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Length-weight relationship and population parameters of the sea bream, *Sparus aurata* (Linnaeus, 1758) in Abu Qir Bay, Mediterranean Sea, Egypt

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ABSTRACT

The present work aimed to study some biological and population parameters of *Sparus aurata* in Abu Qir Bay, Alexandria to understand the status of its stock and give essential information to assess proper management for this species in the bay. A total of 1029 random specimens of gilt-head sea bream, *S. aurata* were monthly collected from commercial catch in the landing site at Abu Qir Bay during the period from January 2020 to January 2021. For each fish sample, total length (cm) and total weight (g) were measured, and scales were used for age determination. The total scales' radius and the radius of each annulus were calculated to the nearest 0.01 cm. The back-calculation method was used to estimate growth in length and weight at the end of each year. Results of the length-weight relationship showed that the growth of *S. aurata* in Abu Qir Bay fishery is nearly isometric (b: 3.01). The longevity of *S. aurata* was more than 5 years. The maximum increment of the linear growth occurred by the end of the first year of life (15.61 cm), but the maximum value of increment in weight (69.95 g) was recorded at age group IV^+. Age groups I^+ and II^+ were the most abundant amounting 55.6% of its total catch. The length at first capture (Lc)was 18.96 cm. Total, natural and fishing mortality rates for *S. aurata* were 1.16 yr^{-1}, 0.56 yr^{-1} and 0.60 $year^{-1}$, respectively. Growth parameters were calculated as $L\infty$ = 35.49 cm, K = 0.25 yr-1 and t_0 = -1.27 yr. Exploitation rate (E = 0.52) indicates that the stock of sea bream was slightly higher than that optimally exploited stock.

INTRODUCTION

The gilt-head seabream, *Sparus aurata* (Linnaeus 1758) is a perciform fish, belonging to the Family Sparidae and to the genus *Sparus*. It inhabits the Atlantic coasts of Europe, the Mediterranean and Black Seas (rare) and is one of the highly important marine fish in fishery and aquaculture (especially in the Mediterranean area). This species is found in seagrass beds and sandy bottoms as well as in the surf zone and commonly inhibit at the depths of about 30 m, but adults may occur at 150 m depth. It is a sedentary fish found either solitary or in small aggregation. In spring, it often occurs in brackish water coastal lagoons and estuaries. Moreover, *Sparus aurata* is mainly carnivorous and accessorily herbivorous **(Bauchot & Hureau, 1990)**. The gilt-head seabream feeds on shellfish, including mussels and oysters. In addition, it is one of the most important fishes in saline and hypersaline aquaculture. *Sparus aurata* is utilized fresh and eaten steamed, pan-fried, broiled, boiled, microwaved and baked **(Frimodt, 1995)**. Due to its ewyhaline and ewythermal habits, the species is fold in both marine and brackishwater environments, such as coastal lagoons and estuarine areas, particularly during the initial stages of its life cycle. The gilt-head seabream is usually male that is converted to a female at size over 30 cm **(Bauchot *et al*., 1981**; **Buxton & Garratt,**

1990). It is a protandric hermaphrodite species that matures firstly as male (during the first or second year of age) and after the second or third year of age, as female. Spawning happens generally from October to December, with sequenced spawning during the whole period. Incubation lasts about 2 days at 16-17°C. Larval stages last about 50 days at 17.5°C or about 43 days at 20°C. Egg size is 0.9-1.1 mm, larval length at hatching is 2.5-3.0 mm. Simultaneous hermaphroditism is suggested for this species **(Mitcheson & Liu, 2008)**.

The total production of gilt-head seabream in the Egyptian Mediterranean coast is 440 tons in 2019, and it is distributed in the commercial markets in fresh or frozen. Trawl nets, bottom set longlines, and hand lines are also commonly used in fishing gilt-head seabream **(GAFRD, 2019)**. Thus, different aspects of biology, management and population dynamics of the investigated fish have been addressed in many early and present researches **(Wassef, 1990; Gurbet & Korkut, 1992; Kraljevic & Dulcic, 1997; Cetinic *et al*., 2002; Santos *et al*., 2002; Chaoui *et al.*, 2006; Emre *et al.*, 2009)**. They studied the age and growth as well as length-weight relationship of gilt-head sea bream, *Sparus aurata* in the Egyptian Mediterranean waters.

The present study addressed some biological and fisheries aspects of *Sparus aurata* collected from Abu Qir Bay, Alexandria to understand the status of the stock in fisheries, providing an essential information to assess a proper management for this species in the bay.

