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# Reproductive Biology of the Brushtooth Lizardfish (*Saurida undosquamis*) (Richardson, 1848) Inhabiting the Northern Gulf of Suez and the South-Eastern Mediterranean Sea

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**ABSTRACT**

The Brushtooth Lizardfish *Saurida undosquamis* is one of the economically successful Lessepsian species, which migrated from the Red Sea to the Mediterranean Sea. The present study was carried out from September 2018 till April 2019 in the Northern Gulf of Suez (at Suez) and from March 2018 to March 2019 in the South-Eastern Mediterranean Sea (at Port Said). A total of 838 specimens were monthly collected from both sites. Overall sex ratio was 1:0.40 and 1:0.54 for the Gulf of Suez and the Mediterranean population, respectively. There was a highly significant difference between the ratios of both sexes in both populations ($P$<0.001). The monthly changes in maturity stages and gonado-somatic index showed that *S. undosquamis* have a prolonged spawning season extending from December to April in the Gulf of Suez and from June to March, with two major spawns occurring in August and February in the Mediterranean Sea. The fish length corresponding to 50% ($L_{50}$) was 17.3 cm for males and 18.2 cm for females from the Gulf of Suez, whereas it was 16.9 cm for males and 17.8 cm for females from the Mediterranean Sea. The absolute fecundity for the Gulf of Suez population ranged from 14750 to 63553 ova (average: 38075 ± 18181 ova) for fish that ranged from 20-22 cm to 30-32 cm (TL). For the Mediterranean Sea population, the absolute fecundity ranged from 18090 to 62025 ova (average: 39274 ± 15783 ova) for fish that ranged from 18-20 cm to 30-32 cm (TL).

## INTRODUCTION

In the Eastern Mediterranean coast of Egypt, the Brushtooth lizardfish, *Saurida undosquamis* (Richardson, 1848) is among the most successful Lessepsian migrant species that had entered the Mediterranean Sea from the Red Sea via the Suez Canal. This species is one of the main coastal demersal target species of commercial interest (**GAFRD, 2014**). This species is caught almost exclusively by trawlers and comprises about 95% of the lizardfish catch from the Gulf of Suez (**El-Ganainy, 2003**). Therefore, a detailed analysis of the population structure and the growth of this exploited fish stock provides essential information for its proper management.

The population characteristics of fishes, particularly those concerning their reproduction, are essential inputs in assessing and managing fish stocks **(Froese, 2004)**. The success of any fish species is ultimately determined by the ability of its members to reproduce successfully in a fluctuating environment **(Moyle & Cech, 1982)**. Thus, understanding the reproductive biology of a fish species is essential to predict the species production and recruits **(El-Ganainy, 1992)** and fundamental in conservation and selecting fish candidates for aquaculture from the wild **(Muchlisin, 2014)**. The knowledge of the sex ratio, the maturity stages of each sex, the size at first maturity, the spawning season, and the estimation of fecundity are principals in evaluating the populations' dynamics **(West, 1990;Caillient *et al.* 1996)**.

The different reproductive biology aspects and population structure of the Brushtooth lizardfish, *S. undosquamis* (Richardson, 1848) have been previously investigated in the Gulf of Suez in many studies **(El-Ganainy, 1992; Amin *et al.*, 2007; El Halfawy *et al.*, 2007; El- Etreby *et al.*, 2013)**. The same aspects have also been studied for the population inhabiting the Mediterranean Sea **(Shenouda & Wadie, 1990; Ismen, 2003; El-Greisy, 2005)**.

This study was conducted to elucidate the current status of the reproductive cycle of the Brushtooth lizardfish *S. undosquamis* in both sites (northern Gulf of Suez at Suez and the southeastern coast of the Mediterranean Sea at Port Said). Meanwhile, the current work carried out a detailed study of this species reproductive biology, including the observations of various maturity stages throughout the year. In addition, the study was undertaken to explain more aspects of reproduction, including sex ratio, length at first maturity, gonado- somatic index (GSI), and fecundity per length and weight.

## MATERIALS AND METHODS

### 2.1. Samples collection

A total of 838 mature specimens were randomly collected (351 from the Gulf of Suez and 487 from the Mediterranean Sea) over a duration of 13 months (March 2018 to March 2019) from the Mediterranean Sea, whereas the period of collection was 8 months (September 2018 to April 2019) regarding the Gulf of Suez (**during the opened fishing season**). Specimens were dissected and examined in order to determine the sex and maturity stages of both sexes. The gonads' weight (GW) was recorded to the nearest 0.01g. The ovaries were preserved in 5% neutral formalin for fecundity estimations.

### 2.2. Sex ratio

The sex of all individuals was determined visually and divided into males, females. The Chi square test at ($P \leq 0.05$) significance level was used to compare sex ratios according to **Sendecore (1956)**.

### 2.3. Determination of gonadal maturity stages

Maturity stages were determined and classified according to the modified scale of **Nikolsky (1963)** into six maturity stages for both sexes as follows:

**1-** Immature stage

Gonads were small, transparent and extended along 1/4 of the abdominal cavity length. Testes were thin and pointed, and ovaries were cylindrical while the ova could not be distinguished with the naked eyes.

**2-** Mature stage

Gonads changed in size and color and extended along 1/3 of the abdominal cavity length. Testes were solid with a light whitish color; ovaries were hollow with yellowish to slightly pink color. Ova can sometimes be distinguished with the naked eye.

