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Age, growth and population parameters of the spiny squirrelfish, *Sargocentron spiniferum* (Forsskål, 1775) from Shalateen fishing area, Red Sea, Egypt

Ashraf S. Mohammad*; Sahar F. Mehanna; Yassein A. A. Osman; Samia M. El-Mahdy
National Institute of Oceanography and Fisheries, Egypt
*Corresponding author: ashrafgro@yahoo.com

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ABSTRACT

The study of age and growth of fish is essential for understanding their biology and population dynamics. Age and growth of *Sargocentron spiniferum*, from the Egyptian Red Sea at Shalateen fishing area were studied, depending on the otoliths' readings using a non-linear back-calculation method. A total of 685 specimens (17.7–45.8 cm in TL) of *S. spiniferum* were aged and their maximum life span was 7 years. The Von Bertalanffy growth parameters for the investigated *S. spiniferum* specimens were: $L\infty$ = 53.25 cm, K = 0.23 y^{-1}, t_o = -0.66 years and the computed index of growth performance ($Ø'$) was 2.81. The mortality rates were 1.04, 0.47 and 0.57 y^{-1} for total, natural and fishing mortality rates, respectively. The spiny squirrelfish fishery in Shalateen fishing area is working around its optimum situation, where the estimated exploitation ratio is 0.55. The obtained data from this study are the basic inputs of the analytical models used to achieve the wise management of this potential fishery.

INTRODUCTION

Sargocentron is a genus of squirrelfish (family Holocentridae) found in tropical portions for each of Indian, Pacific and Atlantic Oceans. The greatest diversity species of *Sargocentron* is found near coral reef areas in the Indo-Pacific **(Froese and Pauly, 2016**; **Kotlyar, 2017)**. The *Sargocentron* fish was found in water from shallow to 120 m depth in the tropical areas on reefs. *Sargocentron* is a nocturnal fish, have large eyes, Red and silvery colors and the preopercular spines (near the gill-opening) are venomous and give painful wounds **(Debelius, 1993; Allen, 1999)**. Most *Sargocentron* have length of 15–25

cm (maximum length), while *Sargocentron iota* reaches only 8 cm, and *Sargocentron spiniferum* reaches more than 50 cm **(Froese and Pauly, 2015 & 2016)**.

Sargocentron spiniferum (Forsskål, 1775) which known as sabre squirrelfish, giant squirrelfish and spiny squirrelfish, is a member of family Holocentridae. *S. spiniferum* is widespread through the tropical part of Indo-Pacific, Red Sea, Indian Ocean up to Hawaii, Japan and southern Australia **(Randall, 1998; Randall and Greenfield, 1999; Kotlyar, 2017)**.

Age determination, growth and population parameters are very important to both fisheries biology and fisheries management as it provides some information pertaining to the growth rate. Moreover, it forms the basic and important information required for estimation both of mortality, recruitment, strategy of management for the exploited stock and yield **(Mehanna, 1996; Mohammad, 2016)**. So, the current study was undertaken to describe the age, growth and population parameters of *S. spiniferum* from Shalateen fishing area, Red Sea, Egypt. This study revisits the information published on life-history parameters of *S. spiniferum*, and provides new estimates for maximum length, population parameters, length and age at-first-maturity for *S. spiniferum* in the area.

MATERIAL AND METHODS

Shalateen fishing port lies in the southern Red Sea at 520 Km south of Hurghada, Egypt **(Fig. 1)**. The fishing landing site location is between latitude (N: 23° 09' 07.31") and longitude (E: 35° 36' 51.14"). Shalateen port is considered part of productive fishing grounds along the Egyptian coasts of Red Sea.