MATERIALS AND METHODS

1. Study area

Abu Qir Bay is a shallow semi-circular basin located at about 35 Km east of Alexandria City (Fig. 1). It is located between the mouth of the Rosetta Branch of the Nile River to the east and Abu Qir head land to the west, and lies between latitudes of 31^o 16 and 31^o 28 North and longitudes 30^o 5 and 30^o 22 East **(Said *et al.*, 1995)**. The area of the bay is about 360 Km^2 with a maximum depth of about 16 m (average depth 10 m) **(Radwan, 1996)**. The surface water temperature varies between 29.7^{o}C in summer and 15.5^{o}C in winter **(El-Mardany, 2006)**. The salinity of the water in the bay varies between 36.4 mg/1 during winter and 39.3 mg/1 during autumn **(Mohamed, 2006)**.

2. Sampling

A total of 1029 random specimens of gilt-head sea bream, *Sparus aurata* were monthly collected from the commercial catch in the landing site of Abu Qir Bay during the period from January, 2020 till January, 2021. For each fish sample, total length (cm) and total weight (g) were taken.

Fig. 1. Abu Qir Bay location between Edku Lake and the Mediterranean Sea

DATA ANALYSIS

Length-weight relationship

The relationship between length and weight was described by the following potential equation: $\mathbf{W = a*L^b}$ **(Ricker, 1975)**

Where: **W** is the total weight (g), and **L** is the total length (cm), whereas **a** and **b** are constants. The calculated weight at the end of each year was estimated by applying length-weight equation.

Age determination

For age determination, the scales were removed from the left side of1029 specimens behind the tip of the pectoral fin. In the laboratory, the scales were cleaned and stored dry in envelopes for a subsequent study. Later on, scales were soaked overnight in 10% ammonia solution. Then, 5-7 scales were placed between two glass slides and examined using a projector with 33 x magnifications. On the clearest scale from each batch, the total scales radius as well as the radius of each annulus were measured to the nearest 0.01 cm.

Back calculation methods

The back-calculated total length at the end of each year was determined from scale measurements using **Lea's (1910)** equation:

$$Lx = Lp\ (Sx/Sp)$$

Where: **Lx** equals length of fish at age (x), **Lp** equals the fish length at capture, **Sx** equals the scale radius at annulus (x) and **Sp** equals total scale radius. The relationship between scale radius and fish total length of this species was found to be linear and was represented by the following equation:

$$L = a + bS$$

Where: **L** is the total body length in cm, **S** is the scale radius in micrometer division, (**a**) is the intercept on the Y-axis and (**b**) is the slope of the regression line.

Back calculation of fish length at various years of life was determined using the following equation:

$$Ln = [(Sn / S)*(L - a)] + a \qquad \text{(Lee, 1920)}$$

Where: **Ln** is the calculated length at the end of nth year of life in cm, **L** is the total length in cm, **Sn** is the scale radius from the nucleus to the n^{th} annual mark (in micrometer division), **S** is the total scale radius in micrometer division from the nucleus to the anterior edge of the scale and **a** is the intercept on the Y axis in the length scale relationship.

The obtained formula expressing length weight relationship was used to estimate the back calculated total weights at various years of life for each species under study. No segregation due to sex was done, since the values of the two constants (a & b) were nearly the same.

Growth parameters

The von Bertalanffy growth equation (VBGE) was used to describe growth in size as follows:

$$Lt = L\infty\,(1- e^{-k\,(t - t_0)})$$

Where: **Lt** is the length at age **t**, **L∞** the asymptotic length, **K** is the body growth coefficient and t_0 is the hypothetical age at which a fish would have zero length. The values of L∞ and K were estimated by plotting **Lt** vs L_{t+1} using the plots of **Ford (1933)** and **Walford (1946)** , while t_0 was estimated by the plot of **Gulland and Holt (1959)**.

