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A Preliminary Study on the Reproduction of the Rabbitfish *(Siganus rivulatus* (Forsskal, 1775)) in the Northeastern Mediterranean

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Abstract: This study was carried out to identify some aspects of the reproductive cycle of the rabbitfish (*Siganus rivulatus*) inhabiting the northeastern Mediterranean. For this reason, monthly sampling was conducted between February 1995 and June 1996, and a total of 473 specimens were used. By using the monthly changes in the values of the gonadosomatic index (GSI) and Condition Factor (K), it was found that their reproduction takes place during July and August. The mean diameter of ripe gonadal eggs was 0.44 mm; and mean fecundity and its standard deviation was found to be 434761±181006. Fecundity-total length, fecundity-total weight and fecundity-age relationships were also estimated using regression analysis as follows:

Total Length (cm)	$F= 0.49 * L^{4.61}$	(r= 0.96)
Total Weight (g)	F= -57584.67 + 4851.96 * W	(r= 0.96)
Age (years)	F= -1029631.33 + 255261.18 * A	(r= 0.64)

Key Words: Northeastern Mediterranean, Rabbitfish *(Siganus rivulatus)*, Reproduction.

Kuzeydoğu Akdeniz'deki Sokar Balığı *(Siganus rivulatus* (Forsskal, 1775))'nın Üremesi Üzerine Bir Ön Çalışma

Özet: Bu çalışma, kuzeydoğu Akdeniz'deki Sokar balıkları (*Siganus rivulatus*)'nın bazı üreme özelliklerini belirlemek amacıyla gerçekleştirildi. Bunun için Şubat 1995-Haziran 1996 tarihleri arasında aylık olarak örnekleme çalışmaları yapıldı ve toplam 473 adet örnek kullanıldı. Ortalama Gonadosomatik İndeks (GSI) değerleri ile Kondisyon Faktörü (K)'nün aylık değişimleri kullanılarak, sokar balıklarında üremenin Temmuz-Ağustos arasında gerçekleştiği saptandı. Gonatlardaki olgun yumurta çapının ortalama 0.44 mm ve Ortalama Fekondite ile Standart Sapma değerlerinin ise, 434761±181006 olduğu; ayrıca Regresyon Analizi kullanılarak tahmin edilen Fekondite-Boy, Fekondite-Ağırlık ve Fekondite-Yaş ilişkilerinin ise;

Boy için (cm)	$F= 0.49 * L^{4.61}$	(r= 0.96)
Ağırlık için (g)	F= -57584.67 + 4851.96 * W	(r= 0.96)
Yaş için (yıl)	F= -1029631.33 + 255261.18 * A	(r= 0.64) şeklinde olduğu bulundu.

Anahtar Sözcükler: Kuzeydoğu Akdeniz, Sokar balığı *(Siganus rivulatus),* Üreme.

Introduction

The presence of several fishing harbors in Iskenderun and Mersin bays, together with the considerable widening of the continental shelf in the offshore waters of the mentioned area and the suitability of its topographical structure has made the Cilician Basin one of the important fishing centers of the eastern Mediterranean. The Lessepsian species distributed in the region have begun to be caught in increasing quantities in recent years. They have become one of the economically important species landed in this area (1, 2). Therefore, amongst them, the rabbitfish (*Siganus rivulatus*) was selected for the present study. Although this species has not yet been included in fisheries statistics, they are caught in considerable numbers in the region by gill nets during the summer months when touristic activities peak and commercial trawling is forbidden. It is therefore very important to identify the reproductive season, sexual maturity and fecundity of this species since such studies convey important information to fisheries biologists before the standing stock in any region declines to an uneconomic level. Therefore this study attempts to define the reproductive biology of the rabbitfish.