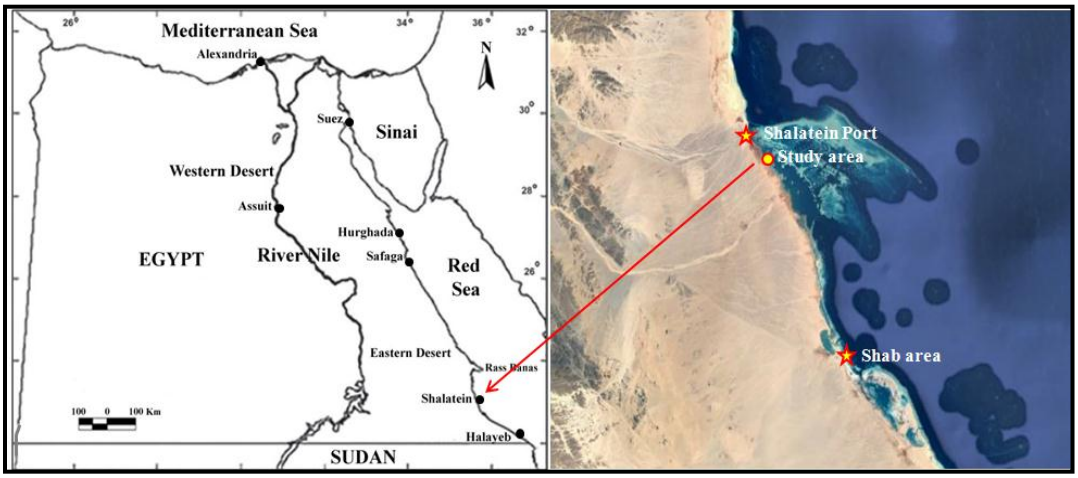


Fig. 1: The Egyptian and Red Sea map showing the site of study area

Collection of samples

A total of 685 specimens (17.7–45.8 cm in TL) of *S. spiniferum* were randomly collected monthly from the commercial landings at Shalateen fishing port in the city of Shalateen during the period from March 2018 to February 2019. Fishes were identified, separated by sex. Total length "TL" (from the anterior border of head to the posterior caudal fin) of each fish was measured by cm and its weight was weighed by gram and recorded.

Age determination

For age determination, otoliths of 685 specimens of *S. spiniferum* were removed, prepared and examined. For the examination and measuring of growth annuli, an **Image Focus Alpha camera** with stereomicroscope was used. Relationship between otoliths radius (R) and total length (TL) was studied to estimate the necessary correction factor for back calculation. On the bases of scatter diagrams, this relationship is represented by the equation:

$$\mathbf{TL = a+b*R}$$

Where "a" (the correction factor) and "b" are constants. The calculated growth in length was determined by the formula:

$$\mathbf{TL_n = a + (R_n / R) (TL – a)} \qquad \textbf{(Lee, 1920)}$$

Where TL_n is the calculated length at the end of n^{th} year, TL is the total length at capture, R_n is the otolith radius corresponding to n^{th} year, R is the otolith radius at time of capture and "a" is the correction factor.

Length-weight relationship

The length–weight relationship of *S. spiniferum*, considered through the whole period of investigation, was described by the following power function equation or its logarithmic form:

$$\mathbf{W = a*TL^b} \qquad \textbf{(Hile, 1936 and Le Cren, 1951)}$$

$$\mathbf{Log\ W = log\ a + b*Log\ TL}$$

Where: W is the fish weight in g. TL is the fish total length in cm.

(a & b) are constants whose values were estimated using the least square method.

Growth parameters

Von Bertalanffy growth model was applied to describe the theoretical growth of *S. spiniferum.* The constants of von Bertalanffy model ($L\infty$ and K) were estimated using the methods of **Ford (1933)- Welford (1946)** plot as follows:

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

Where L_t and L_{t+1} are the fish length at age t and t+1, respectively. This method was applied by fitting L_t against L_{t+1} which gives slope (b) equal to e^{-k} and an intercept (a) equal to $L_\infty (1-e^{-k})$.

While the constant "t_o" was estimated from the following von Bertalanffy equation:

$$\mathbf{\ln [1 - (L_t / L_\infty)] = - k*t_o + k*t}$$

Growth Performance Index (Ø')

Length-based growth performance index (Phi-prime Ø') was computed for *S. spiniferum* using the formula of **Pauly & Munro (1984)** as follow:

$$\mathbf{Ø' = Log_{10} K + 2 Log_{10} L_\infty}$$

Length (L_c) and age (T_c) at first capture

Length at first capture (L_c), length when 50% of the fish at that size are captured, was estimated by the catch curve analysis using Pauly method **(Pauly, 1984)** and the corresponding age at the first capture (T_c) was obtained by converting L_c to age using the von Bertalanffy equation as follows:

$$\mathbf{T_c = -1/K \, Ln \, (1 - L_c / L_\infty) + t_\circ}$$

Mortality rates

Total mortality coefficient (Z) was estimated by two methods; **Ricker (1975)** and **Pauly (1983)** while natural mortality coefficient (M) was estimated using three different methods; **Taylor (1960), Rikhter & Efanov (1976)** and **Pauly (1980)**. The fishing mortality coefficient (F) was estimated using the following: F=Z–M

Exploitation rate (E)

The exploitation rate (E) is the expectation of death from fishing during a limited period when all death causes are affecting on the population **(Everhart *et al*., 1975)**. It was calculated using the relation:

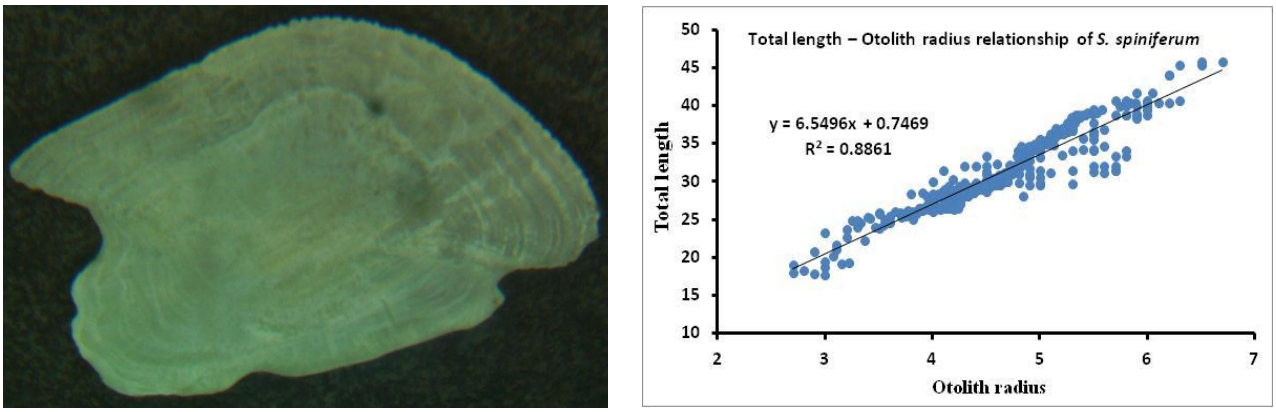
$$\mathbf{E = F/Z}$$ **(Gulland, 1971 & 1983)**

RESULTS AND DISCUSSION

By reviewing the previous scientific literature, it is obvious that this is the first time in which age, growth and population parameters of *S. spiniferum* have been studied from the Shalateen fishing area, Red Sea, Egypt. Hence the results obtained from this study will be a starting point for further research about *S. spiniferum* in the Egyptian waters.

Age determination

From the direct examination of otoliths of the *S. spiniferum*, it was found that they are a reliable tool for age determination for *S. spiniferum* **(Fig. 2A)**. Body length – otolith radius relationship **(Fig. 2B)** showed that there are a strong correlation between TL and R. Based on the number of annuli on the otoliths, the oldest individuals were 7 years old.



A **B**

Fig. 2: (A) Shape of otoliths for the *S. spiniferum*; (B) Total length (TL) – otolith radius (R) relationship of *S. spiniferum* from the southern Red Sea, Egypt.

It was obvious that the maximum growth in length was in the first year of life and after which the growth in length decreased with the increase of age. Similar trends in length increment have been reported on all *S. spiniferum* which previously studied **(Randall & Heemstra, 1985; Letourneur, *et al*., 1998; Kulbicki, *et al*., 2005; Allen & Erdmann, 2012; Kanikawa, *et al*., 2015** and **Nacorda, *et al*., 2017**).

Length-weight relationship

Length-weight relationship is considered as a basic tool in all studies dealing with the fish stock assessment and fisheries management (**Haimovici & Velasco, 2000; Ilkyaz *et al*., 2008; Rodriguez-Romero *et al*., 2009** and **Rojas-Herrera *et al*. 2009; Mehanna and AlMamry, 2012**). The length and weight measurements of 685 *S. spiniferum* were used to compute the fish length-weight relationship **(Fig. 3)**. The length-weight relationship of the *S. spiniferum* is best described by the following power equation:

$$W = 0.0172*TL^{2.9818} \quad r^2 = 0.98$$

It is obvious that the growth in weight for *S. spiniferum* is isometric i.e. b is not statistically significant differ from 3 (b = 2.9818; CI = 2.91 - 3.05). Results in **Table (1)** showed the length – weight relationship constants (a & b) of *Sargocentron* species compared with the present study.

The differences in b values could be due to the fish physiological condition and the seasonal variations of the environmental condition. Also, the fish length-weight relationship and the b value can also be influenced by the exerted fishing pressure into the different localities.

Table 1: Length–weight relationship constants (a &b) of *Sargocentron* species.