For comparison of the growth parameters with previous studies, the growth performance index was calculated from the following equation:

$$(\Phi') = Ln\,K + 2Ln\,L\infty \qquad \text{(Munro \& Pauly, 1983)}$$

Mortality rates

The length-converted catch curve method **(Pauly, 1984a)** was used to estimate the instantaneous rate of total mortality (**Z**) using the **FiSAT** program. The instantaneous rate of natural mortality (**M**) was obtained by the following formula:

$$M = W^{-1/3} \qquad \text{(Ursin 1967)}$$

Where: **W** is the mean weight of the whole sample. The fishing mortality (**F**) was estimated by subtracting the value of natural mortality from the total mortality as the following:

$$F = Z – M$$

Exploitation rate

The exploitation rate was calculated with the equation of **E = F/Z**. The probability of capture was estimated from length-converted catch curve using the running average technique to determine L_{50} **(Pauly, 1984b)**. The model of **Beverton and Holt (1966)** as modified by **Pauly and Soriano (1986)** incorporated in FiSAT program **(Gayanilo *et al.*, 1997)** was used to predict the relative yield-per-recruitment as the following:

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

Where: **U = 1- (Lc / L∞)**, **m = (1-E)/ (M/K) = (K/Z)**; **M** is the natural mortality, **K** is the body growth coefficient and **E** is the exploitation rate and the relative biomass per recruit **(B'/R) = (Y'/R)/F**.

The exploitation rate producing maximum yield is symbolized as (E_{max}), the exploitation rate at which the marginal increase of **Y'/R** is 10% of its virgin stock ($E_{0.1}$) and the exploitation rate which the stock is reduced to 50% of its unexploited biomass (**$E_{0.5}$**) were estimated. Additionally, the yield contours were plotted to assess yields on changes in **E** and **Lc / L∞**.

RESULTS

1. Length-Weight relationship

Data showed that, the total length (**L**) of *Sparus aurata* in Abu Qir Bay varies from 10.2 to 32.2 cm, while the total weight (**W**) varies from 2.64 to 96.01 g. The weight of the fish increases with the increase of fish length (Fig. 2). The length-weight relationship of this fish is expressed by the following equation:

$$W = 0.0142\ L^{3.0133} \qquad R^2 = 0.9792$$

The values of “a” and “b” were: 0.0142 and 3.0133, respectively. From the above mentioned equation, it is clear that “b” value (3.01) is around the ideal, indicating a tendency towards isometric growth. The correlation coefficient ‘R^2’ was 0.98, which is statistically highly significant.

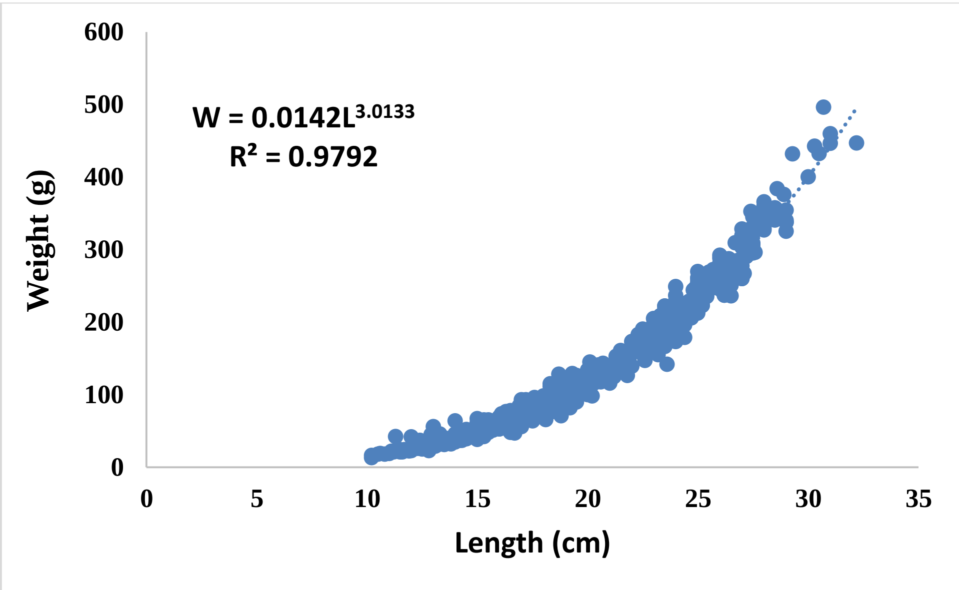

Fig. 2. Length-Weight relationship of *Sparus aurata* from Abu Qir Bay

2. Annual growth

3.1. The body length-scale radius relationship

The relationship between body length (L, cm) and scale radius (S, µ) was found to be linear, but didn’t pass through the origin (Fig. 3). This relationship can be represented by the following equation:

$$L = 6.2212\ S + 7.1352 \qquad R^2 = 0.9346$$

2.2. Back calculation growth in length

The mean back calculated total lengths of *Sparus aurata* at the end of different years of life were estimated and presented in Fig. (4). Fig (4) clarifies that the growth in length increases with age. The maximum increment of the linear growth occurred by the end of the first year of life (15.61 cm), after which a gradual decrease was observed in annual increments with further increase in age (Fig. 4).