Although several studies on this species have been undertaken especially in the Red Sea, as yet, no detailed study has been carried out in the northeastern Mediterranean. Previous studies performed along the Turkish Mediterranean coast are related with more general subjects. Among them Akşiray (3) gives information on their general characteristics such as reproductive season, food and feeding habits and also about the distribution of this species. Geldiay (4) reports the geographical distribution of the rabbitfish in the Mediterranean. He indicates that it is present in the eastern Mediterranean and Aegean Sea, but is not found in the Sea of Marmara or the Black Sea. This author also points out that the rabbitfish is among the economically important fish species of Izmir Bay in the Aegean Sea. The distribution of this species is also given by Ben-Tuvia (5), as being along the coast of Lebanon, Israel and Cyprus in the eastern Mediterranaen; Southern Aegean, Greece and Libya in the central Mediterranean, and in a wide range of zoogeographical regions including Aden Bay in the Red Sea. Fischer (6) reports that the geographical distribution of *S. rivulatus* extends between the shores of Libya and Cyprus, in the neritic waters from the Israeli shores to Anatolia. Papaconstantinou (7) emphasized that the number of Lessepsian fish species in the eastern Mediterranean has been increasing in recent years. He reported that there are 11 Lessepsian fish species around the Aegean Islands and that *S. rivulatus* is one of them. Gücü et al. (2) has already defined the meristic and morphometric characteristics of this species.

It is clearly seen that the literature review reveals that information about the spawning of this species in the northeastern Mediterranean is rather scarce, and that is no comprehensive study was undertaken. Therefore the present study was carried out in order to contribute to the knowledge about this species through the information obtained. It is hoped that the results obtained from this research will contribute to management studies of the present stock of rabbitfish in the northeastern Mediterrarean.

Materials and Methods

This study was carried out between February 1995 and June 1996, during which time a total of 473 specimens were collected through monthly sampling. Individuals were chosen randomly.

Fish samples (N=445) were primarily obtained by using a gill net or rod and line from the neritic waters of Yumurtalık and Karataş towns on the northeastern Mediterranean coast, and samples (N=28) from Mersin Bay (Fig. 1) were caught by fishermen for commercial

