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Fisheries biology and management of *Diplodus Sargus Sargus* (Linnaeus, 1758) in Abu Qir Bay, Egypt

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Abstract

The present study deals with the fisheries of *Diplodus sargus sargus* in Abu Qir Bay (Alexandria, Egypt). Length weight relationship, catch length structure, length scale relationship, total length by the end of each year of life, growth in weight, Von Bertalanffy parameters, the values of (total, natural and fishing mortalities), survival rates, length and age at first capture, length and age at recruit, yield per recruit, biomass per recruit, determination of the biological reference points and the effect of age at first capture on Y/R. Also Cohort analysis (VPA, age based) which represent the estimated values of the population numbers, Survivors, Natural and fishing mortalities for each year of life of *D. sargus sargus* in Abu Qir Bay were studied. The study concluded that, the fisheries status of *D. sargus sargus* in Abu Qir Bay reached the target reference point ($F_{0.1}$) but it did not reach the limit reference point (F_{max}), thus the fisheries status of *D. sargus sargus* in Abu Qir Bay is not in the overexploited phase.

Keywords: Abu Qir Bay, Fisheries management, B.R.P., Virtual population analysis, Sparidae, Diplodus sargus.

1. Introduction

Abu Qir Bay is a shallow semi circular basin located at about 35 Km east of the city of Alexandria (Fig. 1), it is located between the mouth of the Rosetta Branch of the Nile River on the east and the Abu Qir head land in the west and it lies between latitudes 31° 16 and 31° 28 North and longitudes 30° 5 and 30° 22 East (Said *et al.,* 1995). The area of the bay is about 360 Km^2 with a maximum depth of about 16m (average depth 10m) (Radwan, 1996).

Surface water temperature varied between (29.7C°) in summer and (15.5C°) in winter (El-Mardany, 2006). The salinity of the bay water varies between 36.4 mg/1 during winter and 39.3 mg/1 during autumn (Mohamed, 2006).

D. sargus sargus comprises about 62% of Diplodus catch which constitutes about 14.5% of the Sparid landed catch in Abu Qir Bay during 2008 (Saleh, 2010).

The white sea bream (*D. sargus sargus*) is mostly caught by long lines; although sometimes it is caught by trammel nets and gill nets. Due to its economic importance this species made the subject of study of various scientists in different countries (Girardin, 1978; Rosecchi, 1987; Harmelin *et al*., 1995; Gordoa & Moli, 1997; Sala & Ballesteros, 1997; Macpherson *et al*., 1997; Macpherson, 1998; Planes *et al*., 1999; Gonçalves, 2000; Vigliola & Harmelin, 2001; Mariani, 2001; Pajuelo & Lorenzo, 2002; Lanfant, 2003; Morato *et al*., 2003 and Pajuelo & Lorenzo, 2004).

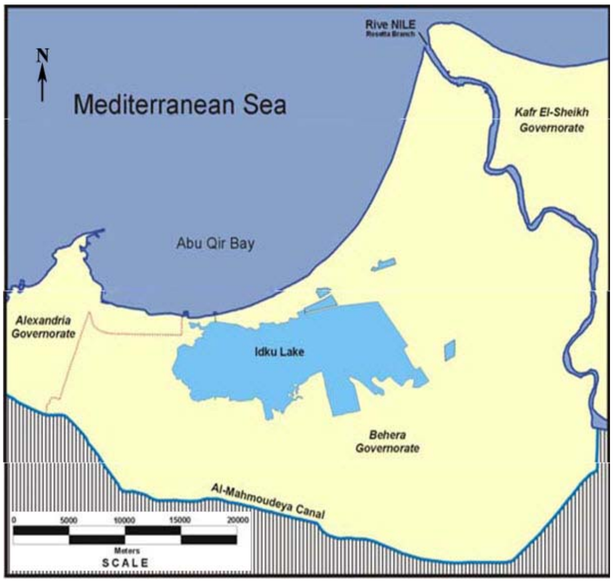

Figure 1: Abu Qir Bay location to Edku Lake and the Mediterranean Sea.

The present study deals with some biological and fisheries aspects of *D. sargus sargus* with the aim of understanding the status of the fisheries of the stock and giving essential information for assessing proper management of this species in the bay.

