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FULL LENGTH ARTICLE

Stock assessment of the alien species Brushtooth lizard fish, *Saurida undosquamis* (Richardson, 1848) in the Egyptian Mediterranean coast

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Abstract The exploitation status of *Saurida undosquamis* (Richardson, 1848) from the Egyptian Mediterranean coast was assessed. Fish samples (3444 specimens) that ranged between 9 and 36 cm total length were collected from commercial trawlers. The information used for the assessment of the stock consisted of catch length structure, length–weight relationship and Von Bertalanffy's growth parameters. The vector of natural mortality (M) by age was calculated using the PROBIOM Excel spreadsheet while total (Z) and fishing (F) mortalities, length cohort analysis and Beverton and Holt Yield per recruit analysis were performed by FiSAT, LFDA and Vit 4 win programs in order to estimate the limit and target reference points of stock exploitation.

The results revealed that the average fishing level of *S. undosquamis* (0.575) was higher than the biological reference points $F_{0.1}$ (0.247) and F_{max} (0.368). Moreover the ratio between F_c and $F_{0.1}$ was 2.326 indicating that, the *S. undosquamis* stock in the Egyptian Mediterranean coast is in a state of high overfishing and severe overexploitation.

Introduction

Stock assessment for the sustainable exploitation of marine resources is worldwide recognized as a matter of major concern. In Egypt, the Mediterranean Sea supports large fisheries that catch about 70,000 tonnes per annum characterized as multispecies, with different fleet segments containing a variety of fishing gears (GAFRD, 2014).

Some of the alien fish species have become economically important after the establishment of sustainable populations, such as lizard fish, goatfishes, Spanish mackerel and round herring mostly in the Eastern Mediterranean region (Öztürk, 2010). *Saurida undosquamis* is among the Lessepsian species that had invaded the Mediterranean Sea from the Red Sea via the Suez Canal, Kosswig (1951) was the first author to report this species in Turkish seas. According to Bilecenoglu et al. (2002), *S. undosquamis* appears in the catch from the Levant basin and extends as far as the Aegean Sea.

S. undosquamis is one of the main coastal demersal target species of commercial interest in the Eastern Mediterranean particularly in Egypt. The species is caught almost exclusively

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by trawlers operating on the shelf of the Egyptian Mediterranean coast from muddy and sandy bottoms.

Some studies on the age, growth, reproduction, fisheries and ecology of Lizardfish were conducted in the Mediterranean and in the Red Sea (as an original ground) as well as in Indo pacific regions (Sanders et al., 1984; Faltas, 1993; Golani, 1993; Gucu et al., 1994; Yousif, 2003; El-Ganainy, 2003, 2004; El-Greisy, 2005; Amin et al., 2007; El-Halfawy et al., 2007; Manaşırlı et al., 2011; Metar et al., 2011; El-Etreby et al., 2013). However, no recent assessment was conducted on Lizard fish in the Egyptian Mediterranean coastal waters.

The aim of the present work is to evaluate the current exploitation status of *S. undosquamis* by analyzing the commercial landings from the Egyptian Mediterranean fishing ports.

Materials and methods

The Egyptian Mediterranean coast extends for 950 km from the Libyan border in the West to the Gaza stripe border in the East. There are nine official main landing centers (Fishing ports) most of them are located along the Nile River Delta region as shown in Fig. 1.

The fisheries statistics were obtained from the general authority for fish resources development (GAFRD, 2013, 2014). These data include the monthly landed catch of lizard fish in each port during the period from January 2012 to December 2013.

For biological data, monthly samples were collected from the landings of the largest four fishing ports along the Egyptian Mediterranean coast (Maadia, Burullus, Damietta and Port Said) during 2012, while in 2013 samples were collected on a bimonthly basis within a fisheries data collection system supported by GAFRD and FAO EastMed Project.

For each collected fish specimens; total length (L) and total weight (wt) were recorded to the nearest centimeter and gram respectively. Length–weight relationship was estimated for 3444 fish of *S. undosquamis* according to Le Cren (1951). The length–frequency distribution of the catch was studied and Bhattacharya's (1967) method was used to determine the length at age. Von Bertalanffy's growth parameters then were estimated according to Ford (1933) and Walford (1946) method for the sexes combined.