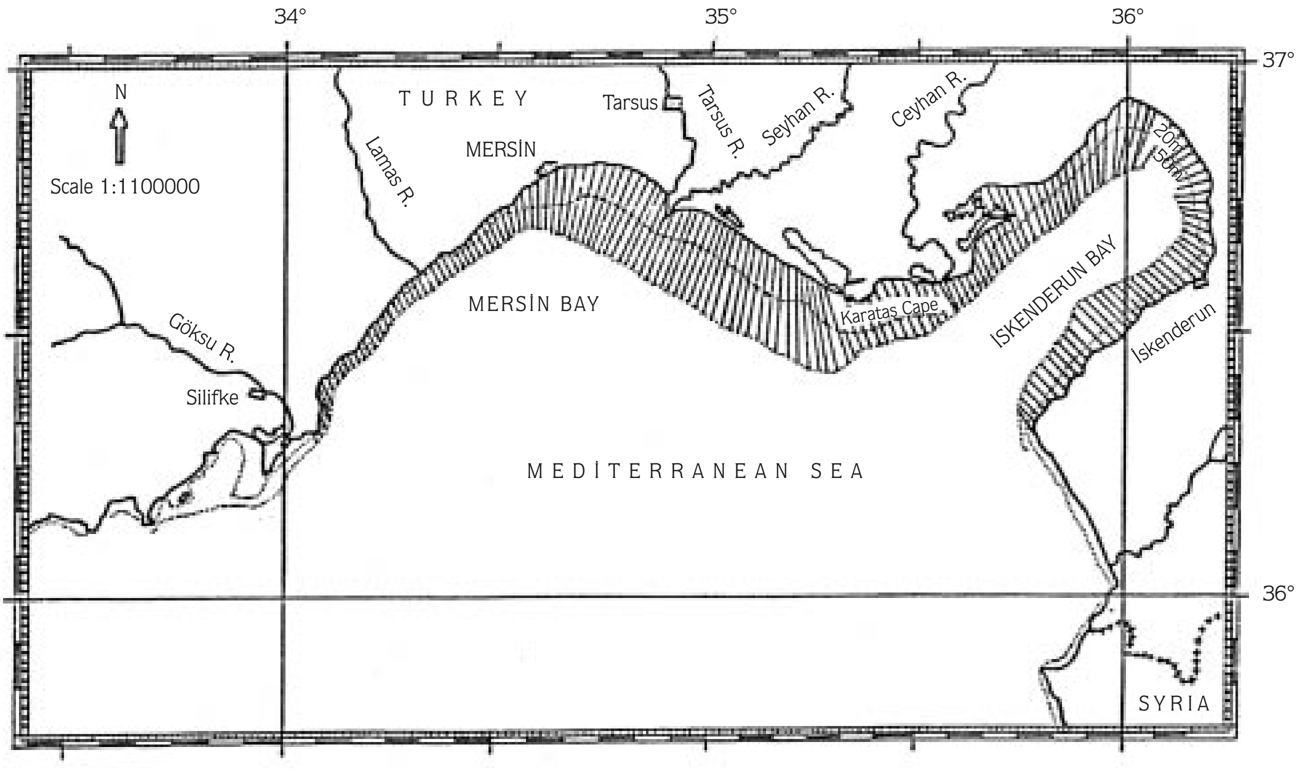

Figure 1. Sampling locations (dashed area) in the northeastern Mediterranean.

purposes using a bottom trawl. The samples were preserved either in 10 % formalin solution buffered with borax, or by freezing. For length measurement, a millimetrically calibrated measuring board was used. Class intervals of 1cm were used during processing of the data. For total weight measurements and the weighing of gonads, scales with 0.1g and 0.0001g sensitivity respectively were used.

In defining the ages of the samples, scales in the anterior region between the lateral line and the dorsal fin were used. These were preserved in glycerine in PET containers (Eliza container) of $0.5cm^3$ volume. For ageing, a stereo binocular microscope was used, and the recommendation made by Nikolsky (8) was taken into consideration.

In order to determine the breeding season, individual gonads were taken; the monthly mean gonadosomatic index (GSI) and Fulton's Condition Factor (K) values were calculated for males and females separately. Gender determination was done by the naked eye for mature individuals and by microscope in young specimens. For GSI and K values Gibson and Ezzi's equation (9) of

GSI=(Gonad Weight / (Body Weight - Gonad Weight))*100

and Htun-Han's equality (10)

K=((Body Weight-Gonad Weight)/Total Length^3)*100

were used respectively.

To calculate individual fecundity, after total weighing, the female ovaries were removed and weighed. Sub samples taken from the front, middle and rear sections of the ovaries were placed on a microscope slide which was divided into 3mm squares and a drop of glycerine. Five squares were then observed under the microscope for counting. Later by taking the mean number, the total number of eggs in the sub sample was found. This value was proportioned to the ovarium weight and the total fecundity (F) was estimated using the equation below:

F=((Gonad Weight * Egg Number in the Subsample) / Subsample Weight)

Results

Sex Ratio

Monthly changes in the percentage ratio of females to males are presented in Table 1.

The percentage sex ratio of the northeastern Mediterranean rabbitfish shows an increase during March-May and October-December. From February until June, the number of females shows a rapid increase. However, during June-September this number shows a

Table 1. Monthly changes in the percentage sex ratio (Females (F) to the Males (M)).

Months	Percentage Sex ratios (F/M)	
February 1995	44.8	
March	60.7	Prespawning
April	70.4	
May	69.7	
June	44.4	
July	50.0	
August	33.3	
September	33.3	
October	62.1	After spawning
November	60.6	
December 1995	60	
January 1996	48.9	
February	54.5	
March	46.2	
April	52.9	
May	45.5	
June 1996	47.1	

decline. During the period that includes November, there is an increase, which lasts until January. In January, another slight decrease in females occurs until the increase in February which lasts until June. Although the changes in the sex ratio appear regular, with regard to our observation period for the pre spawning time in 1995 and 1996 during March, April, May and June a satisfactory result could not be obtained due to the fact that the number of samples was low.