**3-** Maturing stage

During this stage, gonads were larger in size, occupying about 1/2 to 2/3 of the body cavity. Testes lobes were clear, finger-like, flattened, more whitish in color and nearly full of sperms. Ovaries varied between pale yellow and slightly whitish. It was easy sometimes to observe the blood vessels with the naked eye.

**4-** Full ripe

Both testes and ovaries were larger in size and occupied most of the body cavity. Testes were milky with stout lobes which were distended with sperms. It was easy to observe the blood vessels in the ovaries and sometimes in the testes. Ovaries were voluminous with large viable ova which can be seen through the thin ovarian wall. Their color varied between pale yellow and pinkish, but the ova couldn’t be extruded by pressure.

**5-** Running stage (spawning)

This stage extends the ripening stage; the body cavity is distended with the testes or ovaries that reach the maximum development. Gonads started to release their sexual products (ova or sperms), which can be extruded by pressure on the abdominal wall. Testes extended along the body cavity with opaque white color and soft, loose wall and milt ran out when pressure was applied. Ovaries were loose with soft walls and red or reddish-brown in color. Their volume decreased and started to become hollow again, while the blood vessels were engorged with blood having a bright reddish color.

**6-** Spent stage

During this stage, testes turned reddish-gray in color, slender and flaccid, reduced in volume and blood vessels. Ovaries got dark red in color, in the form of a flaccid bag with few mature ova as remnants, while veins were less turgid with purplish color.

### 2.4. Size and age at first sexual maturity ($L_m$ and $t_m$)

The length at which 50% of the individuals reach their sexual maturity was estimated by fitting the percentage maturity against mid-length **(King, 1995)**. The age at first sexual maturity ($t_m$) was computed by converting $L_m$ to age using the growth equation of **Bertalanffy (1938)** as follows:

$t_m = t_0 – (1/K * \ln [1- (L_m/L\infty)])$

## 2.5. Gonado – somatic Index (GSI)

The monthly changes in the gonado somatic index (GSI) of both males and females were calculated as follows:

GSI = 100 (GW/ Twt) **(Anderson *et al.*, 1983)**.

Where, GW is the gonad weight, and Twt is the total fish weight.

## 2.6. Fecundity estimations

Ripe ovaries were removed carefully from fishes collected during the spawning season. Both ovaries were preserved in 5% neutral formalin, then they were air-dried and weighed, and three subsamples of 0.01gm were taken from each lobe and crumbled in a divided Petri-dish containing drops of water. The number of mature ova in each subsample was counted using a binocular microscope.

Two terms were applied in studying fish fecundity. The absolute fecundity ($F_{abs}$) is the total number of mature ova in the ovary, and the relative fecundity ($F_{rel}$) is the number of ova per unit length or weight of the fish (**Nikolosky, 1963)**.

The relationships between length, weight and both fecundities were estimated according to the following formula:

$F= aL^b$ and $F= a+bW$

Where, F = absolute fecundity and relative fecundity, L and W = independent variable (length or weight), a = constant and b = exponent value **(Bagenal, 1978)**.

# RESULTS

## 3.1. Sex ratio

Males outnumbered females in both populations, 250 individuals, 71.23% (of males) and 101 individuals, 28.77% (of females) from the Gulf of Suez population; 316 individuals, 64.89 % (of males) and 171 individuals, 35.11% (of females) from the Mediterranean Sea population. For the Gulf of Suez population, males exhibited higher number than females all of the year except for March 2019, where females were dominant (52.4%), as shown in Fig. (1). Males recorded the highest percentage in September 2018 by 85.1%. Overall sex ratio was 1:0.40 and Chi-square test showed a highly significant difference between the ratios of both sexes ($P$<0.001).

For the Mediterranean Sea population, males also dominated almost all the year except in July and August 2018 where females recorded the higher values (51.7% and 53.1%, respectively) as shown in Fig. (1). Males recorded the highest percentage in January 2019 by 87%. Overall sex ratio was 1:0.54 and the chi-square test showed a highly significant difference between the ratios of both sexes ($P$<0.001).

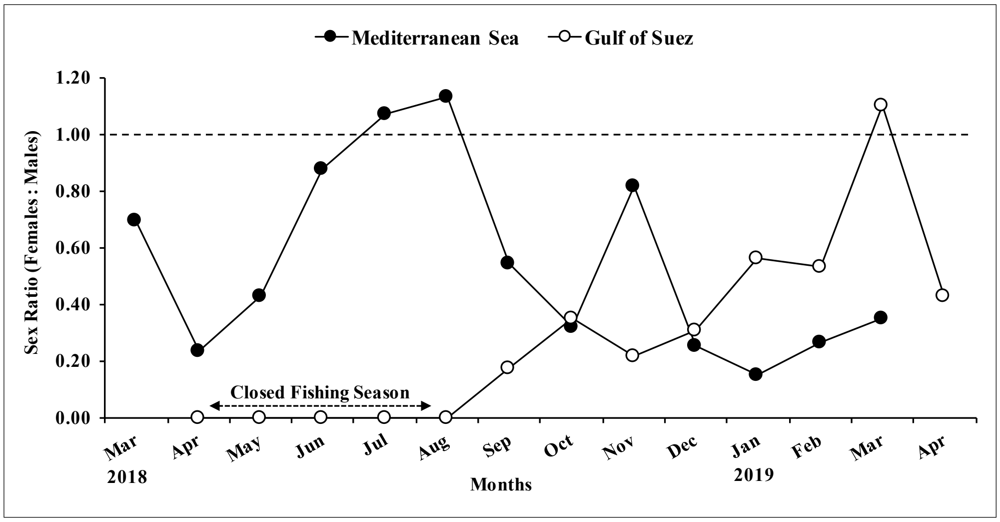



**Fig. 1.**
Monthly variations in the sex ratio of *S. undosquamis* collected from both study sites

Dotted line indicates a ratio of 1:1 (females: males).