The maximum age was obtained according to Pauly and David (1981), and the growth performance in length and weight were estimated according to Moreau et al. (1986). The length at which 50% of fish population reaches sexual maturity (L_{m50}) was considered to be the length at first sexual maturity according to Pitt (1970).

Length and age at first capture (L_c and t_c) were investigated from the equation of Beverton and Holt (1956, 1957). Length and age at recruitment (L_r and t_r) were estimated by applying the growth equation of Von Bertalanffy (1938).

The monthly length frequencies distribution was raised to the monthly landings for each fishing port then raised to the total landing of *S. undosquamis* from the Egyptian Mediterranean coast.

LFDA program was used for age slicing (Kirkwood et al., 2001). The vector of natural mortality by age was calculated from Caddy's formula, using the PROBIOM Excel spreadsheet (Abella et al., 1998, 1999). VIT software was used for pseudo cohort analysis by using the age distribution obtained by age slicing (Lleonart and Salat, 1992) then the total and fishing mortalities in the different age groups were estimated.

The exploitation ratio (E) was calculated according to Baranov (1918) formula. The Y/R analysis implemented in the VIT was applied for the calculation of the reference points $F_{0.1}$ & F_{max}. The Y/R analysis indicates the average level of fishing mortality, the biomass per recruit, the spawning stock biomass and the biological references points. The ratio $F_{cur}/F_{0.1}$ was calculated to indicate the stock status.

Results

Fishery description

Otter bottom trawl fishery in Egypt exploits a highly diversified species assemblage (Multispecies gear), it is a modified Italian type of otter bottom trawl net with different

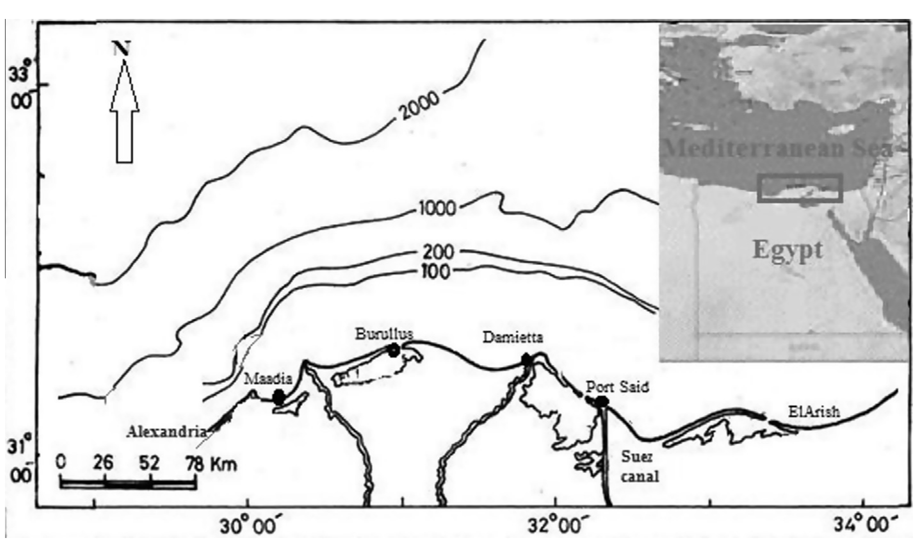

Figure 1 Map of the Egyptian Mediterranean coast illustrated the main fishing ports.

measurements according to the size of the boat used, it is mainly designed to catch shrimp but also targeting lizard fish, red mullet, soles and seabreams. About 1095 registered trawlers are fishing in the Egyptian Mediterranean coast, with different sizes from 12 to 28 m in length (average length of 19.2 m). Each vessel is powered by an inboard engine ranged from 50 to 800 hp with the majority having an engine of 100–250 hp (GAFRD, 2013). All vessels are provided with mechanized winches and many of them are equipped by echo-sounders and GPS.

The total landing of the Lizard fish from the Egyptian Mediterranean coast increased from 645 tonnes (Mt) in 2004 to 2371 Mt in 2011and then sharply decreased to 821 tonnes in 2013 (GAFRD, 2014) as shown in Fig. 2.