Maturity Stages of the Gonads

The sexual maturity stages of the gonads were defined macroscopically and the general characteristics were determined as follows:

Stage I (Immature): The samples defined as immature consisted of very young individuals which were seen during the period of December and January (Table 2). Immature individuals which were on average 14.3 cm in length had very small and thinly structured gonads which had not yet begun to mature. Due to this fact, sex determination proved to be extremely difficult. The testes were whitish or greyish-brown and spindle shaped. Ovaries were dirty yellowish-red and eggs were not visible to the naked eye. Therefore sex differentiation for this stage was done by microscopic inspection.

Stage II (Beginning to mature): Samples with gonads of transparent ovaries and testes (which were heavier) were observed in February-March and in a lesser amount in April (Table 2). According to their morphology males and females were easily distinguished by the naked eye. The ovaries of the females began to have a granular structure and looked swollen. Testes also looked swollen due to the sperm accumulation and thin structure especially on the ends. The ovaries were symmetrical and were pinkish or transparent; the testes were of different sizes and were all whitish.

Stage III (Maturing): The distinction of the genders was made easily with the naked eye. Mature individuals were seen around April-May and June (Table 2). Ovaries were pinkish-yellow and granular. Testes were whitish, yellow-cream, soft textured and the ends were sharp like a knife edge.

Stage IV (Mature): 4th stage individuals with ovaries and testes that filled the whole abdomen were seen in July and August (Table 2). Ovaries were orange or pink and they were surrounded with developed veins. The females of this period contained large, transparent and mature eggs in their gonads. Testes were whitish-cream and soft textured.

Table 2. Monthly changes in the sexual maturity stages.

Months	Sexual Maturity Stages
February 1995	II
March	II
April	II, III
May	III
June	III
July	IV
August	IV
September	V
October	V
November	V
December 1995	I
January 1996	I
February	II
March	II
April	II, III
May	III
June 1996	III

Stage V (Spent): Individuals which had spawned and released sperm were seen from September to November (Table 2). The spent ovaries had returned to the size seen between the first and the second stage. Some aggregations of dark, mature eggs were seen. Ovaries were dark or transparent whilst the testes were full of blood and looked flabby.

The monthly changes in the sexual maturity stages are given in Table 2.

Stage IV mature individuals were seen in July and August. During the period from September to November spent individuals were seen. The diameter of these ripe eggs ranged between 0.39 and 0.48 mm, and their mean was found to be 0.44 mm. Between December and January, which could be considered the resting period, immature individuals were observed. In both years (1995 and 1996) around February-March, individuals that had begun to mature were seen (Stage II). In April-May, both Stage III and Stage IV individuals were observed and in July again mature individuals were seen (Table 2). This means that the rabbitfish begin to mature during the winter. In the spring their sexual development rapidly increases. They spawn mainly between July and August after which there is a resting period during the autumn.

Gonadosomatic Index (GSI)

Since the gonadosomatic index value is directly related to the development of the gonads, it is widely used, especially for the bony fishes in order to identify their breeding periods (9, 11, 12). The changes in the monthly GSI values of individuals of both sexes are given in Fig. 2.

It is observed that the GSI values of males and females were low during February 1995 and May 1995. Index values began to increase after May 1995 and reached maximum values in July 1995, then began to decrease

