species *Saurida undosquamis* and *S. tumbil* in Foul Bay (Berenice fishing area) and estimate the population parameters required for the assessment and management of those important species along the southern Red Sea, Egypt.

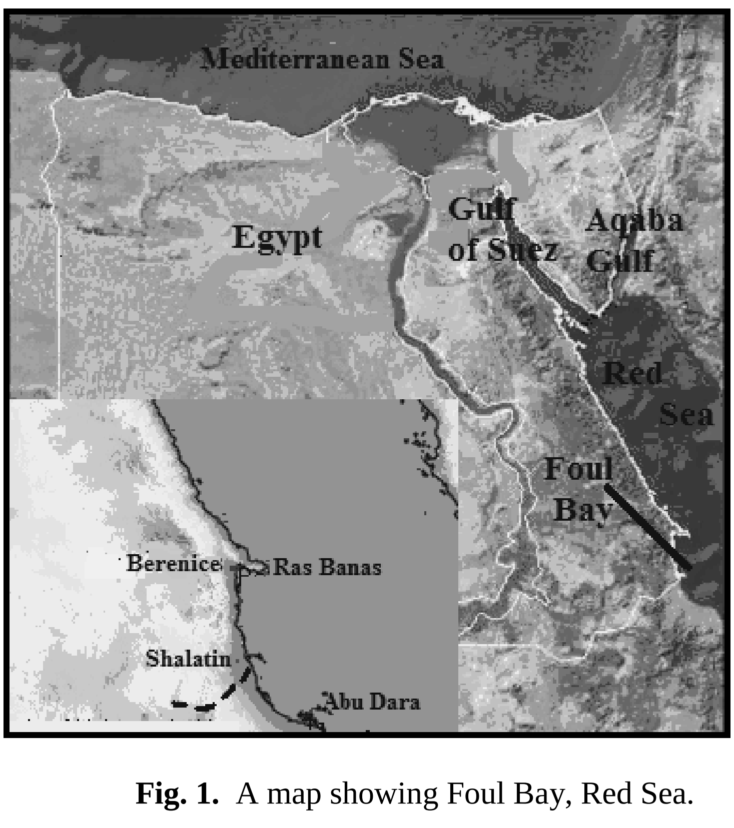

Fig. 1. A map showing Foul Bay, Red Sea.

MATERIAL AND METHODS

1. Sampling

A total of 1553 and 1320 of *Saurida undosquamis* and *S. tumbil* specimens were, respectively, collected from the commercial catches of the trawl fishery in Foul Bay (Berenice landing site) through 2013 to 2021. Each fish individual was measured to the nearest mm for total length and weighed to the nearest 0.1g for total weight. Otoliths were taken for each specimen, cleaned and stored dry for later age determination.

2. Methods

2.1 Age determination

Otoliths were cleaned with 1% HCl and rinsed with water then immersed in clove oil as a clearing solution and examined. Annual rings on otoliths were identified and counted using optical system consisting of Zeiss research microscope at 4× and 10× magnifications, connected to AxioCam HRC and Ziess KL 1500 LCD using transmitted light. The total radius of each otolith and the radius of each annulus were measured to the nearest 0.001mm.

2.2 Total length - otolith radius relationship and back-calculations

The total radius of otolith was plotted against the total fish length to determine the body length-otolith radius relationships. The lengths of the previous ages were back-calculated using the following equation of **Lee (1920)**:

$$L_n = (L - a)\, S_n/S + a$$

Where, L_n is the calculated length at the end of n^{th} year (cm); L is the length at capture (cm); S_n is the radius of n^{th} annulus (mm); S is the total otolith radius (mm), and “a” is the intercept of the regression line with the Y-axis.

2.3 Length-weight relationship

To estimate the relation between total length (L) and total weight (W), the variables were log-transformed to meet the assumptions of normality and homogeneous variance. A linear version of the power function $W = a\, L^b$ was fitted to the data.