Brushtooth lizard fish is now considered to be one of the most important demersal target species of the commercial fishery in Egypt. It represented about 70% (912 and 575 tonnes) of the total landings of the Lizard fish (including *Synodus saurus*) during 2012 and 2013 respectively.

Length–weight relationship

The sampled fish were found to be varying in length between 9 and 36 cm while the total individual weights ranged between 7.5 and 380 g. in (Fig. 3). The length–weight relationship of *S. undosquamis* was described by the power equation as follows:

$$W = 0.0094L^{2.8992} \quad (R^2 = 0.9506)$$

Growth in length and growth in weight

Fig. 4 shows the average lengths for each age group, from this figure it appears that, the maximum increment of the linear growth occurred by the end of the first year of life (12.59 cm), after which a gradual decrease in annual increments with a further increase in age was observed.

The calculated weights by the end of each year of life were estimated (Fig. 5). It was noticed that, the annual increment of growth in weight increases with a further increase in age until it reaches its maximum value at age group V (57.13 g), after which it shows a gradual decrease with a further increase in age.

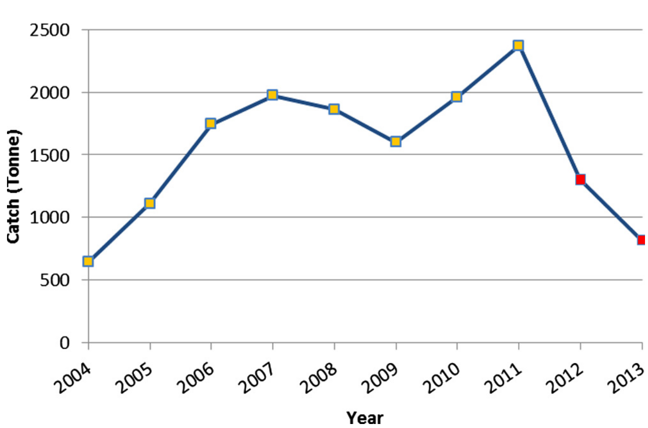

Figure 2 Landings of lizard fish from the Egyptian Mediterranean coast during the years from 2004 to 2013.

The mean lengths at the end of each year of life were used to set Von Bertalanffy growth model. The estimated growth parameters are $K = 0.232$, $L_\infty = 41.765$ cm and $t_o = -0.589$ year.

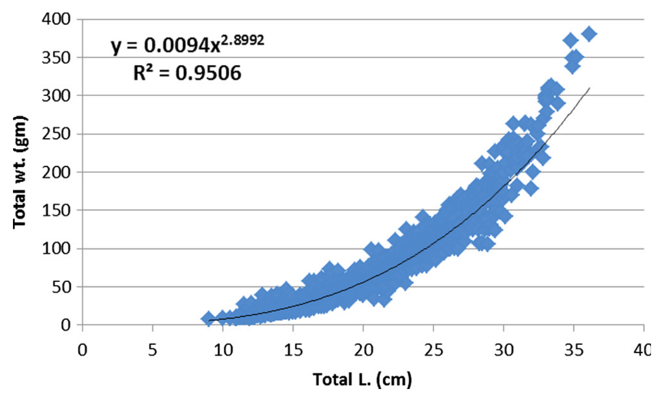

Figure 3 Length–weight relationship of *S. undosquamis* in the Egyptian Mediterranean coast.

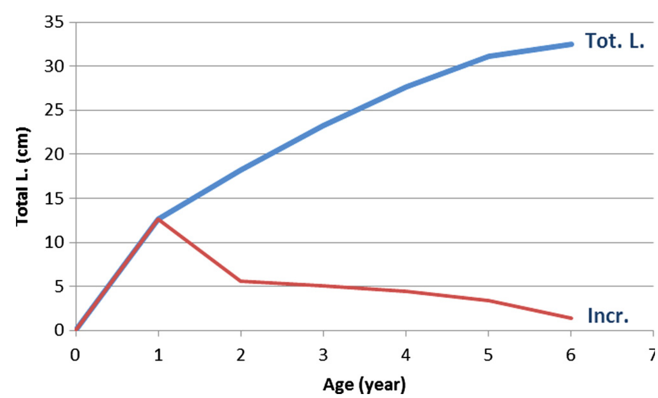

Figure 4 Growth in length and increments at the end of each year of life of *S. undosquamis* in the Egyptian Mediterranean coast.