### 3.2. Monthly variations of maturity stages

Monthly variations in the percentage of the different maturity stages of *S. undosquamis* from Gulf of Suez and the Mediterranean Sea are shown in Figs. (2 & 3), respectively for males and females.

For the Gulf of Suez population, the immature stage was found between September 2018 and December 2018 for both males and females. *S. undosquamis* has a prolonged spawning season that extended from December 2018 to April 2019 for males and females. The highest percentage of the running stage (V) was found during April 2019 with 42% for males and 65% for females. Males, with fully ripe gonads, were found between November 2018 and April 2019 with varying percentages. Females followed the same trend except that fully ripe individuals occurred also in September 2018 with a small percentage (7%). However, the highest percentage was observed during April 2019 (53%) and March 2019 (25.11%) for males and females, respectively.

For the Mediterranean Sea population, the immature stage was found between March 2018 and May 2018 for males and in March 2018, May 2018 and September 2018 for females. Similar to the Gulf of Suez population, the *S. undosquamis* has a prolonged spawning season, extending from June 2018 to March 2019 for both sexes. The highest percentage of the running stage (V) was found during February 2019 (47.37%) and (60%) for males and females, respectively. Male and female individuals with fully ripe gonads were found in the period between June 2018 and March 2019 with varying percentages. The highest percentage was observed during February 2019 (31.58%) and January 2019 (50%) for males and females, respectively. The chi-square test showed a highly significant difference (*P* <0.001) between maturity stages for males and females in both study sites.

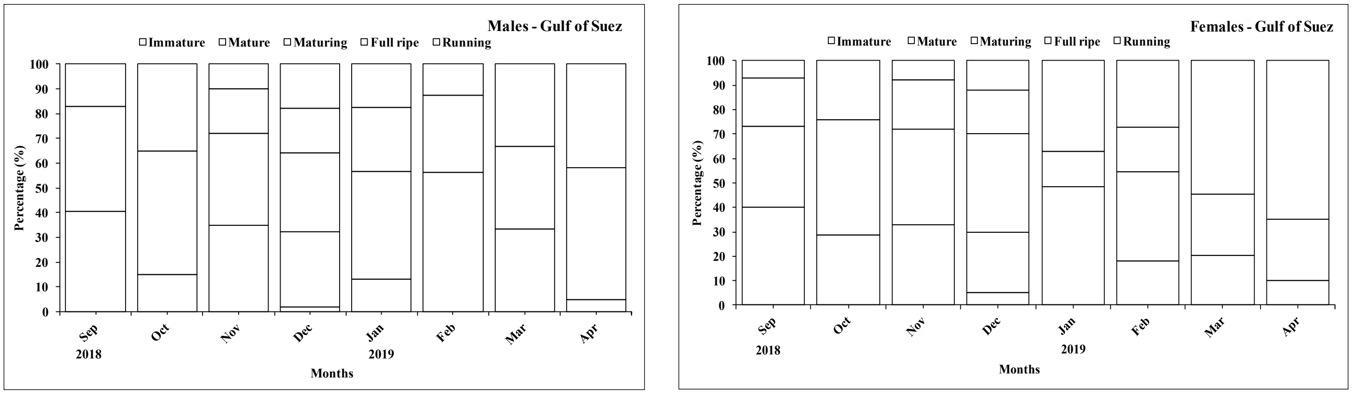



**Fig. 2.** Monthly variations in the maturity stages for both sexes of *S. undosquamis* collected from the Gulf of Suez

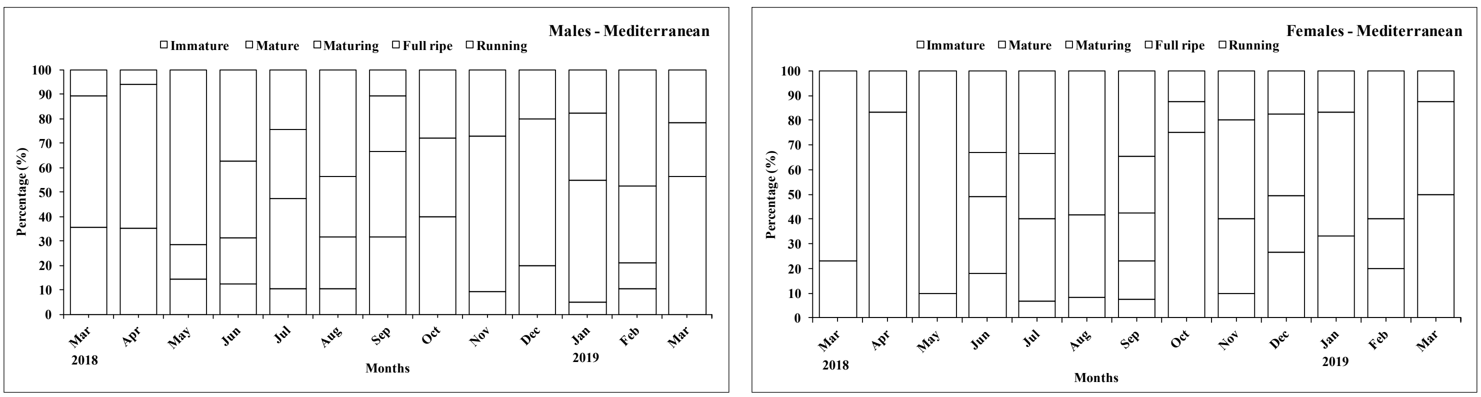



**Fig. 3.** Monthly variations in the maturity stages for both sexes of *S. undosquamis* collected from the Egyptian Mediterranean Sea