2.4 Von Bertalanffy growth parameters

The von Bertalanffy growth model was applied to describe the theoretical growth of the two species. The constants of the von Bertalanffy model ($L\infty$ & K) were estimated by fitting the **Gulland and Holt (1959)** plot for females, while those of males were estimated using von Bertalanffy plot.

2.5 Growth performance index (φ)

The growth performance index (φ) for length was estimated as: $\varphi = \log K + 2 \log L\infty$ **(Pauly & Munro, 1984)**; where, K and $L\infty$ are parameters of von Bertalanffy growth model.

2.6 Mortality and exploitation rates

The total mortality coefficient (Z) was estimated as the geometric mean of two methods: the converted catch curve of **Pauly (1983)** and the catch curve method as described in **Ricker (1975)**. The natural mortality coefficient (M) was computed as the geometric mean of three different methods **(Taylor, 1960; Ursin, 1967; Hoenig, 1984)**. The fishing mortality coefficient (F) was computed as $F = Z – M$, while the exploitation ratio (E) was calculated from the ratio F/Z **(Gulland, 1971)**, and the exploitation rate was estimated as $U = (F/Z) * (1-e^{-Z})$.

2.7 Length at first capture L_c

The length at first capture (the length at which 50% of the fish are vulnerable to capture) was estimated by applying the method of **Caddy (1982)**.

2.8 Stock size, biomass and MSY

Total stock (P) and biomass (B) were estimated from the ratios Y/U and Y/F, respectively; where, Y is the annual average yield in ton. Maximum sustainable yield MSYwas calculated by the equation for exploited fish stocks given by **Gulland (1979)** as: MSY = Z x 0.5 x B.

2.9 Yield per recruit analysis

The relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)' were estimated by using the model of **Beverton and Holt (1966)** as modified by **Pauly and Soriano (1986)** and defined by the following formula:

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

$$(B/R)' = (Y/R)'/F$$

Where, $m = (1-E)/(M/K)) = K/Z)$,

and $U = 1 - (Lc/L_\infty)$

This analysis was done for sexes combined since any management measures are planned for sexes combined.

RESULTS AND DISCUSSION

1. Age and growth

Sagittal otoliths were used for age determination of lizardfish collected from Foul Bay. Otoliths as a reliable and valid method for aging was proven. Body length – otolith radius relationship showed a strong correlation between the body length and otolith radius. In addition, the increase of fish size is accompanied by an increase in the number of annuli on the otoliths. Besides, back-calculated lengths accord with the observed lengths for the different age groups. As there is no significant difference between males and females for the two species, the length-otolith radius relationships were estimated for pooled data (Fig. 2). The results showed that, the maximum life span of *S. undosquamis* is two years for males and five years for females, while for *S. tumbil* the longevity is two years for males and four years for females.

Males *S. undosquamis* attained lengths of 19.58 and 27.59cm for total length with respect to the two years of life, while for females, the mean back-calculated lengths were 19.98, 27.83, 33.96, 38.60 and 41.02 cm by the end of 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} year of life, respectively.

The mean back-calculated lengths of males *S. tumbil* were 17.59 and 23.81cm for the two years of life, while females attained lengths of 18.05, 24.19, 27.95 and 30.81cm for the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} year of life, respectively.

The highest growth rate in length for the two species was observed during the first year of life then decreased with further increase in age (Fig. 3), while *S. undosquamis* is the largest and the fastest one in the growth. On the other hand, lizardfish in Foul Bay achieve greater sizes and higher growth rates than that in the other Egyptian waters.