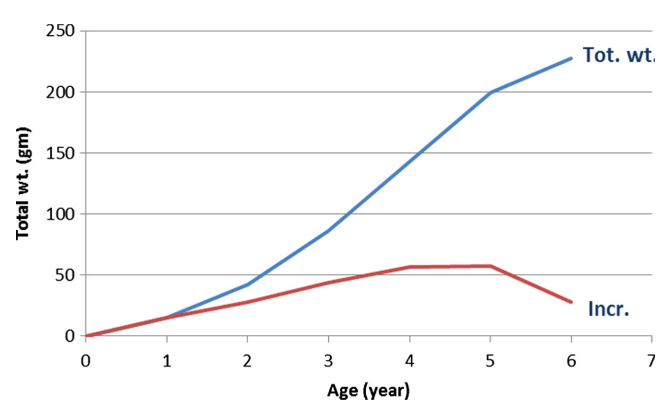

Figure 5 Growth in weight and increments at the end of each year of life of *S. undosquamis* in the Egyptian Mediterranean coast.

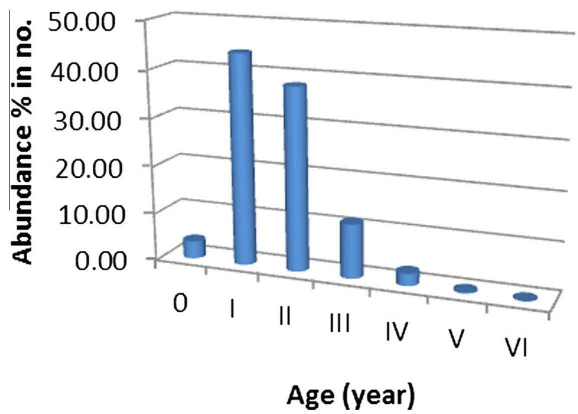

Figure 6 Age composition of *S. undosquamis* in the Egyptian Mediterranean coast.

Maximum age and growth performance

It was found that maximum age (longevity) of *S. undosquamis* in the Egyptian Mediterranean coast was 12.32 years. The growth performance index in length ($\o_L$) was computed as 2.61 and in weight ($\o_{wt}$) as 1.15.

Age composition

The landed catch of *S. undosquamis* was represented by seven age groups (Fig. 6). The most abundant age groups were age group I (43.9%) and age group II (38.06%) followed by age group III (11.31%), while age groups 0, IV, V and VI had low abundance (3.7%, 2.58%, 0.32% and 0.13% respectively). The mean and lower age, length and weight of the six age groups plus age group 0 were estimated and represented in Table 1.

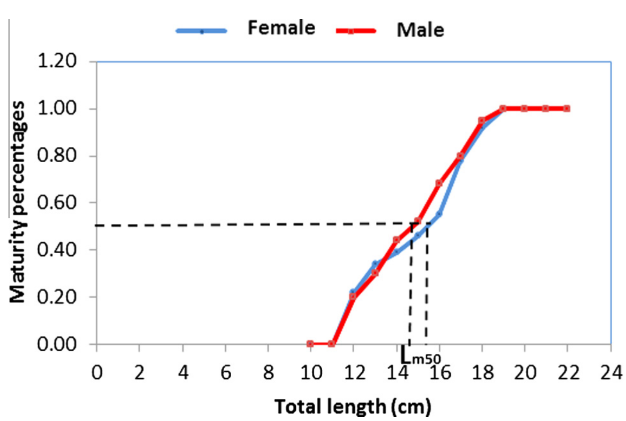

Figure 7 Length at first sexual maturity for *S. undosquamis* in the Egyptian Mediterranean coast during 2012 and 2013.

Length at first sexual maturity

Length at first sexual maturity for *S. undosquamis* in the Egyptian Mediterranean coast during the period of study was recorded as 14.6 for male and 15.4 cm for female in total length (Fig. 7).