***Sargocentron* species**	**b**	**a**	**Locality**	**Reference**
Sargocentron coruscum	0.0161	3.069	USA	**Bohnsack&Harper**, 1988
Sargocentron punctatissimum	0.0117	3.089	India	**Murty,** 2002
Sargocentron rubrum	0.0275	2.998	New Caledonia	**Kulbicki *et al*.,** 2005
Sargocentron hastatum	0.0309	2.779	Senegal	**Oliveira *et al*.**, 2015
Sargocentron diadema	0.0238	3.00	Guam	**Kanikawa *et al*.**, 2015
Sargocentron tiere	0.0415	2.80	Guam	**Kanikawa *et al*.**, 2015
Sargocentron spiniferum	0.0238	3	Guam	**Kanikawa *et al*.**, 2015
Sargocentron caudimaculatum	0.0391	2.941	Philippines	**Gumanao *et al*., 2016**
Sargocentron spiniferum	**0.0172**	**2.982**	**Red Sea**	**The present study**

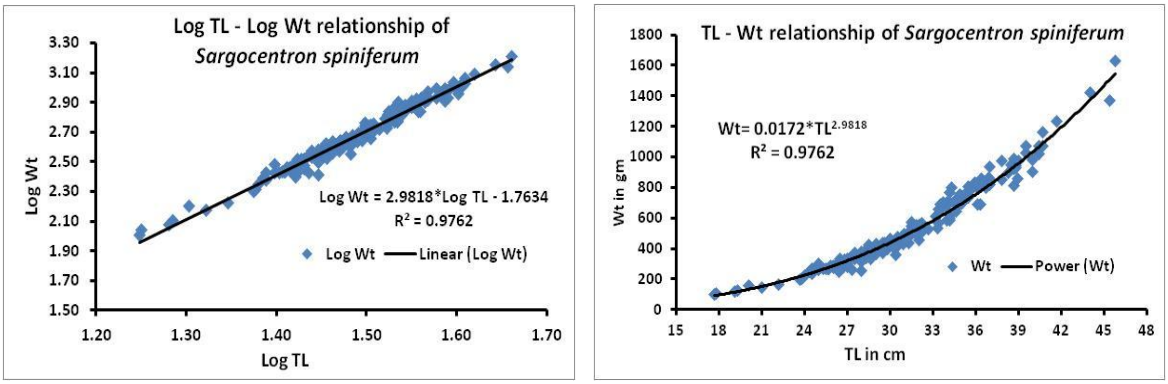


Fig. 3: Length -weight relationship and its logarithmic form for *S. spiniferum* from the southern Red Sea, Egypt.

Length frequency distribution and age composition

The length classes of the *S. spiniferum* were varied in total length between a smallest one at 17.7 cm and a largest one at 45.8 cm, and the lowest represented length classes in the catch were 18, 22, 44 and 46 cm. The most representative length classes were lengths from 26 to 36 cm with the highest one at 30 cm **(Fig. 4)**. Further, the age of *S. spiniferum* was composed of seven groups with the age groups three and four were the most frequent groups in the catch **(Fig. 4)**.

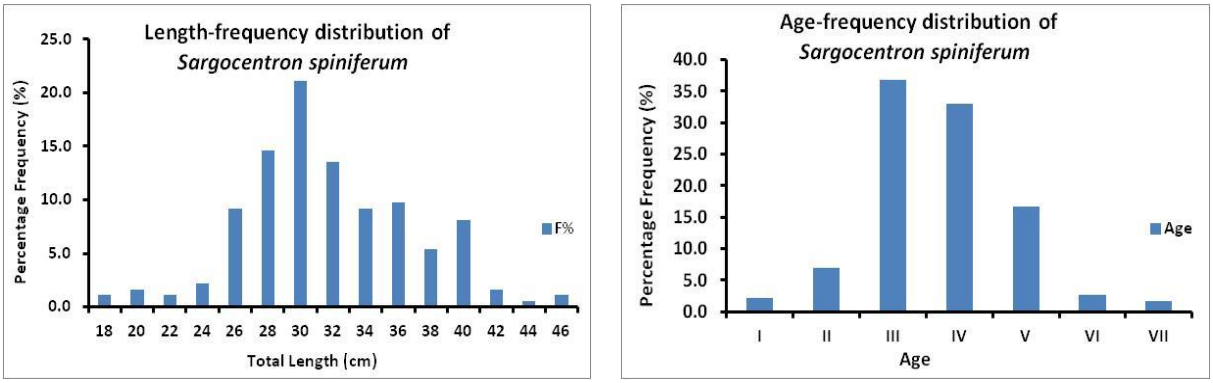


Fig. 4: Length-frequency distribution and age composition of *S. spiniferum* from the southern Red Sea, Egypt.