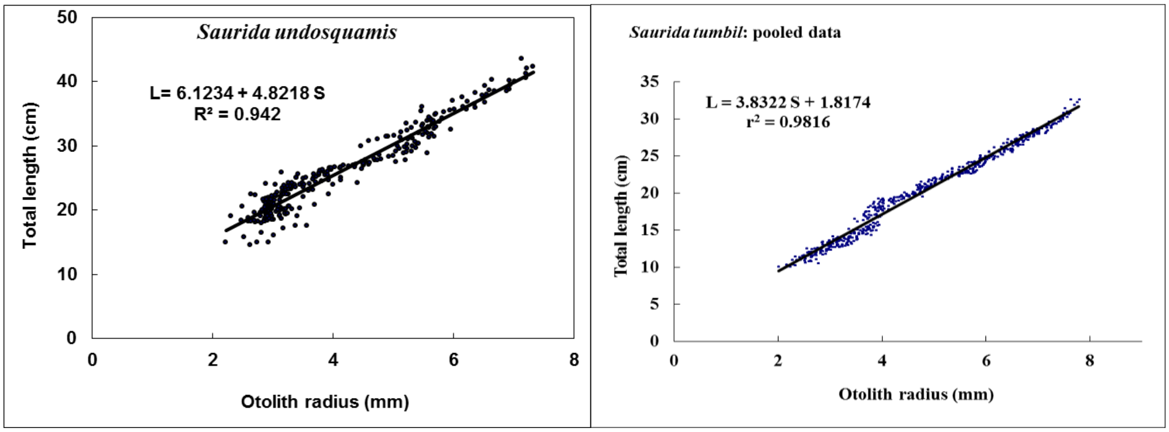

Fig. 2 . Length-otolith radius relationship of the lizardfish in the Foul Bay

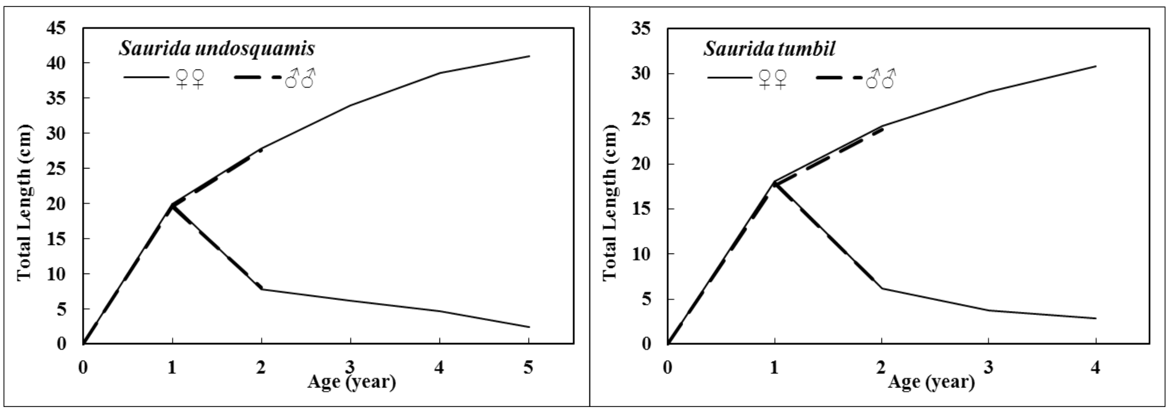

Fig. 3. Growth in length and growth increment of the lizardfish in the Foul Bay

2. Length-weight relationship

The length-weight relationship is helpful in the estimation of metamorphosis, gonad maturity and the fish feeding rate **(Le Cren, 1951)**, and it is the basic parameter in fishery biology and stock assessment of fish **(Mehanna & Farouk, 2021)**. Lengths of males *S. undosquamis* ranged from 14.6 to 33.5cm, while weights varied between 30 and 265g. Females' samples comprised larger individuals; their lengths varied from 15 to 43.5cm, and their weight ranged between 35 and 555g. Obtained length-weight relationships (Fig. 4) were:

Males $W = 0.0081\ L^{2.9602}$ (95% confidence limits of b was 2.784 – 3.136)

Females $W = 0.0064\ L^{3.0470}$ (95% confidence limits of b was 2.970 – 3.124)

Pooled data $W = 0.0060\ L^{3.0656}$ (95% confidence limits of b was 2.983 – 3.148)