2.3. Back calculation growth in weight

The mean back calculated total weights of *Sparus aurata* at the end of different years of life were estimated and presented in Fig. (5). Contrary to the growth in length, the annual increment in weight showed its minimum value (47.38 g) during the first year of life. Then, it gradually increased with further increase in age until it reached its maximum value (69.95 g) at age group IV^{+}, after which it recorded a gradual decrease with further increase in age.

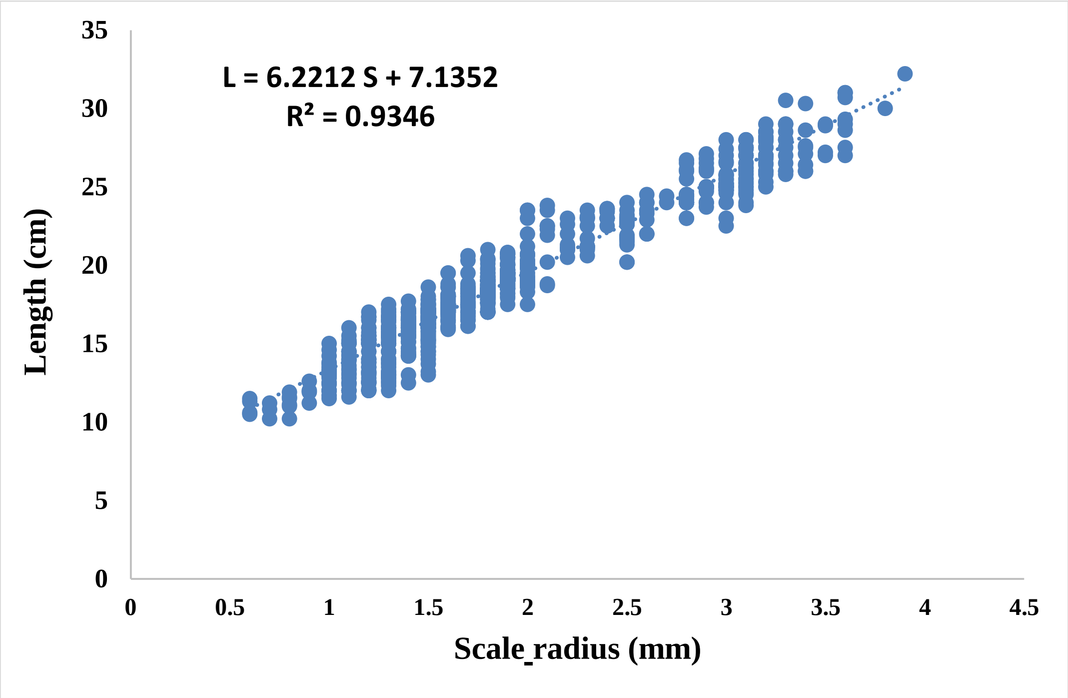

Fig. 3. Body length scale radius relationship of *Sparus aurata* from Abu Qir Bay