### 3.3. Size and age at first sexual maturity ($L_m$ and $t_m$)

In the present study, the 2nd to 5th maturity stages in the adopted maturity scale were considered to be mature. For the Gulf of Suez population, the frequency percentages of immature and mature individuals, corresponding to different length groups of males showed that individuals ranged between 12-14 cm (mid-length: 13 cm) were 100% immature, while females that ranged between 12-16 cm (mid-length: 13-15 cm) were 100% immature. The fish length corresponding to 50% ($L_{50}$) was 17.3 cm for males and 18.2 cm for females (Fig. 4). The corresponding age was equal to 2.17 and 2.34 for males and females respectively. The smallest lengths at which the mature gonads were recorded for the first time were 14.1 cm (at age 1.4) for males and 16.1 cm (at age 1.8) for females.

For the Mediterranean Sea population, individuals ranged between 8-12 cm and 8-16 cm (mid-lengths: 9-11 cm and 9-15 cm) were 100% immature for males and females, respectively. The fish length corresponding to 50% ($L_{50}$) was 16.9 cm for males and 17.8 cm for females (Fig. 5). The corresponding age was equal to 1.9 and 2.10 for males and females, respectively. The smallest lengths at which the mature gonads were recorded for the first time were 12.5 cm (at age 1.1) for males and 16 cm (at age 1.6) for females.

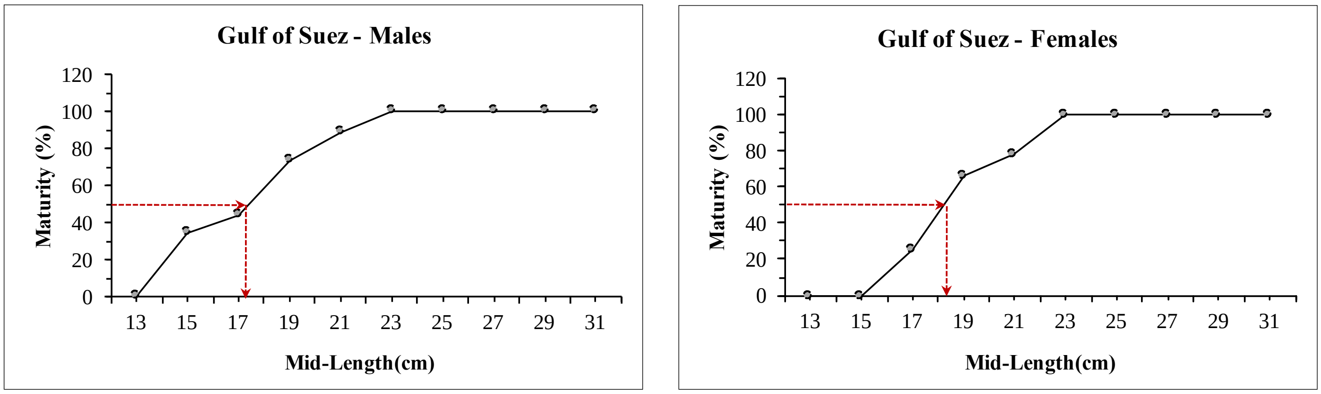



**Fig. 4.** Length at first sexual maturity for both sexes of *S. undosquamis* collected from Gulf of Suez

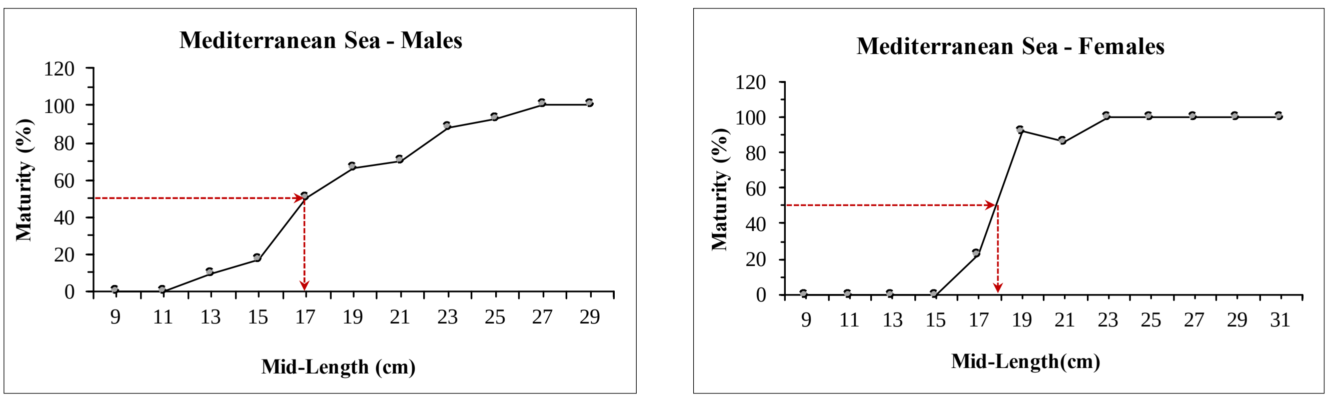



**Fig. 5.** Length at first sexual maturity for both sexes of *S. undosquamis* collected from the Egyptian Mediterranean Sea