2. Materials and Methods

Random samples of *D. sargus sargus* were collected every two weeks from the commercial catch in the landing site in Abu Qir Bay during the period from January, 2008 to January, 2009.

From each fish sample, the following information were taken (Total length & total weight to the nearest mm & gm respectively and Scale sample for age determination).

Length weight relationship was computed according to Le Cren (1951). Back calculations of fish length were done by using Lee's method (1920). These lengths were used to estimate the growth parameters of the Von Bertalanffy growth model (1938) by fitting the Ford (1933) and Walford (1946) plot, while 't_o' was estimated by inverse Von Bertalanffy growth equation and 'W_∞' was estimated by converting 'L_∞' to the corresponding weight using the obtained formula for length weight relationship.

The instantaneous total mortality coefficient 'Z' of *D. sargus sargus* in Abu Qir Bay was obtained by constructing an age based catch curve (Ricker, 1975). Natural mortality was calculated according to Pauly's formula (1980):

$$\text{Log } M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T.$$

Where, L_∞ & K are Von Bertalanffy growth formula parameters and T is the annual mean temperature.

Instantaneous fishing mortality 'F' was calculated by subtracting the natural mortality coefficient from the total mortality coefficient. Estimation of survival rates 'S' was done according to Ricker (1975) equation. The exploitation ratio 'E' was calculated according to Baranov (1918) formula.

Length and age at first capture (L_c & t_c) were computed by the equations of Beverton and Holt (1956 & 1957).

Length and Age at recruitment (L_r & t_r) were estimated by applying the growth equation of Von Bertalanffy.

The yield per recruit (Y/R) was estimated by Beverton and Holt yield per recruit model (1957). Beverton and Holt biomass per recruit (B/R) model was obtained by the equation: B/R = Y/R / F where 'F' is the fishing mortality.

The extreme values of the fishing level, which might seriously affect the self renovation of the stocks, were defined as biological reference points 'BRP'. These values of fishing mortality such as 'F_{max}' and '$F_{0.1}$' were obtained according to Cadima (2003).

The effects of age at first capture on yield per recruit at the present value of fishing mortality and at different fishing mortality values were estimated.

The age based cohort analysis (Pope's cohort analysis 'Virtual population analysis' 1972) was used to analyze the historical data for estimation of population parameters of *D. sargus sargus* (Sparre & Venema, 1998).

3. Results

3.1. Age and Growth

3.1.1. Length weight relationship

The length weight relationship for *D. sargus sargus* in Abu Qir Bay was found to be:

$$W = 0.0207\ L^{2.9421} \qquad R^2 = 0.9844$$

3.1.2. The body length scale radius relationship

The body length scale radius relationship proved to be linear and could be represented by a straight line. The following formula representing this relationship:

$$L = 1.0713\ S + 1.316 \qquad R^2 = 0.9923$$

Where, 'L' is the total length (cm) and 'S' is the total scale radius (micrometer division).

3.1.3. Back calculation of length

Figure (2) shows the average back calculated 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 (11.42 cm), after which gradual decrease in annual increments with further increase in age was observed.

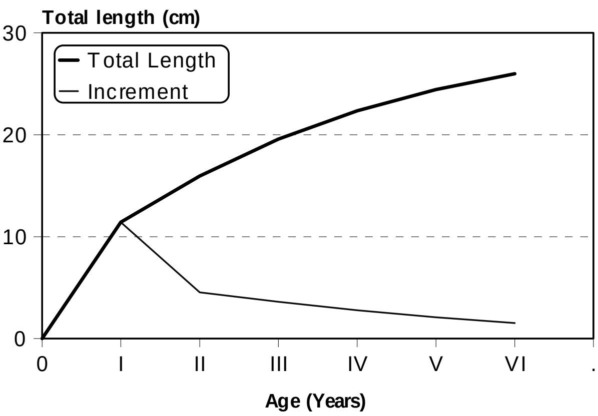

Figure 2: Growth in length and increments at the end of each year of life of *D. sargus sargus* in Abu Qir Bay.

3.1.4. Growth in weight

The back calculated weights by the end of each year of life were estimated (Fig. 3). It was noticed that, the annual increment of growth in weight increases with further increase in age until it reaches its maximum value at age group IV (62.24 gm), after which it shows gradual decrease with further increase in age.