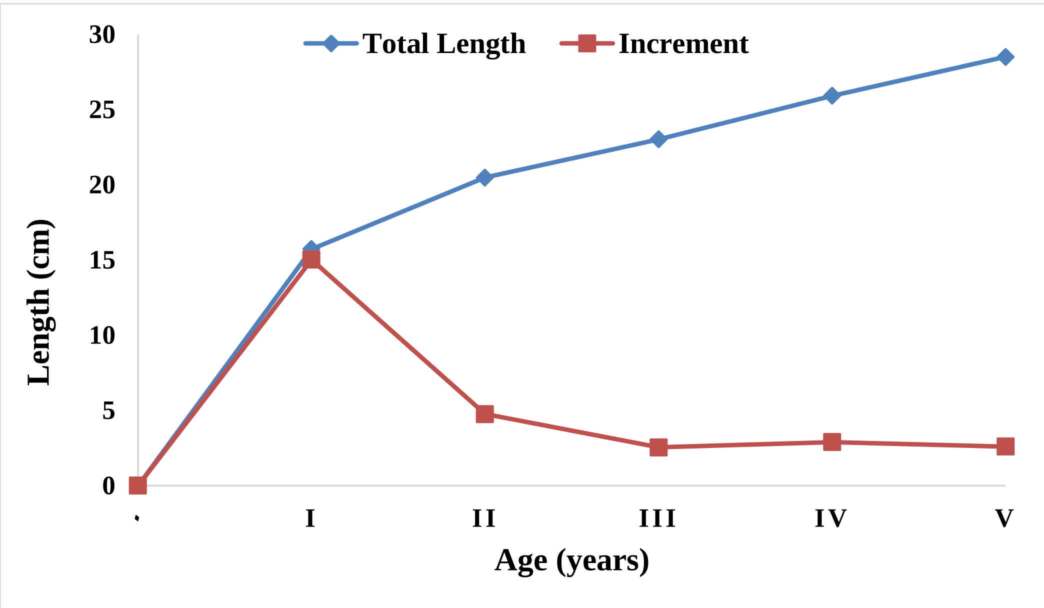

Fig. 4. Growth in length and increments at the end of each year of life of *Sparus aurata* from Abu Qir Bay

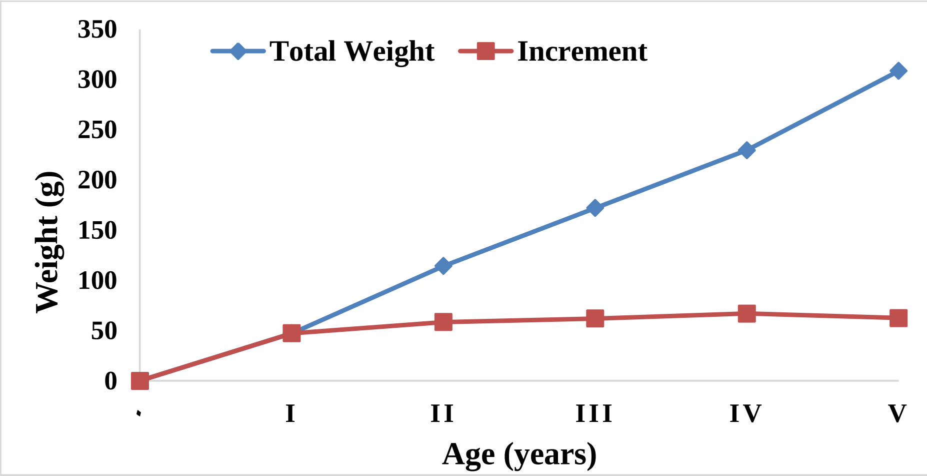

Fig. 5. Growth in weight and increments at the end of each year of life of *Sparus aurata* from Abu Qir Bay

3. Population Structure

3.1. Length frequency distribution

The smallest fish length in the catch of *Sparus aurata* was 10.2 cm, while the largest length was 32.2 cm. Most fish represented in the catch of this species lie within the length groups of 15-15.9 and 25.0-25.9 cm (Fig. 6).

3.2. Age composition

The longevity of *Sparus aurata* was more than 5 years by counting the annual growth rings on its scales. The data of the abundance percentage revealed that fishes belonging to age group I^+ is the most abundant (36.5%), followed by age group II^+ (17.6%), while age group V^+ has very low abundance (4.4%) of the total catch (Fig. 7).

3.3. Mortalities and exploitation rate (E)

Total mortality (Z) from length-converted catch curves for *S. aurata* was estimated as 1.16 yr^{-1} (Fig. 8), while natural mortality (M) was estimated as 0.56 yr^{-1}, and the fishing mortality rate (F) was 0.60 $year^{-1}$. From these results, the current exploitation rate (E = 0.52) shows an exploited stock according to **Gulland (1971)**, who suggested that the optimum exploitation rate for any fish stock is about 0.5 at F=M. More recently, **Pauly (1987)** proposed a lower optimum F that was equal to 0.4 M. **Patterson (1992)** reported that an exploitation rate of about 0.4 is safe for the stock. The value of growth performance index (Φ') was calculated as 2.49.

3.4. Length at first capture (Lc)

The length at first capture (The length at which 50% of fishes retained by the gear is the mean selection length, Lc) was 18.96 cm; 25 % of all fish were caught with 16.38 cm, whereas 75 % had lengths of 20.79 cm (Fig. 9).