## 3.4. Gonado – somatic Index (GSI)

For the Gulf of Suez population, females acquired higher average values of GSI than males. The average values for males and females showed a trend of successive increase from November 2018 to April 2019. Values fluctuated throughout the year having their minimum in September 2018 (0.40 ± 0.54) and (0.52 ± 0.75) for males and females, respectively. Their maximum was in April 2019 (4.95 ± 3.75) and (5.51 ± 3.54) for males and females, respectively (Fig. 6). There was no significant difference ($P$ >0.05) in the monthly values between males and females. The average value of all months was higher in females (2.06 ± 0.36) than in males (1.94 ± 0.33).

For the Mediterranean Sea population, the maximum average values of GSI for both sexes were recorded in August18 (5.30 ± 3.58) and (5.39 ± 3.71) for males and females, respectively. Females obtained higher average values (in nine months out of thirteen) than males. Values reached their minimum in March18 (0.36 ± 0.33) and (0.36 ± 0.28) for males and females, respectively (Fig. 7). There was no significant difference ($P$ >0.05) in the monthly values between males and females. The average value of all months was higher in females (2.33 ± 0.46) than in males (2.27 ± 0.40).

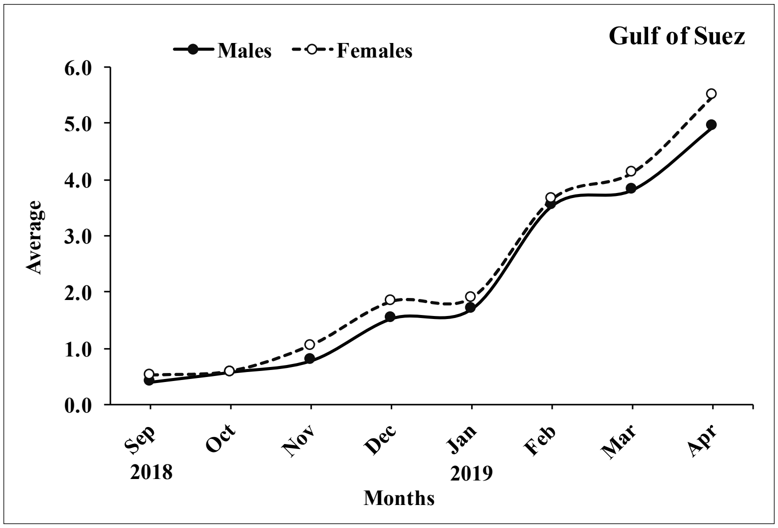



**Fig. (6):** Monthly variations in the Gonado-Somatic-Index (GSI) for separate sexes of *S. undosquamis* collected from Gulf of Suez.

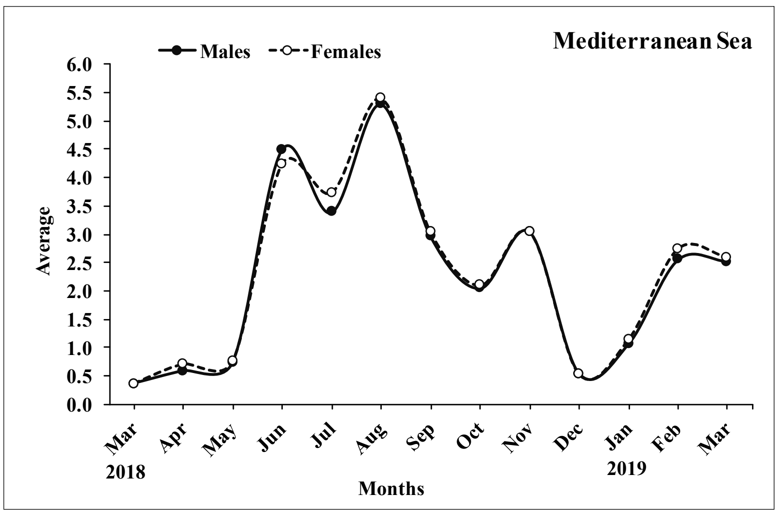



**Fig. 7.** Monthly variations in the Gonado-Somatic-Index (GSI) for separate sexes of *S. undosquamis* collected from the Egyptian Mediterranean Sea

## 3.5. Fecundity estimations

### - Relationship between fecundity and fish length

Fecundity increased with fish length. For the Gulf of Suez population, the absolute fecundity ranged from 14750 to 63553 ova (average: 38075 ± 18181 ova) for fish that ranged from 20-22 cm to 30-32 cm (TL). For the Mediterranean Sea population, the absolute fecundity ranged from 18090 to 62025 ova (average: 39274 ± 15783 ova) for fish that ranged from 18-20 cm to 30-32 cm (TL). The regression equations between the absolute fecundity and fish length (described by a power equation) for both populations are shown in Fig. (8).

The relative fecundity ranged for the Gulf of Suez population from 701 to 2091 ova/cm with an average of 1399 ± 509 ova/cm, while the relative fecundity ranged from 923 to 1969 ova/cm, with an average of 1510 ± 377 ova/cm for the Mediterranean population. The regression equations between the relative fecundity and fish length (described by a power equation) for both populations are shown in Fig. (8).