Growth parameters

The growth parameters "L∞, K**,** W∞ and t_o" for *S. spiniferum* were estimated at 53.25 cm, 0.23 y^{-1}, 2415.84 g and -0.66 year respectively.

Accordingly, the estimated von Bertalanffy growth equations in both length and weight were as follows:

For growth in length: $\mathbf{L_t = 53.25\ (1 - e^{-0.23\ (t\ +0.66)})}$

For growth in weight: $\mathbf{W_t = 2415.84\ (1 - e^{-0.23(t\ +0.66)})^{2.9818}}$

The only study dealing with the growth parameters of *S. spiniferum* is that of **IGFA (2001)** in USA which gives $L\infty$ = 53.0 cm, K = 0.35 year^{-1} and t_o = -0.40 years.

Growth performance index

The value obtained for the computed growth performance index ($Ø'$) for the *S. spiniferum* in Shalateen fishing area was 2.81. This value is smaller than that computed for the same species in USA (2.99) by **IGFA (2001)** indicating that the environment in USA more suitable for the growth of *S. spiniferum* than in the Egyptian Red Sea.

Length and age at the first capture (L_c & T_c)

The length at first capture (L_c) was estimated to identify the fishing regime of *S. spiniferum* in Shalateen fishing area as it is used for detect the mesh sizes of applied nets. According to the resultant curve derived from catch curve, the estimated L_c was 29.06 cm TL for *S. spiniferum*, this length was corresponding to an age (T_c) of 2.64 year **(Fig. 5a)**.

Mortality estimates

The mean value of total mortality coefficient (Z) for *S. spiniferum* was 1.04 y^{-1} **(Fig. 5b)**, while the mean value of natural mortality coefficient (M) was 0.47 y^{-1}. The Fishing mortality (F) of *S. spiniferum* was calculated at 0.57 y^{-1}. The relatively high fishing mortality rate is a big challenge facing the *S. spiniferum* population health. Also, by comparing estimates of the current fishing mortality rate with the target F (F_{opt} = 0.5 M), we found that the *S. spiniferum* stock is heavily exploited.

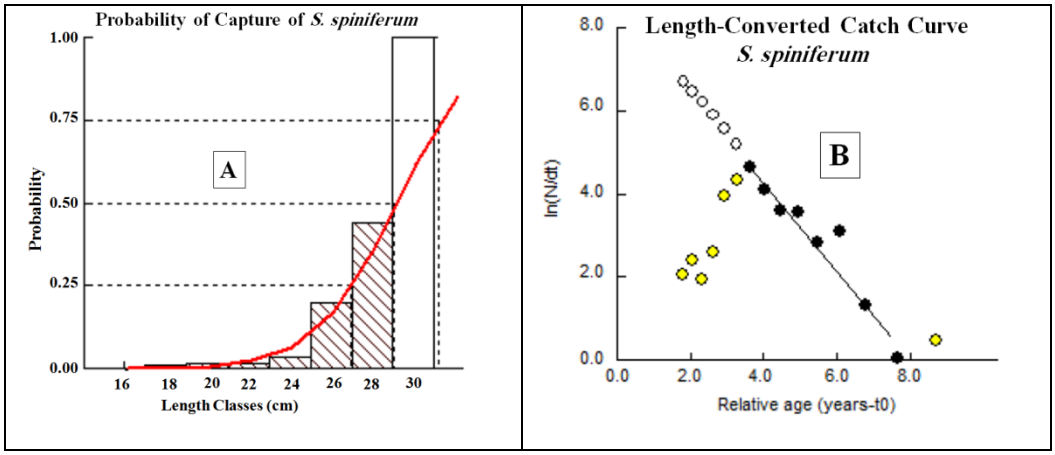


Fig. 5: Probability of capture of *S. spiniferum* (A) and length converted catch curve of *S. spiniferum* (B) from the southern Red Sea, Egypt

Exploitation rate (E)

The exploitation rate of *S. spiniferum* was estimated at 0.55. **Beverton & Holt (1966)** suggested that when the natural and fishing mortality are equal (E = 0.5), then the stock is in a health condition and optimally exploited. The current of exploitation rate (E= 0.55) in this study indicated a relatively high exploitation level.

In conclusion, *S. spiniferum* stock exploitation level should be monitored and the present level of fishing mortality should be controlled in Shalateen fishing ground. Also, further study to estimate some target reference points to manage and conserve this potential stock should be carried out.

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