The regression coefficient b-value in length-weight relationship equation of *S. undosquamis* was calculated as 2.9602 for males, 3.047 for females and 3.0656 for pooled data. These values are more or less similar to the values calculated for the same species in other localities. **Tureli and Erdem (1997)** recorded b-value= 3.022 in Iskenderun Bay, while **FishBase (2008)** mentioned that b= 3.031 for the coast of India, 3.00 for the coast of Philippine and 3.03 for the coast of Yemen. **Manaşırlı *et al*. (2011)** estimated b= 3.0906 for males, 3.1394 for females and 3.0950 for pooled data in the

Babadıllimanı Bight, Turkey. On the other hand, **Al- Kiyumi *et al*. (2014)** estimated the b-value as 3.118 for males, 3.087 for females and 3.227 for pooled data in the Arabian Sea off Oman. Furhermore, **Kalhoro *et al*. (2014)** gave a b-value at 3.0 for pooled data in Pakistan.

On the other hand, the total length of *S. tumbil* varied from 10.2 to 25.0cm for males and from 10.5 and 32.9 cm for females, and their weights ranged between 7.4 and 150g for males and from 7.0 to 250 g for females. The length- weight relationship equations (Fig. 4) were:

Males $W= 0.0033 L^{3.2461}$ (95% confidence limits of b was 3.061 – 3.326)

Females $W= 0.0031 L^{3.2565}$ (95% confidence limits of b was 3.055 – 3.46)

Pooled data $W= 0.0031 L^{3.2571}$ (95% confidence limits of b was 3.067 – 3.437)

The obtained values of b and the positive allometric growth of *S. tumbil* in Foul Bay are similar to the previous studies. **Rao (1983)** observed that, the b-value was greater than 3 for males and females (3.29 and 3.20, respectively) from Indian waters. **Mathews and Samuel (1989)** reported that b= 3.08 in Kuwait. While, **Mehanna *et al*. (2006)** estimated the b- values as 3.226 for males, 3.251 for females and 3.256 for pooled data. Additionally, **Fofandi (2011)** gave b values of 3.190 for males, 3.267 for females and 3.255 for pooled data in Veraval. From the calculated confidence limits of the exponent, it is statistically not different from cube for *S. undosquamis*; accordingly, the growth of this species is isometric; while for *S. tumbil*, the growth is positive allometric. Furthermore, the covariance analysis revealed that there is no significant difference between males and females for the two species.

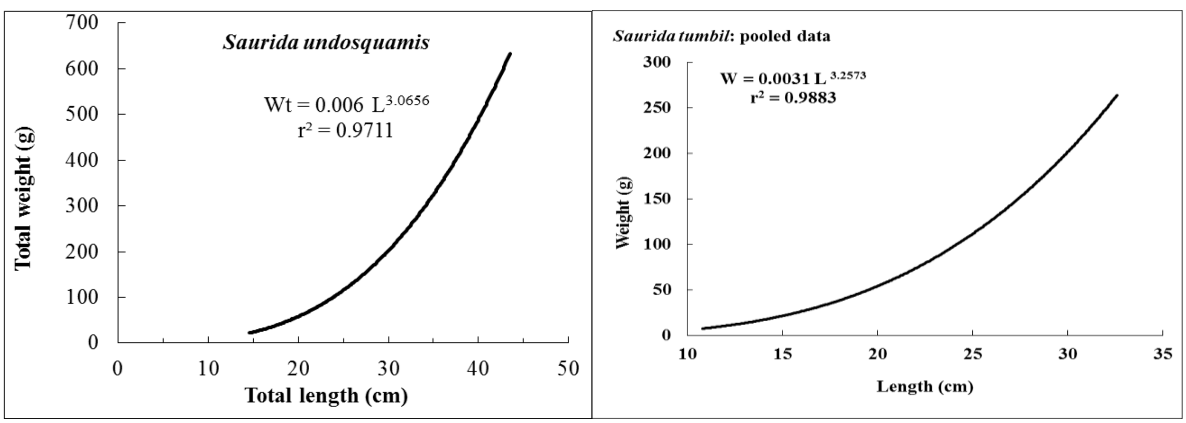

Fig. 4. Length weight relationship of lizardfish (pooled data) from Foul Bay

3. Population parameters

The constants of von Bertalanffy's growth model, the growth performance index, mortality and the exploitation rates were estimated for the two lizard fish species from Foul Bay, and the results are given in Table (1).