In the present study, the constants of Von Bertalanffy growth formula (L_∞, W_∞, K and t_o) were computed using the obtained values of back calculated lengths at different years of life; there are (31.38 cm, 524 gm, 0.262 year^{-1} and -0.73 year^{-1}) respectively.

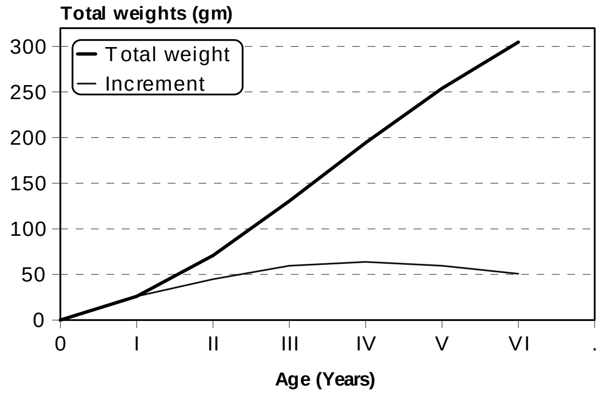

Figure 3: Growth in weight and increments at the end of each year of life of *D. sargus sargus* in Abu Qir Bay.

The maximum age (t_{max}) was computed as 11.45 year for *D. sargus sargus* in Abu Qir Bay.

3.2. Population Structure

3.2.1. Length frequency distribution

The smallest fish length in the catch of *D. sargus sargus* was 7.5 cm TL, while the biggest length was 27.5 cm. Most fish represented in the catch of this species lie within the length range 10.5 and 20.5 cm TL (Fig. 4).

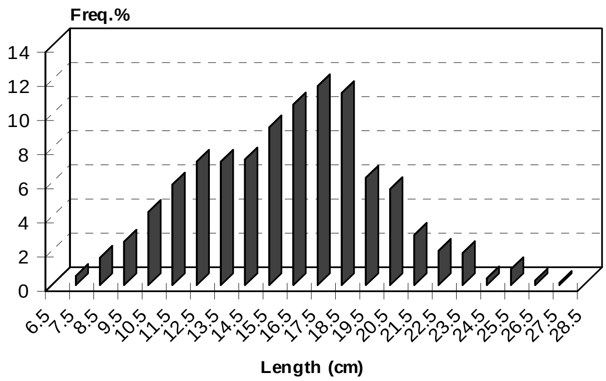

Figure 4: Percent frequency distribution of lengths of *D. sargus sargus* in Abu Qir Bay.

3.2.2. Age composition

The most abundant age group is age group II (42%) followed by age group I (29%), while age groups V and VI are of very low abundance (Fig. 5).

3.2.3. Survival and instantaneous mortality coefficients

The instantaneous total mortality coefficient (Z) of *D. sargus sargus* in Abu Qir Bay was obtained by the age based catch curve by taking the minus value of the slope (-b) of the straight descending portion of the curve as the value of 'Z' (Fig. 6).

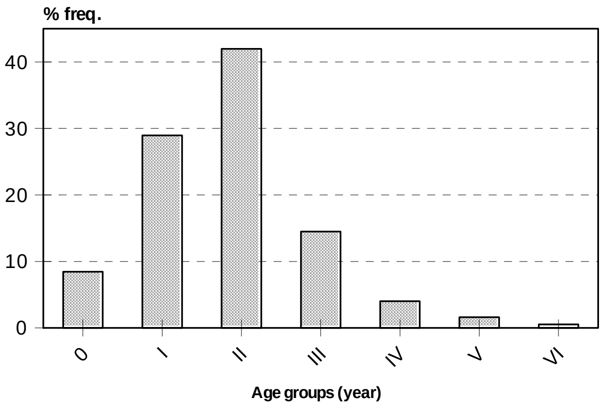

Figure 5: Age composition of *D. sargus* in Abu Qir Bay.

Natural mortality as obtained by Pauly's equation (1980), was found to be 0.606 year^{-1}, the fishing mortality was 0.486 year^{-1}. Length and age at first capture and those at recruitments were (12.5 cm, 1.208 year, 10.4 cm and 0.81 year respectively). These values show that, *D. sargus sargus* is recruited at an age lower than one year. The rate of exploitation was found to be 0.445.