3.5. Growth parameters

Growth parameters of von Bertalanffy were calculated as:

$$L_\infty = 35.491 \text{ cm} \qquad K = 0.250 \text{ year}^{-1} \qquad t_0 = -1.270 \text{ year}$$

The obtained equations for length and weight were as the followings:

$$L_t = 35.491*(1-e^{-0.250(t+1.270)})$$

$$Wt = 665.685*(1-e^{-0.250(t+1.270)})^{3.0133}$$

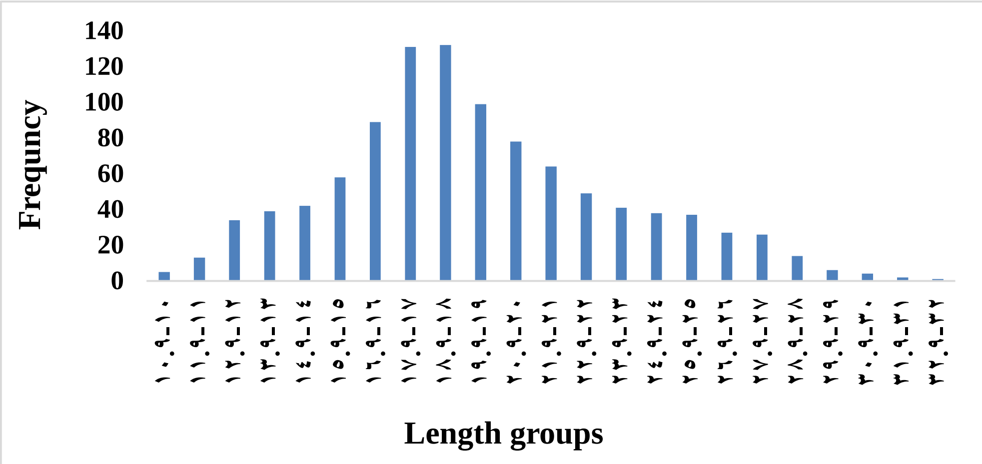

Fig. 6. Frequency distribution of lengths of *Sparus aurata* in Abu Qir Bay

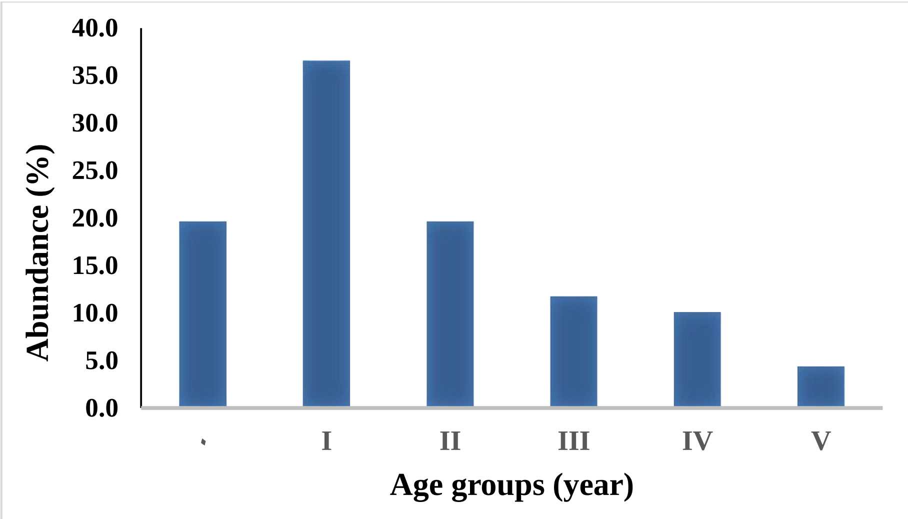

Fig. 7. Age composition of *Sparus aurata* in Abu Qir Bay

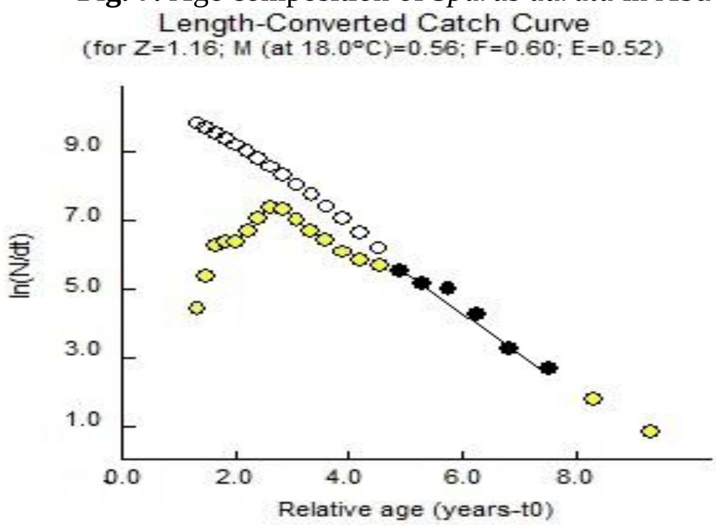

Fig. 8. Length-converted catch curve of *Sparus aurata* from Abu Qir Bay

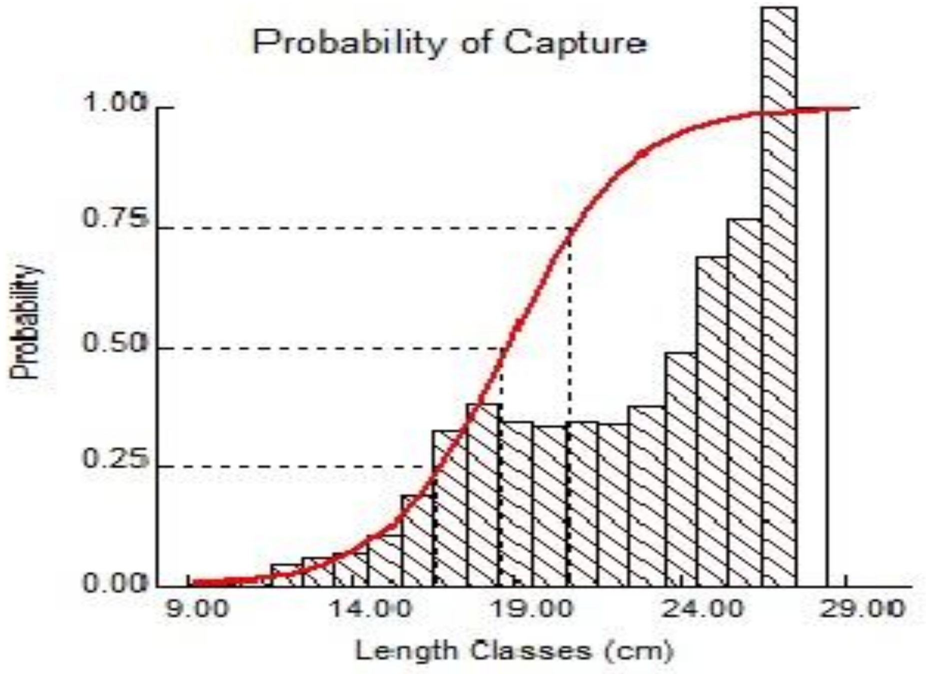

Fig. 9. Analysis of capture probability of *Sparus aurata* from Abu Qir Bay

4. The relative yield–per-recruit (Y'/R) and biomass per-recruit (B/R)

The knife edge selection procedure was used and presented in Fig. (10). The analysis of relative yield–per-recruit (Y′/R) and biomass per-recruit (B/R) of *Sparus aurata* versus the exploitation rate in Abu Qir Bay were as follows:

E_{max} = 0.768, $E_{0.1}$ = 0.67 and $E_{0.5}$ = 0.372.

Therefore, the computed current exploitation rate (**E= 0.52**) was lower than the predicted maximum sustainable yield (**E_{max}= 0.61**) and the predicted maximum economic yield (**$E_{0.1}$= 0.67**) and it maintains 50% of stock (**$E_{0.5}$ = 0.372**).