Considering the geographical differences, the present value of asymptotic length of *S. undosquamis* is in the range of the previous studies. It was reported that the asymptotic length ($L\infty$) of *S. undosquamis* is 40 cm **(Aksiray, 1987)**, 42.11 cm **(Bingel, 1987)**, 50 cm **(Bauchot, 1987)**, 42 cm **(Gokce *et al*., 2007)**, 40 cm **(CIESM, 2008)**, 41.44 cm for males, 43.55 cm for females and 41.57 cm for the total in Turkey **(Manaşırlı *et al*., 2011)**. Generally, the asymptotic length L∞ of *S. udosquamis* around the world fluctuated between a minimum value of 22.43cm from Turkish water using otolith method **(Tureli & Erdem, 1997)** and a maximum value of 51.8 cm from Vietnam **(Thuoc *et al*., 2000)**. In contrast, the estimated K-value showed higher values with the low values of L∞.

On the other hand, the asymptotic length of *S. tumbil* in the previous studies varied between 37 and 64cm **(Tiews *et al*., 1968; Shindo, 1972; Ingles & Pauly, 1984; Rao, 1984; Ambak *et al*., 1986; Mehanna *et al*., 2006)**.

Given that the L∞ and K parameters are correlated with each other **(Pauly and Morgan, 1987)**, the higher K values are usually associated with the lower L∞ values and vice versa. The differences of those values among localities may be related to the sampling strategy, different data sets and differences of their life pattern and ecological characters **(Adam, 1980)**.

The t_0 values were calculated from the estimated growth parameters for males, females and pooled data of the two lizardfish species (Table 1). As the positive t_0 value indicates that the juveniles grow more slowly, and the negative t_0 value indicates that the fish grow faster during juvenile stage **(King, 1995, 2007; Sparre & Venema, 1998; Mehanna *et al*., 2013)**; the two lizardfish grow faster in their juvenile stage.

Growth performance index (φ) of the two lizardfish species reflects its adaptations to the environment factors. The obtained growth performance index of *S. undosquamis* was 2.95 and 2.89 for males and females, respectively. For *S. tumbil*, the φ value was 2.67 for males and 2.73 for females. It was noticed that, the φ values of *S. undosquamis* was higher than that of *S. tumbil*, indicating that the environmental condition of Foul Bay is more suitable for the growth of *S. undosquamis* than *S. tumbil*.

Table 1. Population parameters for the lizardfish in the Foul Bay

Parameter	*S. undosquamis*			*S. tumbil*		
	Male	Female	Pooled	Male	Female	Pooled
L∞	35.26	48.81	48.66	27.11	36.02	35.30
K	0.71	0.33	0.33	0.63	0.41	0.43
t_0	-0.13	-0.61	-0.57	-0.23	-0.55	-0.65
W∞	308.2	893.7	891.8	148.1	363.5	341.0
Ø’	2.95	2.89	2.90	2.67	2.73	2.73
Z	2.55	1.93	1.73	1.95	1.66	1.65
M	0.36	0.43	0.45	0.59	0.51	0.46
F	2.19	1.50	1.28	1.36	1.15	1.19
E	0.86	0.78	0.74	0.70	0.69	0.72
U	0.79	0.67	0.61	0.60	0.56	0.58

According to **Gulland (1971)** the exploitation rate should be lower than 0.5. He also suggested that the stock may be considered as over-exploitation if the exploitation rate is more than 0.5. According to Patterson (1992) the exploitation rate should be lower than 0.4 levels. The obtained results showed that both the exploitation rate and ratio were greatly higher (Table 1) than that biological reference points so that the two lizardfish stocks in Foul Bay are overexploited.