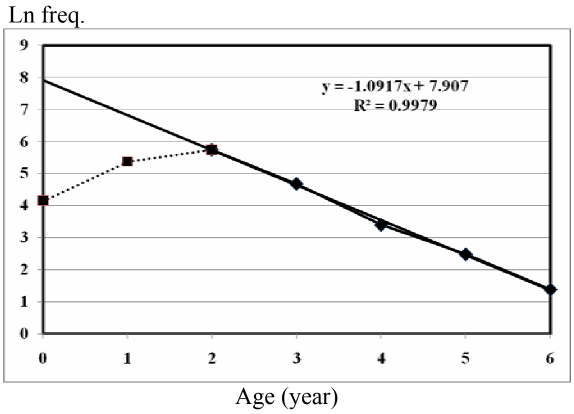

Figure 6: Catch curve of *D. sargus sargus* in Abu Qir Bay.

3.3. Management

3.3.1. Yield per recruit and biomass per recruit

The yield per recruit and biomass per recruit of *D. sargus sargus* in Abu Qir Bay were found to be 27.8 gm and 57.2 gm respectively at the actual fishing mortality (0.486 year^{-1}).

3.3.2. Estimation of the biological reference points (F_{max} & $F_{0.1}$)

The values of yield per recruit and the biomass per recruit as a function of fishing mortality are shown in Figure 7. F_{max} indicates the value of "F" which gives the maximum possible yield per recruit from a cohort during its life for a given exploitation pattern. The limit reference point was 1.239 year^{-1} corresponding to maximum Y/R 31.123 gm.

The target reference point ($F_{0.1}$) as recommended by various authors (Cadima, 2003) was found to be0.486year^{-1}, which is equal to the actual value of the fishing mortality. The percentage of biomass per recruit with respect to the virgin biomass at the target reference point ($F_{0.1}$) for *D. sargus sargus* in Abu Qir Bay was 36.99% which is equal to the actual percentage value.

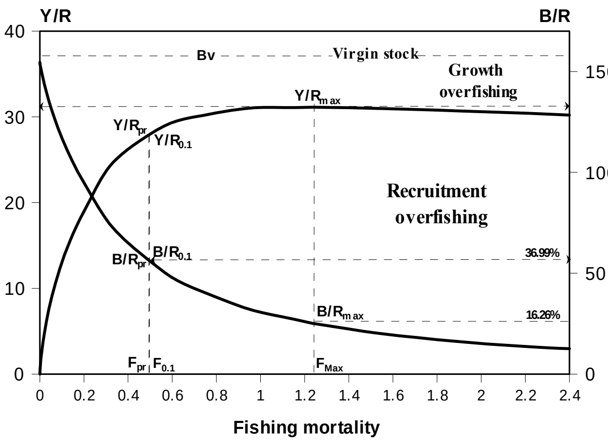

Figure 7: Yield per recruit and average biomass per recruit curves of *D. sargus sargus* in Abu Qir Bay.

3.3.3. The effect of variations of t_c on y/r

Table (1) represents the effect of age at first capture on yield per recruit according to the actual value of fishing mortality. From this table it was noticed that, going from the low values of t_c (0.1) to its actual value a rapid rise in the value of Y/R occured. Hence, no big difference occurred between the actual value of t_c (1.208) and that corresponding to the maximum value of Y/R (1.33).

Table 1: Yield per recruit as a function of tc at a fixed level of fishing mortality for *D. sargus sargus* in Abu Qir Bay.

tc	Y/R
0.100	22.5639
1.000	27.4367
1.208 (pr)	**27.7617**
1.325	27.8120
1.33 (max)	**27.8121**
1.335	27.8120
1.500	27.7189
2.500	24.2224

pr = present. ***max = maximum***

3.3.4. The effect of 'F' on 'Y/R' at different values of 'tc'

The effects of fishing mortality together with the age at first capture on the values of yield per recruit are represented in Table (2). Two values of t_c beside the observed value were used with a difference of 0.5 year higher and lower than the actual value of t_c. From this table; it could be noticed that, as 't_c' increases fishing mortality (Fishing effort) needed to be increased in order to reach a higher maximum yield per recruit value.

Table 2: The relationship between yield per recruit and fishing mortality for *D. sargus sargus* with different values of age at first capture.