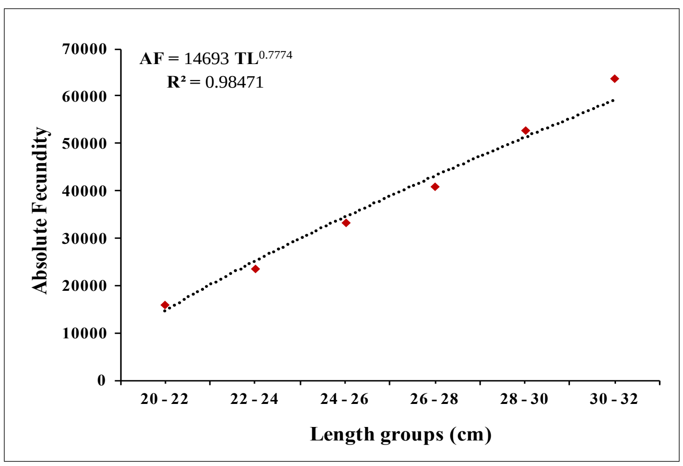
- **Relationship between fecundity and weight**

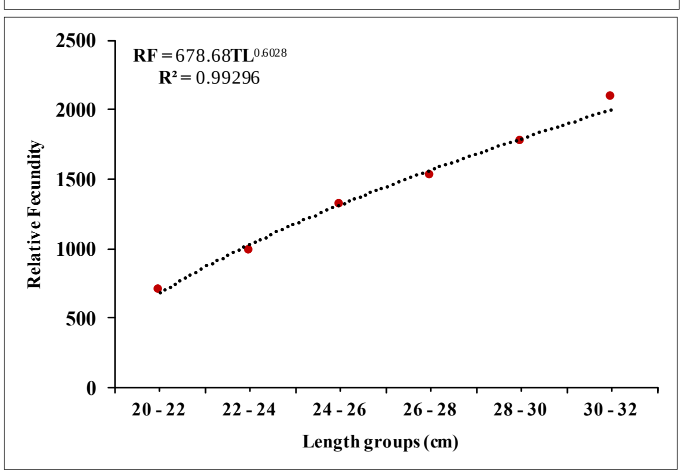
Fecundity increased with fish weight. Absolute fecundity ranged from 14750 to 63553 ova for fish that ranged from 57.79 gm to 194.53 gm (Twt), with an average total weight of 127.81± 58.19 gm (average absolute fecundity 38075 ± 18181 ova) for the Gulf of Suez population. For the Mediterranean Sea population, the absolute fecundity ranged from 18090 to 62025 ova for fish that ranged from 54.83 gm to 193.55 gm (Twt), with an average total weight of 114.934 ± 50.83 gm (average absolute fecundity 39274 ± 15783 ova). The regression equations between the absolute fecundity and fish weight (described by a linear equation) for both populations are shown in Fig. (9).

The relative fecundity for the Gulf of Suez population ranged from 255 to 327 ova/gm, with an average of 295 ± 27 ova/gm, while for the Mediterranean Sea population it ranged from 320 to 381 ova/gm with an average of 346 ± 21 ova/gm. The regression equations between the relative fecundity and fish weight (described by a linear equation) for both populations are shown in Fig. (9).

The independent t-test showed a significant difference in the absolute fecundity and relative fecundity regarding the length ($P$<0.05), whereas a highly significant difference was observed in relative fecundity regarding the weight ($P$<0.001) between both populations.