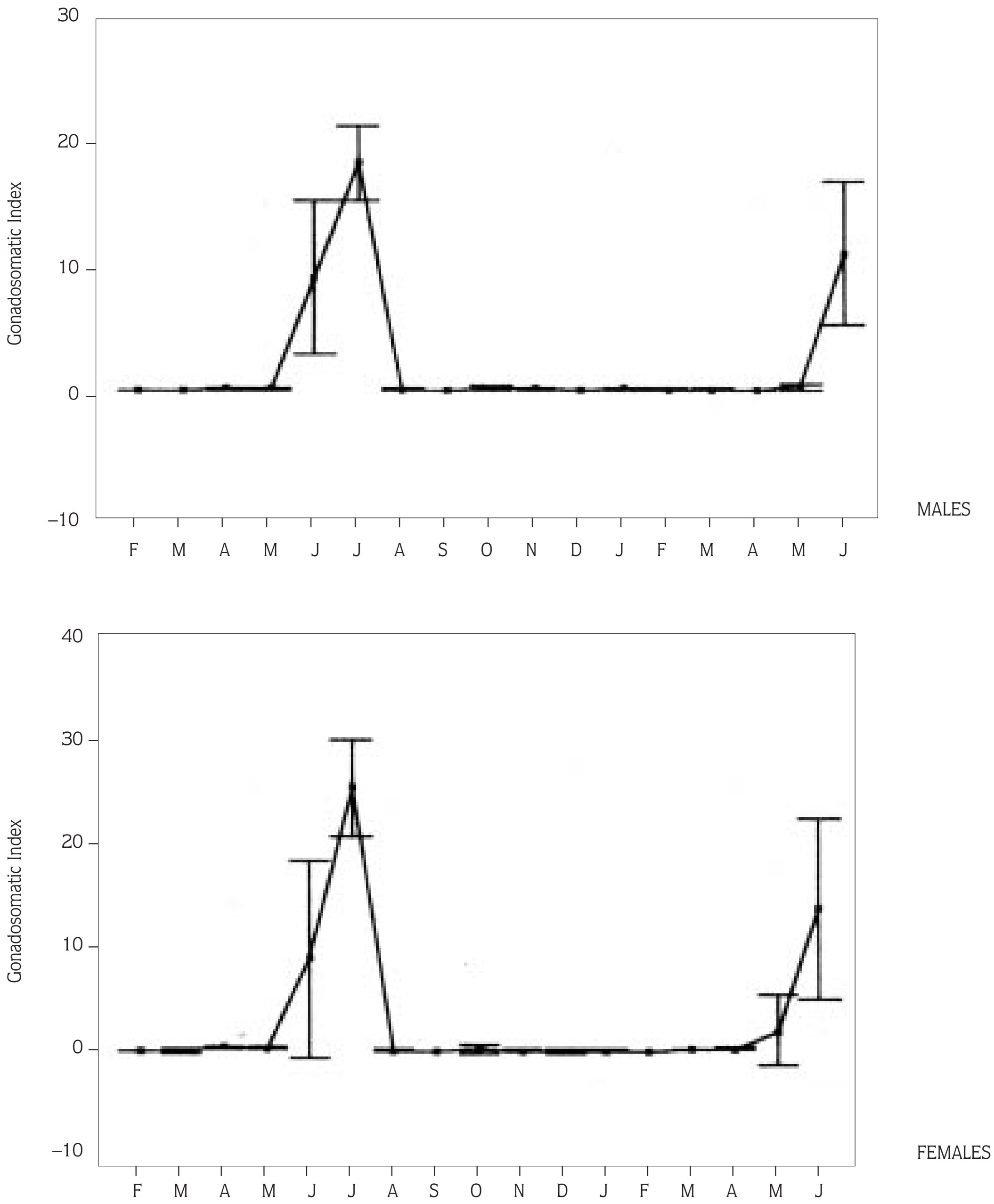

Figure 2. Monthly changes in the Gonadosomatic Index values of each sex (Vertical bars denote 2xS.E. of the mean (95% confidence limits).

towards the end of August and after that continued at very low levels until May 1996 (Fig. 2). The cyclic changes in the GSI values show that the rabbitfish begin to spawn in the northeastern Mediterranean in July and continue until the end of August. Moreover, it is clearly observed that sexual maturity begins in March and continues very slowly until June.