Fishing mortality	Y/R at different values of tc		
	tc= 0.708	**tc= 1.208**	**tc= 1.708**
0.0000	0.0000	0.0000	0.0000
0.4857	**26.4514**	**27.7617**	**27.3684**
0.7700	27.5350	30.3302	30.8978
0.7740	**27.5351**	30.3485	30.9288
0.7770	27.5350	30.3620	30.9518
1.2320	26.6588	31.1232	32.9256
1.2390	26.6394	**31.1233**	32.9409
1.2450	26.6227	31.1232	32.9539
1.9000	24.8554	30.6886	33.6159
2.3410	23.8911	30.2697	33.6794
2.3530	23.8677	30.2586	**33.6795**
2.3640	23.8463	30.2484	33.6794
3.0000	22.7863	29.7057	33.6190

3.3.5. Virtual population analysis (VPA)

Figure (8) represents the estimated values of the population numbers, survivors, natural and fishing mortalities for each year of life of *D. sargus sargus* in Abu Qir Bay. It is noticed that, the population of *D. sargus sargus* decreased gradually with age, this is due to the exposure to a sequence of natural mortalities (which decreases with age) and fishing mortalities.

The maximum value of fishing mortality was noticed in age group III (0.5238 year^{-1}) then it decreased till it reaching 0.4316 year^{-1} in age group IV then increased in age group V (0.5038 year^{-1}), while the fishing mortality in age group VI is 0.4857 year^{-1}. The high values of "F" at age group V and VI is due to small numbers of individuals in these two age groups. The catch of this species seem to depend on age groups I and II.

4. Discussion

Length weight relationship is important information to be obtained from the biological data for management purposes. The value of 'b' in the length weight relationship of the species under study (2.9421) showed slight negative allometry (less than "3"). This means that, the fish becomes lighter for its corresponding length. This relationship made the subject of study of various authors in Table (3).

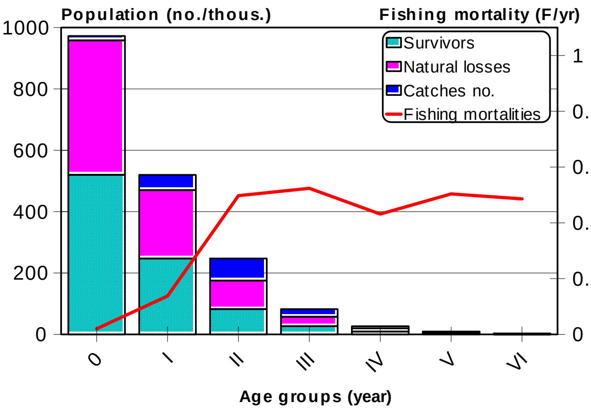

Figure 8: Age structured V.P.A. of *D. sargus sargus* in Abu Qir Bay.

It is to be noted that, the obtained value of 'b' is lower than those obtained by the other authors. However it is not much different from that given by Lahlah (2004).

Table 3: The value "b" of length weight relationship of *D. sargus sargus* in different geographic locations.

Author & date	"b"	area
El-Maghraby & Botros, 1981	3.144	Egy. Medit. water
Morato *et al.*, 2001	3.18	N/E Atlantic
Man Wai & Quignard, 1982	3.123	Gulf of Lion
Mouine *et al.*, 2007	3.05	Tunis (Central Med.)
Lahlah, 2004	2.859	Egy. Medit. water
Present study	**2.942**	**Abu Qir Bay**

Table (4) shows that, the present values of lengths at various years of life in different bodies of water show various controversies between them.

The mean back calculated weight values for *D. sargus sargus* in the present study are much lower than those given by El-Maghraby *et al.* (1982) and Man Wai & Quignard (1982) in France, while they are higher than those given by Lahlah (2004) as shown in Table (5). Asymptotic length and weight according to the present study for *D. sargus sargus* were found to be equal to 31.4 cm T.L. and 524 gm respectively, it is noticed that, the biggest observed length in the present study was about 27.5 cm which is smaller than the estimated L_∞.

The value of growth coefficient "k" was found to be equal to 0.262. Various authors gave different values for asymptotic length and weight of *D. sargus sargus* (Table 6).

From the mentioned table, it appears that the values of Von Bertalanffy growth formula parameters show differences among various geographic localities for the same species. Such differences are due to variations in

Table (4): Back calculated lengths (cm) for *D. sargus sargus* by the end of each year of life in different geographic locations.