**(A)** Gulf of Suez Population



**(B)** Mediterranean Sea Population

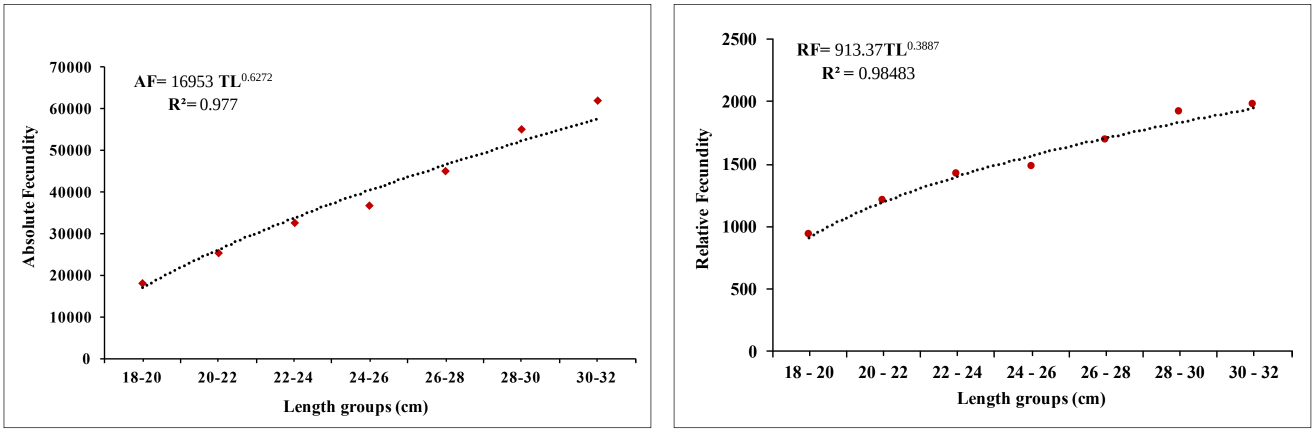
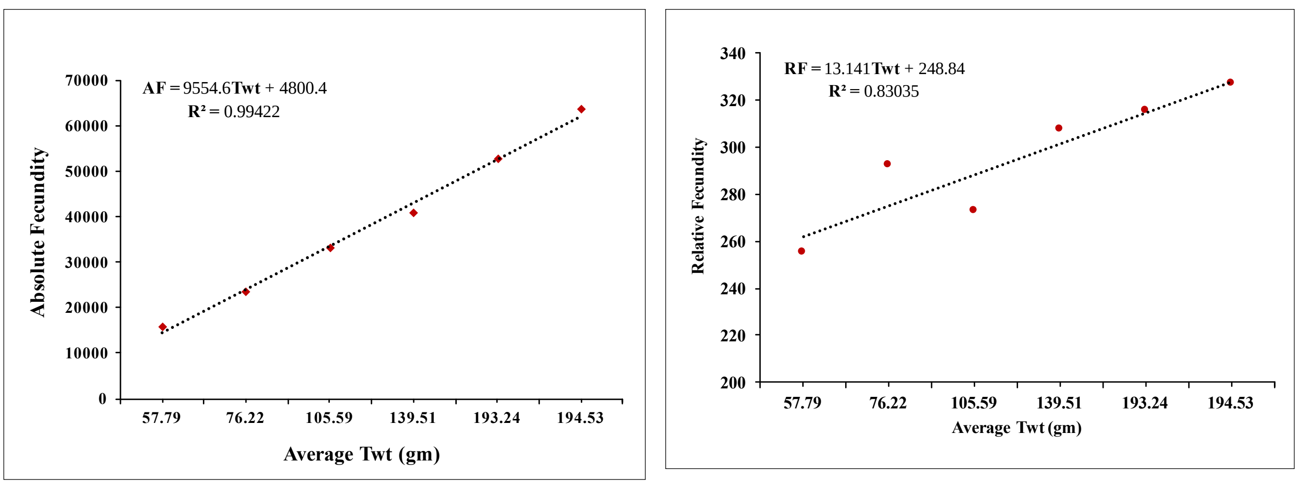



**Fig. 8.** Relationships between absolute fecundity and relative fecundity with length groups of *S. undosquamis* collected from both study sites

**(A)** Gulf of Suez Population




**(B)** Mediterranean Sea Population

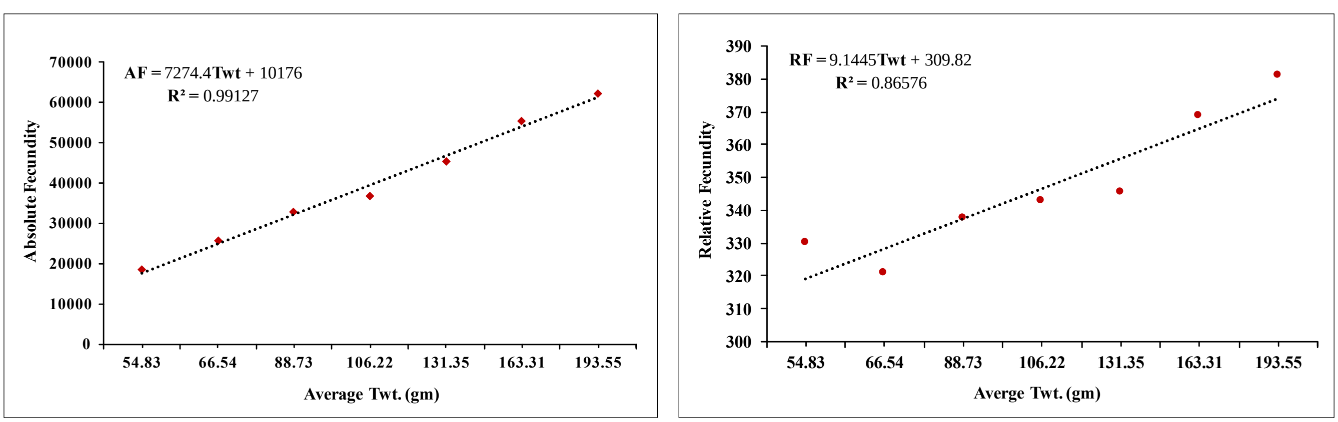



**Fig. 9.** Relationships between absolute fecundity and relative fecundity with average weight of *S. undosquamis* collected from both study sites

## DISCUSSION

The sex ratio in both sites showed an excess of males for most of the study period. Nevertheless, the ratio of males to females declined in one month of the spawning season for the Gulf of Suez population and for two months for the Mediterranean Sea population. Such deviation and predominance of one sex might result from the behavioral differences between the two sexes, which is, in turn, a result of differential fishing proportion, one being caught more than the other **(Mali *et al.*, 2017)**. It could also be due to natural selectivity, and gear selectivity concerning sex difference in activity and morphology, segregation of the sexes through various periods of the year, including segregation resulting from sex differences in the size of maturity **(Smith, 1956)**; migration for spawning and feeding **(Yeldan & Avsar, 2000)**, or the strong predation capability of one sex than the other **(Sabrah *et al.*, 2016)**.