4. Length at first capture L_c *4*

The length at first capture (L_c) was estimated using the method of Caddy (1982). The obtained values were L_c = 17.8 cm and 15.9 cm for *S. undosquamis* and *S. tumbil* respectively (Fig. 6).

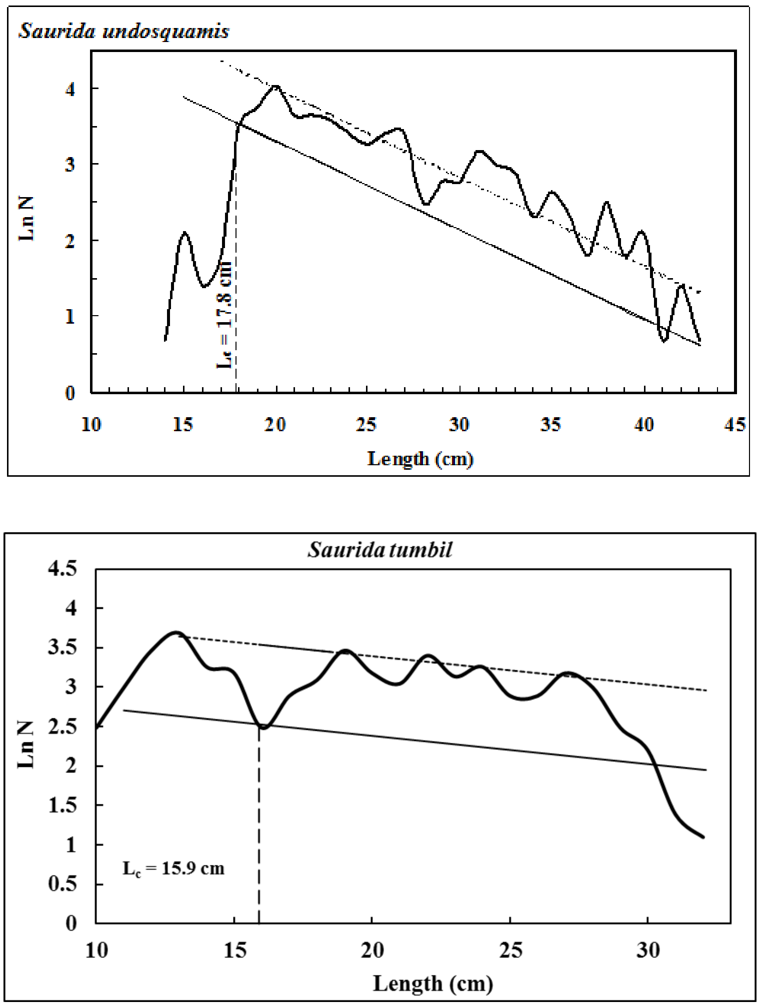

Fig. 6. Length at first capture (L_c) of lizardfish from Foul Bay

5. Stock assessment

5.1 Estimation of stock and MSY

As there is no separated statistics for each lizardfish species, the mean values of F and U were used for stock assessment. The estimated annual total stock, biomass and MSY of lizardfish in Foul Bay were 3813.6 and 1875 and 1546.9 ton, respectively. The estimated MSY which will achieve the sustainability of the fishery is higher than the current annual catch (1100 ton).

Relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)'

Relative yield per recruit (Y/R)' and biomass per recruit (B/R)' analysis (Fig. 7) showed that the maximum (Y/R)' of *S. undosquamis* was obtained at E_{MSY} = 0.56 in the Foul Bay, while the obtained values of $E_{0.10}$ and $E_{0.5}$ were 0.46 and 0.32 respectively. The results indicated that the present levels of E (0.74) was greatly higher than both that which gives the maximum (Y/R)' and the exploitation rate ($E_{0.5}$) which maintain 50% of the stock biomass.