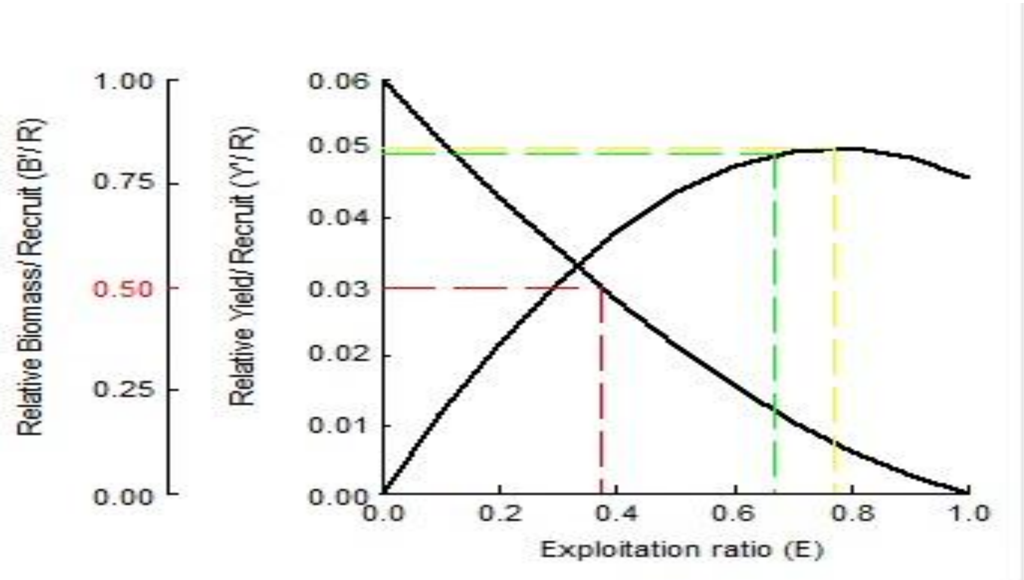

Fig. 10. The relative yield–per-recruit (Y'/R) and biomass per-recruit (B/R) of *Sparus aurata* from Abu Qir Bay

DISCUSSION

The length-weight relationship is one of the most biological characters of fishes where weight of the fish increases as a function of its length. In the present study, the exponent “b” in length-weight equation of *Sparus aurata* is around the ideal (3.01). This result is nearly similar in the same species to that obtained by **Kraljevic and Dulcic (1997)** in the Mirna Estuary, Northern Adriatic (b = 3.052). While it differs with that of **Lasserre (1976)** who found the exponent “b” in length-weight equation of the same species lower at Leyre and Adour estuaries estuaries (b = 2.618; b = 2.590).

This variation in b constant could be attributed to different slopes in genetic development as well as to differences in the age, maturity, sex, geographic location and associated environmental conditions **(Andreu-Soler *et al*., 2006; Cicek *et al*., 2006; Olim & Borges, 2006)**. In the current case, the isometric relationship could refer to the already spawned larger individuals caught during the spawning period; when a very high percentage of juveniles (55.6%) were caught.

In the present study, a total of 1029 fish specimens (5-7 scales of each) were used for the estimation of growth parameters. The results revealed that the maximum life span of *S. aurata* was 5 years, and age groups I^+ and II^+ were the most frequent in the catch, constituting together more than 55% and the age group V^+ that was represented by only 4.4% in the catch. These results is in the range with those of **Khalifa (1995)** and **Ahmed (2011)** on *S. aurata* in Bardawil Lagoon.

On the other hand, **Kraljevic and Dulcic (1997)** found that the longevity of gilt-head sea bream in the Marina Estuary (Northern Adriatic) was 12 years. Whereas, **Lasserre (1976)** recorded 11 years for this species in Lyon Bay Estuary.

In the present study, the growth in total length increased with age. However, the annual increment in total length of *S. aurtata* exhibited its highest value (15.61 cm) during the first year of life, then, gradually decreased during the remaining years of life. These results are in agreement with those of other studies on the same species in Bardawil Lagoon **(Khsalifa, 1995**; **Ahmed, 2011)**.

In the present study, the length at first capture (Lc at 50%) of *S. aurata* was estimated to be 18.96 cm. This length is higher than that obtained for the same species in Port Said fishery **(Mehanna, 2007)** and that found in Bardawil Lagoon **(Ahmed, 2011; Al-Zahaby *et al*., 2018** and **El-Aiq *et al*., 2021)**.

The total mortality (Z) of *S. aurata* was estimated as 1.16 yr^{-1}, while natural mortality (M) was 0.56 yr^{-1}, and the fishing mortality rate (F) was 0.60 $year^{-1}$. These results are in consistence with that recorded on *S. aurata* in Bardawil Lagoon **(Ahmed, 2011**; **Al-Zahaby *et al*., 2018)** and higher than that obtaind by **Mokbel *et al*. (2020)** on the same species in the Bardawil Lagoon.

The exploitation rate E was computed as 0.52 in the present study. According to **Gulland (1971)**, when the exploitation ratio is more than 0.5, an overexploitation of fish population is recognized. The present exploitation rate is slightly higher than that optimally exploited stock (50%) according to **Gulland (1971)**. Furthermore, this rate is lower than that recorded for *S. aurata* in the Bardawil Lagoon **(Ahmed, 2011; Al-Zahaby *et al*., 2018**; **Mokbel *et al*., 2020)**.

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