Our findings agree with that reported for the same species in the study of **Ismen (2003)** in the Mediterranean Sea, Turkey (1: 0.73). Similarity was also considered between the current findings and those of **El-Ganainy (1997)** for *Saurida tumbil* in the Red Sea, Egypt (1:0.77). Whereas, results differ from those of **EL-Greisy (2005)** whose study was conducted on the Egyptian Mediterranean Sea. Furthermore, reversely to the present results, **Kadharsha *et al.* (2013)** in the Southeast coast of India, estimated the sex ratio with values of 1:1.6 for *S. undosquamis.* The dominance of males in almost all years for the different species of lizard fishes is commonly known as a distinctive feature of these species and was proved by many authors in various regions, such as **Tiews *et al.* (1972)**, **Budnichenko and Dimitrova (1981)**, **Nair *et al.* (1992)** and **El-Ganainy (1997)**.

The monthly variations of the different maturity stages and their distribution throughout the study period reflect the spawning time. In the present study, for the Gulf of Suez population, *S. undosquamis* have a prolonged spawning season (where mature gonads in stages IV and V occurred in five months out of eight) for both males and females with an extensive peak in spring. This result agrees with that of **El-Ganainy (2004)**, who indicated that the highest values of specimens in stage (V) were recorded during spring for *S. undosquamis* from the Red Sea. Those peaks of the present study and El-Ganainy's might have occurred precisely during spring because of the oceanographic conditions, which are optimal for developing the eggs and larvae of fish since semi-low temperature and salinity are conductive to the hatching and development of the larvae **(Bapat, 1955)**.

For the Mediterranean Sea population, males and females followed the same trend of having a prolonged spawning season. Maturity stages (IV and V) occurred in ten months out of thirteen, with two peaks during summer and winter. This result is close to those of **Ismen (2003)**, who indicated that the spawning season for *S. undosquamis* occurred throughout the year, with two peaks in July and May in the Iskenderun Bay, Turkey. The difference in temperatures in both study sites seemed to be the principal factor affecting the gonadal development of the species **(Golani, 1990)**.

In the present work, males generally matured earlier than females in both study sites. Mediterranean Sea males and females attained their sexual maturity at an earlier size than those of the Gulf of Suez. These results are close to those estimated for the same species in different study regions such as that of **Faltas (1993)**, who estimated $L_{50}$ for combined sexes at 19 cm from the Egyptian Mediterranean waters, **Amin *et al.* (2007)** at 17.4 cm for males, **El-Halfawy *et al.* (2007)** at 18.1cm for females from the Gulf of Suez and **Kadharsha *et al.* (2013)** at 19.5 cm for combined sexes from the Southeast coast of India. The present results are higher than those obtained by **Ismen (2003)**, who estimated $L_{50}$ by 16 cm for males and 16.5 cm for females, and **El-Etreby *et al*., (2013)** who determined it by 15 cm and 15.5 cm for males and females, respectively. These differences in maturity size might be related to the environmental conditions, especially temperature, that induces phenotypic flexibility (genetic differences) in fish which may change size at maturity **(Pyper *et al.*, 1999)**. It might also be associated with the difference in habitats as well as the variations in the number of specimens and the size range.

Many authors consider the gonado-somatic index a more accurate method for studying the cyclic changes in maturity and the determination of the spawning season. The minimum, maximum and average values of GSI of *S. undosquamis* from both study sites confirm the above conclusion that the mentioned species have a prolonged spawning season in the Gulf of Suez with high values during spring; and in the Mediterranean Sea with peaks during winter and summer. **El-Ganainy (1997)** stated that the year-round spawning of lizardfish species could be due to the intermittency of the spawning and the variations in the spawning times of the different populations. The rates of GSI values were higher in females than males, particularly during the spawning season. Regarding the mode of GSI values and its fluctuations along the period for both sexes, **Moyle and Cech (2004)** stated that the ovaries of teleost fishes are larger by several times than the testes.

Conclusively, regarding the present result of seasonal variations in maturity stages and GSI values, the spawning season of *S. undosquamis* in both sites is prolonged. This conclusion is in agreement with the studies of **Ismen (2003)** at the Eastern Mediterranean Sea, **EL-Gresiy (2005)** at the Mediterranean coast of Egypt, **Amin *et al.* (2007)**, **El-Halfawy *et al* (2007)**, **El-Etreby *et al.* (2013)** at the Gulf of Suez and **Kadharsha *et al.* (2013)** at the southeast coast of India.

Fecundity estimates can be used to investigate the reproductive potential of fish stock, the survival from ova to recruitment, and the minimum adult stock necessary to ascertain the required recruitment level **(El-Ganainy, 1997)**. Considerable variation in the fecundity of the two populations of *S. undosquamis* was observed in the present study.

The results of the present study regarding the number of ova of *S. undosquamis* coincide with those of **Torcu (1995)** in Mersin Bay, Turkey, who estimated the range of absolute fecundity from 14,226 to 65,833ova. The results were slightly lower than that obtained in the study of **El- Greisy (2005)** from the Mediterranean coast of Egypt and that of **Kadharsha *et al*. (2013)** from the southeast coast of India, who found that absolute fecundity ranged from 19,856 to 79,282 ova for the same species. **Bagenal (1963)** concluded that these changes in fecundity are related to the changes in hydrographic conditions and might be due to variations in food availability.

To conclude, by comparing the absolute and relative fecundity of the two studied populations, the number of ova was recorded higher in the Mediterranean Sea habitat than that recorded in the Gulf of Suez. The differences between the two populations might be related to the temperature, the timing of spawning, fish length or weight and age **(Nikolsky, 1963;Bagenal, 1978)**. Additionally, for a migrant species, the production of a high number of ova during the spawning season indicates that *S. undosquamis* has adapted itself well to the Mediterranean habitat and is very likely to increase its abundance in the future.

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