Fulton's Condition Factor (K)

Due to some correlation between the Fulton's Conditon Factor and changes in the food elements deposited in the muscle tissues of fish, it was used to determine the breeding seasons of bony fishes by some authors (10, 11). The monthly changes in the Fulton's Condition Factor values obtained for both sexes are

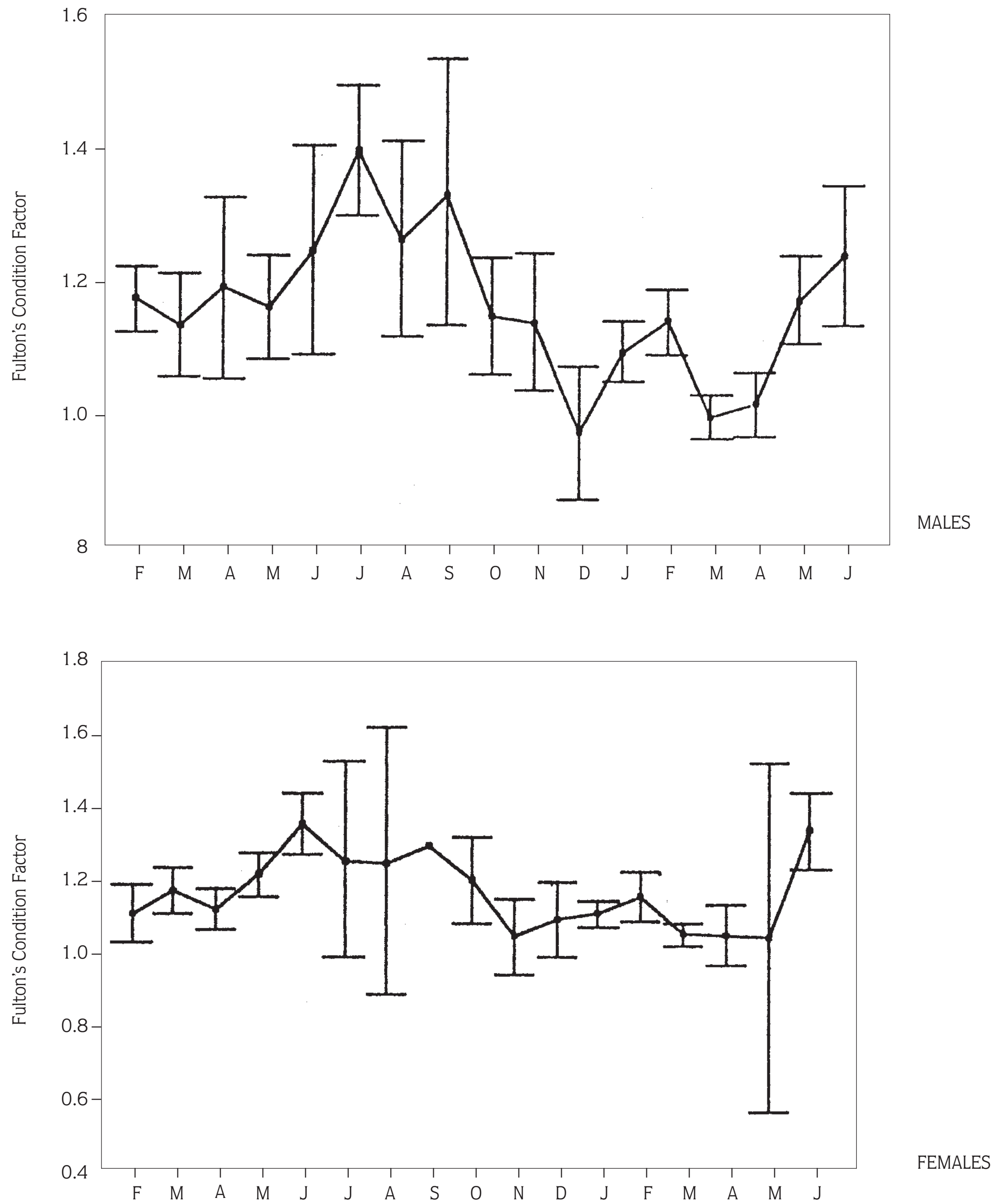

Figure 3. Monthly changes in the Fulton's Condition Factor values of each sex (Vertical bars denote 2xS.E. of the mean (95% confidence limits).

shown in Fig. 3. Due to the inverse relationship between the gonadal development and the food elements deposited in the muscle tissue, as the gonadosomatic index increases, the Fulton's Condition Factor is expected to decrease. As observed in Fig. 3, Fulton's Condition Factor values showed a decrease at the beginning of November 1995. It seems that the food consumed after November was mainly used for producing the reproductive cells. So the Fulton's Condition Factor showed a decrease, and this lasted until December. After this month most probably gonadal development slowed down which continued until February. It speeded up during March-April and gonads became mature in May. The development pattern as revealed by the Fulton's Condition Factor was in the opposite direction to that of the gonadosomatic index (GSI). Both values showed that the northeastern Mediterranean rabbitfish began to spawn only in July and that spawning continued until August.