In respect to the *S. tumbil*, the maximum (Y/R)' was obtained at E_{MSY} = 0.60, while the obtained values of $E_{0.10}$ and $E_{0.5}$ were 0.52 and 0.34 respectively. The results indicated that the present levels of E (0.72) was higher than both that which gives the maximum (Y/R)' and the exploitation rate ($E_{0.5}$) which maintain 50% of the stock biomass.

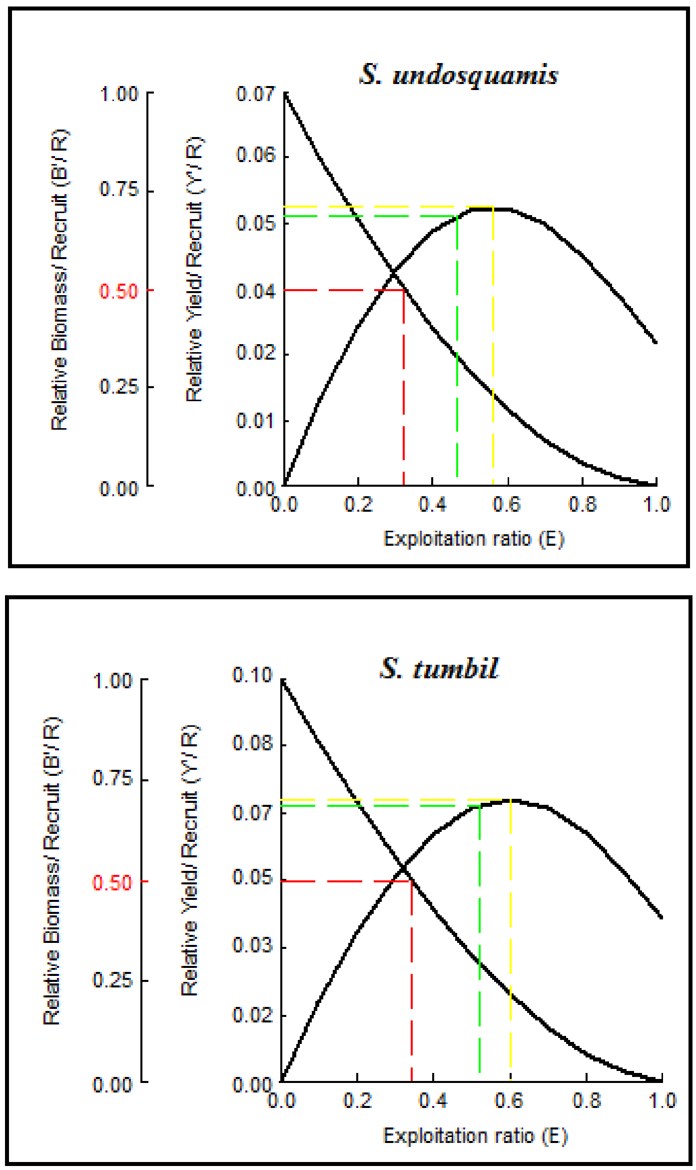

Fig. 7. Yield per recruit analysis of lizardfish from Foul Bay

CONCLUSION

It could be concluded that the two species of lizardfish in Foul Bay are heavily exploited. For the management purpose, the present level of exploitation rate should be decreased by about 50 - 60% in Foul Bay to maintain a sufficient spawning biomass for recruitment. This can be achieved by reducing the fishing effort by at least 40% of its current level to conserve the spawners, establishing the relation between the spawning stock and the recruitment, as well as all commercial stocks exploited by trawling should be assessed to propose a realistic management plan for this multispecies fishery. In addition the fisheries statistics recording system should be improved to give a real picture about the catch and effort statistics from the Egyptian Red Sea fisheries.

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