Mortality estimations

Instantaneous natural (*M*), fishing (*F*) and total (*Z*) mortalities were estimated for each age group as shown in Table 2 which shows that, the highest value of natural mortality was at age group 0 (1.25 year^{-1}) then decreases gradually till age group V (0.15 year^{-1}), while fishing mortality increased from age group 0 (0.013 year^{-1}) to age group II (1.053 year^{-1}) then decreased gradually up to age group VI (0.15 year^{-1}). The mean fishing mortality was 0.575 year^{-1} and the exploitation ratio was 0.613.

The length and age at first capture (L_c and t_c) were found to be 13.22 cm and 1.05 year, while length at recruitment (L_r) was 10.78 cm with the corresponding age at recruitment (t_r) being 0.7 year.

Yield per recruit and biomass per recruit

Yield per recruit (Y/R) for *S. undosquamis* was found to be 10.4 g and the biomass per recruit (B/R) was 16.65 g. The percentage of biomass per recruit value with respect to the virgin biomass was found to be 16.89%.

Table 2 Natural (*M*), fishing (*F*) and total (*Z*) mortalities of *S. undosquamis* in the Egyptian Mediterranean coast during 2012–2013.

Age group	*M*	*F*	*Z*
0	1.25	0.013	1.263
I	0.38	0.440	0.820
II	0.24	1.053	1.293
III	0.19	1.170	1.360
IV	0.17	0.938	1.108
V	0.16	0.261	0.421
VI	0.15	0.150	0.300
Mean	0.363 ± 0.4	0.575 ± 0.47	0.938 ± 0.43

Table 1 The mean and lower age, length and weight of the different age groups of *S. undosquamis* in the Egyptian Mediterranean coast.

Lower age	Mean age	Lower length	Mean length	Lower weight	Mean weight
0	0.397	5.334	8.475	1.205	5.424
1	1.432	12.877	15.579	15.515	27.844
2	2.395	18.859	20.823	46.891	63.195
3	3.39	23.602	25.139	89.858	108.42
4	4.41	27.362	28.64	137.951	157.845
5	5.465	30.344	31.49	186.197	207.576
6	6.475	32.709	33.636	231.45	251.16

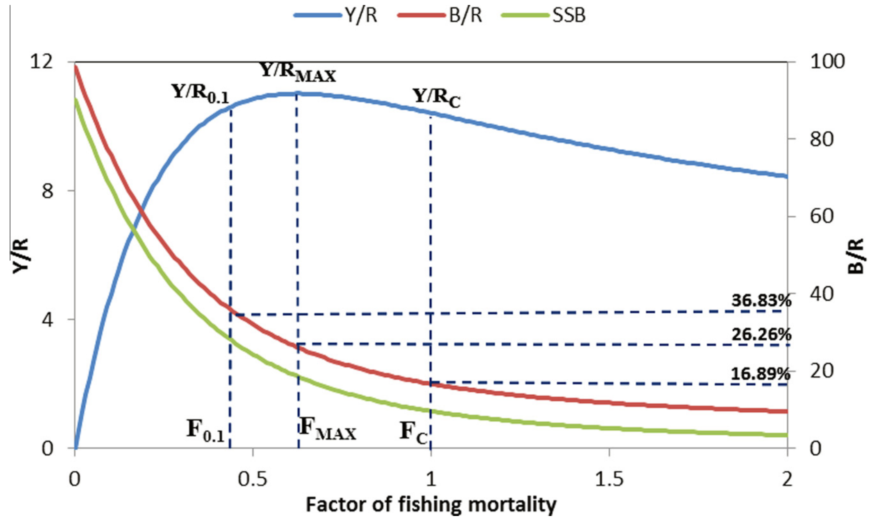

Figure 8 Yield per recruit, biomass per recruit and biological reference points of *S. undosquamis* in the Egyptian Mediterranean coast.