Fecundity

It was observed that the lengths of individuals used for the study of fecundity were 15.5-22, and their weights varied between 49.3 and 162. The mean fecundity and its standard deviation was found to be 434761±181006.

Since mature individuals were seen only between July and August (Table 2), it can be shown that this species spawn once a year, and can also be defined as one of the total spawner species. The data obtained by counting the eggs from the samples taken during the spawning period (July-August) was analysed as fecundity-total length, fecundity-total weight and fecundity-age and these relationships were calculated as described below.

Fecundity (F) - Total Length (L) has an exponential relationship of

$F=0.49 * L^{4.61}$ (r=0.96)

Fecundity (F) - Total Weight (W) has a linear relationship of

$F=-57584.67 + 4851.96 * W$ (r=0.96) and

Fecundity (F) - Age (A) has also a linear relationship of

$F=-1029631.33 + 255261.18 * A$ (r=0.64).

Although a logarithmic-exponential relationship was found for fecundity-total length, the samples show that as the length increases, fecundity also increases. The regression coefficient calculated for fecundity-age (r=0.64) is too small when compared with that of total length (r=0.96) and weight (r=0.96). Moreover, it is considered that the mature individuals in the same age group show more range, and this may decrease the regression coefficient.

Discussion

The changes in the percentage of females to males in Table 1, were most probably due to spawning and feeding migrations. In fact the increase in the ratio of females February-June which is the prespawning period, shows that the rabbitfish migrate to neritic waters of the north eastern Mediterranean for feeding earlier than their male counterparts. The percentage sex ratio value of 50 for July supports this assertion and also shows that both sexes were evenly distributed around the study area. During July, which is accepted as the beginning of the spawning period, all population members come together and form a sex ratio of 1:1. However, this composition lasts only one month and in the following month the females were observed together with many other pelagic species (*Engraulis engrasicolus* (13); *Sprattus sprattus phalericus* (11)) in the open sea for spawning. After spawning migration the percentage ratio of the female individuals, especially during the period between October and December and until June stays a little over 50 which might be a sign that they remigrate for feeding in the neritic waters during the period until June (Table 1).

The present study indicates that the rabbitfish inhabit the northeastern Mediterranean for their sexual maturation period during March, April and May. They spend July and August spawning (Table 2, figs. 2 and 3). The monthly changes in the GSI values as shown in Fig. 2, clearly show that after September they enter a resting period.

When other studies carried out along the southeastern Mediterranean and the Red Sea regarding the reproductive biology of the rabbitfish are taken into consideration, it is seen that there are some differences between those results and the results of the present study. Indeed, among the earlier studies e.g. Ben-Tuvia (14), reports that the larvae and juveniles of *S. rivulatus* from the eastern Mediterranean are found between July and November and the mature females during the summer months. Amin (15) reported about *S. rivulatus*, sampled from the Jeddah region of the Red Sea, that they reached sexual maturity earlier than those found in the eastern Mediterranean. Indeed, the results obtained by Amin (16), using the temporal changes in GSI values obtained from different samples collected in Red Sea show that gonadal maturation occurs over a three month period (January- March), with the spawning period continuing for about seven months (March-September). This result may be related to the fact that the water temperature in the Red Sea is considerably higher than that of the eastern Mediterranean. Ben-Tuvia (5) also reported that this species spawn between July and August. In addition, Hussein (17) has defined the spawning period of this species collected from the Mediterranean coast of Egypt as July to September, but Golani (18) reports that their spawning takes place between May and August along the Mediterranean shores of Israel. In addition to this, there are some contradictions between the results obtained from this study and the results mentioned by some Turkish authors. Indeed, Akşiray (19), reports that rabbitfish extend from the Mediterranean shores of Turkey to the southern parts of the Aegean Sea. They begin their spawning activities in the early summer months and continue for a short time until midsummer. Torcu (20), also presented data on their reproduction, and indicated that the spawning period of this species in the Mediterranean is between April and August.