Estimation of the biological reference points ($F_{0.1}$ and F_{max})

Fig. 8 shows the values of yield per recruit and the biomass per recruit as a function of fishing mortality factor (which is considered as a percentage of the current fishing mortality). The maximum yield per recruit was found to be 11.01 g corresponding to maximum fishing mortality (F_{max}) 0.368 year^{-1} (0.64 *F* factor), this value of "*F*" could be considered as a limit biological point. The target reference point ($F_{0.1}$) was found to be 0.247 year^{-1}, this value is lower than the current value of fishing mortality (F_c = 0.575 year^{-1}). The percentage of biomass per recruit value to the virgin biomass at the target reference point ($F_{0.1}$) for *S. undosquamis* was 36.83%.

The ratio between F_c and $F_{0.1}$ calculated as 2.326 for the period of study indicates that, the Brushtooth lizard fish (*S. undosquamis*) stock in the Egyptian Mediterranean coast is in a status of overexploitation.

Discussion

Many fish stocks that constitute a major part of the biological wealth of Eastern Mediterranean Seas have been declining due to over fishing problems together with other environmental factors. In the last century new fish species have been introduced in the Mediterranean Sea fauna through the Suez Canal from the Red Sea.

Therefore, positive contributions have been made to fishing activities by most of these economically important fish species (Bingel, 1987).

S. undosquamis was first recorded in 1953 along the Mediterranean coast of Israel (Ben Tuvia, 1953). However, by 1955 it became an important part of the trawl catch, with commercial catches increasing steadily to 20% of the total annual trawl catch (Oren, 1957).

In Egypt *S. undosquamis* (misidentified as *Saurida tumbil*) dominated the catch at El-Arish representing up to 53% of the total catch in the spring of 1959 (Gorgy, 1966). In 1962, 652 tonnes were landed in the area from Damietta to Port Said (El-Zarka and Koura, 1965). The sudden increase in the populations of *S. undosquamis* was attributed to a rise of 1.0–1.5 °C in sea temperature during the winter months of 1955 (Chervinsky, 1959). There are a lot of factors influencing the success of the species with respect to their migration, spreading and establishment (Mavruk and Avsar, 2007).

The explosion of *S. undosquamis* was made possible by a combination of changes in the environmental conditions (abiotic and biotic), one of these being the retreat of, or the recession in, the native hake population (Ben-yami and Glaser, 1974). Ben Rais et al. (2009) suggested that endemic fish species are facing a growing number of exotic species. Mediterranean Sea is acting as a catchment basin for southern species, for example, the Brushtooth lizardfish is among the most common species caught in the trawl fishery in Turkey, accounting for 17–18% annually (Bingel et al., 1993), and one-third of the commercial catch in the Northeastern Levant Sea (Cınar et al., 2005).

The value of (*b*) in the length-weight relationship of the species under study (2.899) showed slight negative allometry (less than "3") i.e. the fish becomes lighter for its corresponding length. It is noted that, the present obtained value of (*b*) is lower than those obtained by the various authors in different regions. However it is close to that presented by Çiçek and Avsar (2011). It is also clear that the values of Von Bertalanffy growth parameters are different among various geographic localities for the same species as shown in Table 3. Such differences are due to variations in environmental conditions as well as sampling techniques and computations (Hernandez, 1986).

Total (*Z*), natural (*M*), fishing (*F*) mortalities rate and the level of exploitation (E) of *S. undosquamis* comparing with other values calculated at different geographic localities are given in Table 4. It was found that, exploitation rate in various regions are higher than 0.5 except in Turkey where, it was 0.47 (Manaşırlı et al., 2011), these results indicate that, the stocks of the species under study is a target species and is suffering from a high rate of exploitation in the different geographic localities.

Knowledge of the length at first sexual maturity is an important indicator in fishery management. In the present study, the size at 50% sexual maturity of *S. undosquamis* was 14.6 cm for males and 15.4 cm for females; this result agreed with those of EL-Ganainy (1992) who estimated size for females as 15.5 cm and 14.5 cm for males in the Gulf of Suez

Table 3 The value "*b*" of length–weight relationship and Von Bertalanffy growth parameters for *S. undosquamis* in different geographic localities.

Author	Year	Area of study	*b*	*Lα*	*K*	Method
Abd Allah	2002	Egyptian Medit.	3.3			
Yoneda et al.	2002	Japan		44.2	0.162	Otolith
Yoneda et al.	2002	Japan		51.8	0.16	Otolith
Rajkumar et al.	2003	India	3.115	39.5	0.31	L. freq.
Gookce et al.	2007	Turkey		42	0.51	L. freq.
Amin et al.	2007	Gulf of Suez	3.131	31.03	0.44	L. freq.
El-Halfawy et al.	2007	Gulf of Suez	3.167	35.56	0.26	L. freq.
Metar et al.	2011	India		34.6	0.87	L. freq.
Manasirli et al.	2011	Turkey	3.095	41.57	0.118	
Cicek and Avsar	2011	Turkey	2.879	38.05	0.124	Otolith
Xuehui et al.	2012	China	3.043	34	0.52	L. freq.
El-Etreby et al.	2013	Gulf of Suez	3.167	51.25	0.131	Otolith
The present study	2014	Egyptian Medit.	2.899	41.77	0.232	L. freq.

Table 4 Different values of total (*Z*), natural (*M*), fishing (*F*) and exploitation rate (*E*) for *S. undosquamis* in different geographic localities.

Author	Year	Area of study	*Z*	*M*	*F*	*E*
Bingel	1987	Mersin Bay	1.07	0.26	0.81	0.76
Bingel	1987	Iskenderun Bay	0.87	0.26	0.61	0.70
Rajkumar et al.	2003	India	1.81	1.05	0.76	0.58
Amin et al.	2007	Gulf of Suez	1.59	0.27	1.32	0.83
Gookce et al.	2007	Turkey	1.76	0.862	0.898	0.51
Metar et al.	2011	India	3.48	1.51	1.91	0.53
Manasirli et al.	2011	Turkey	0.766	0.403	0.363	0.47
Cicek and Avsar	2011	Turkey	1.77	0.35	1.42	0.8
The present study	2014	Egyptian Medit.	0.938	0.363	0.575	0.613

Table 5 Different values of length at first maturity (L_{m50}) for *S. undosquamis* in different geographic localities.

Author	Year	Area of study	L_{m50}
EL-Ganainy	1992	Gulf of Suez	15.5 F
			14.5 M
Rajkumar et al.	2003	India	23
El-Greisy	2005	Egyptian Medit.	19.5
Amin et al.	2007	Gulf of Suez	17.4
El-Etreby et al.	2013	Gulf of Suez	15.5 F
			15.0 M
Present study	2014	Egyptian Medit.	15.4 F
			14.6 M

and El-Etreby et al. (2013) who found it to be 15.5 for females and 15 for males of *S. undosquamis* in the Gulf of Suez as shown in Table 5. The length at first sexual maturity is used to determine the minimum legal size that should be avoided in fishing activities in order to assure an adequate spawning stock and guarantee at least one spawning for mature individuals (Mahmoud, 2010). In the present investigation, the estimated length at first capture of S. *undosquamis* was 13.22 cm. This implies that juvenile individuals are caught before they reached length at first sexual maturity and the stock dynamics of this species could be seriously affected.

In spite of the wide distribution and importance of *S. undosquamis* there are just few publications existing on their fisheries management in Egypt. Fisheries managers request estimates of harvest levels that provide maximum yield on a long term basis. Beverton and Holt (1957) model can be used to forecast the effects of development and management measures, such as increase or reduction of fishing fleets, changes in minimum mesh sizes, etc. Therefore this model forms a direct link between fish stock assessment and fisheries resource management.

On the basis of the VIT analyses, the biological reference points were given, corresponding to $F_{0.1} = 0.247$ and $F_{max} = 0.368$. Since the current fishing mortality ($F_c = 0.575$) is higher than $F_{0.1}$ and F_{max}, the stock of lizard fish in the Egyptian Mediterranean coast was assessed as in a status of overfishing. A reduction of F_c of about 55% is advisable to reach the proposed TRP (target reference point), such a reduction can be approached by fishing activity limitations, reducing the number of working days and the enforcement of the closed fishing season. Moreover the improvement of the selection patterns of the trawl fishery is needed with consideration of the social aspects of the fishermen and other stakeholders.

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