When the percentage sex ratios presented in Table 1 and the monthly changes in the sexual maturation periods presented in Table 2 are taken into consideration, it can be clearly observed that in fact breeding takes place mainly during July and August. This shows that the general statement about bony fishes whereby it is said that a species living at higher latitudes breeds later and over a shorter period than those living at lower latitudes is also valid for individuals of the rabbitfish living on the Egyptian, Israeli and Turkish shores of the Mediterranean.

It is well known that effective management of a fish stock is of importance for the sustainable fishery of that stock (21, 22). Therefore, it may be necessary to reduce fishing pressure due to the selectivity of fishing gear, and it may in fact be necessary to stop fishing during certain periods (23, 24). Since the rabbitfish begin to spawn in the northeastern Mediterranean in July and continue only until the end of August, it can be reasonably stated that the fisheries carried out on the rabbitfish stock distributed in this area should stop during July and August.

The result of 0.44mm for the mean diameter of mature eggs found in the present study agrees with the results of 0.30-0.48mm found by Amin (15) from the Red Sea rabbitfish. Hussein (17) studied rabbitfish collected from the Mediterranean coast of Egypt, and reported that the egg diameters of his samples varied between 0.23 and 0.50mm but on average were 0.48mm. When the egg diameters reported in these studies are compared with those found in the present study, it is seen that there are no significant differences between them. However, the results of 0.44mm for northeastern Mediterranean rabbitfish, and 0.48mm for the Red Sea and southeastern Mediterranean rabbitfish contradict the general fact that there is an inverse relationship between the diameter of the produced egg and a decrease in the salinity level (25).

Estimation of the length of the sexually mature individuals being from 15.5 to 22.0cm and fecundity 434761±181006 makes it possible to compare the rabbitfish from the northeastern and southeastern Mediterranean and those from the Red Sea. Indeed, Hussein (17) carried out a study on the rabbitfish sampled from the shores of the Mediterranean at Alexandria, Egypt and he reported that the sexually mature individuals were 15-28cm in length, and the calculated fecundity values varied between 103200 and 396600. Hashem (26) reported the lengths of sexually mature rabbitfish in the Red Sea to be 15-17cm and that fecundity varied between 40000 and 300000. It can therefore be shown that although the smallest sexually mature rabbitfish individuals of the three regions are about the same length (≈ 15 cm); larger individuals are seen more frequently along the Egyptian shores and the highest fecundity values are obtained among the rabbitfish of the northeastern Mediterranean.

As can be seen in the monthly changes in the Fulton's Condition Factor values in Fig. 3, they show a decline beginning in May for 1995 and 1996. It is observed that this decline begins to slow down after May. This slowing continues until July 1995 in the samples obtained in 1995 and increases until the end of August and decreases again from September to December. It can be inferred that the reason for this decline may be due to the fact that a high portion of the food elements have been used for the development of reproductive cells. By looking at the monthly changes in the Fulton's Condition Factor it can be easily shown that the northeastern Mediterranean rabbitfish breed between July and August. However, by referring to monthly changes in the GSI values, Hashem (26), reported that the breeding season for the rabbitfish in the Jeddah, Red Sea is between March and April. This indicates that the rabbitfish population of the northeastern Mediterranean spawn one month later than the Red Sea population which is in a warmer region (7) than the former one (27). The higher Fulton's Condition Factor values estimated for early spring, autumn and especially for winter (Fig. 3), emphasize that the period when the northeastern Mediterranean rabbitfish are fattest and in best condition is from the end of autumn until the beginning of spring.

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