Author & date	L_I	L_{II}	L_{III}	L_{IV}	L_V	L_{VI}	Area
El-Maghraby & Botros, 1981	10.37	15.93	20.40	23.62	26.67	29.20	Egy. Med.
Lahlah, 2004	9.44	12.47	14.86	16.67	18.33	20.43	Egy. Med.
Gonçalves 2000	12.50	16.50	20.00	23.00	25.00	26.50	Portugal
Man Wai & Quignard 1982	10.90	16.50	20.30	23.20	25.20	26.70	Gulf of Lion
Present study	11.42	15.96	19.57	22.35	24.44	25.98	**Abu Qir Bay**

Table 5: Back calculated weights (gm) for *D. sargus sargus* by the end of each year of life in different geographic locations.

Author & date	W_I	W_{II}	W_{III}	W_{IV}	W_V	W_{VI}	Area
El-Maghraby *et al.*, 1982	18.4	69.5	151.1	240.9	348.9	460.0	Egy.
Lahlah, 2004	8.2	21.3	33.3	46.8	64.3	-	Egy.
Man Wai & Quignard, 1982	20.0	86.0	160.0	235.0	280.0	355.0	Gulf of Lion
Present study	**26.8**	**71.7**	**130.6**	**193.1**	**251.2**	**300.5**	**Abu Qir Bay**

environmental conditions as well as sampling techniques and computations (Hernandez, 1986). It was also noticed that the present estimation of t_{max} for *D. sargus sargus* is far lower than in other areas, especially South Africa (Mann & Buxton, 1997).

In spite of the wide distribution and importance of *D. sargus sargus* there are just few publications existing on their fisheries management. Fisheries management needs estimates of harvest levels that provide maximum yield on a long term basis. Beverton & 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.

The Y/R depends on the exploitation pattern or fishing regime and natural mortality. For a given exploitation pattern, rate of growth and natural mortality, an equilibrium value of Y/R can be calculated for each level of 'F'. It increases with 'F' up to a point where the maximum sustainable yield is obtained. Beyond this point overfishing occurs and the population collapses.

Table 6: Von Bertalanffy growth parameters for *D. sargus sargus* in different geographic locations.

Authors & date	L_∞	K	t_o	t_{max}	W_∞	Area
Man Wai & Guignard, 1982	46.70	0.12	-0.63	-	-	N/W Medit.
Pastor & Cuadros, 1996	48.48	0.18	-0.06	-	-	N/E Atlantic
Gordoa & Moli, 1997	41.70	0.25	-0.08	-		N/W Medit.
Mann & Buxton, 1997	30.94	0.25	-1.05	21.00		South Africa
Pajuelo & Lorenzo, 2002	47.30	0.14	-1.97	12.00		Canary Islands
Abecasis *et al.*, 2008	40.93	0.18	-1.28	-	-	South Portugal
	39.55	0.15	-1.89	-	-	
Erzini *et al.*, 2001	41.22	0.18	-0.86	-	-	South Portugal
Man Wai & Quignard, 1982	45.86	0.17	-1.18	14.00	870.4	Gulf of Lion
Lahlah, 2004	32.72	0.13	-1.84	13.40	-	Egypt
Present study	**31.38**	**0.26**	**-0.73**	**11.45**	**524**	**Abu Qir Bay**

Biomass per recruit is also affected by a change in fishing mortality. The present results show, that as the fishing mortality increases the B/R and % Bv decreases. This observation was previously given by different authors on different fish species (Griffiths, 1997 and Booth & Buxton, 1997).

$F_{0.1}$ is considered as a target reference point and F_{max} as a limit reference point. $F_{0.1}$ of *D. sargus sargus* in the present study was found to be equal to the actual value of fishing mortality in Abu Qir Bay. Since the actual values of fishing mortality did not reach the value of the limit reference points F_{max}, therefore the fisheries status in Abu Qir Bay for *D. sargus sargus* are still in good condition.

To determine the most appropriate age at first capture (t_c) for *D. sargus sargus* in Abu Qir Bay, the yield per recruit values were determined as a function of age at first capture. The results show that, there is no significant difference between the value of t_c maximum (which is corresponding to the maximum Y/R) and the actual value obtained. The Y/R increases as the value of t_c increases till it reaches t_c maximum, then the value of Y/R decreases with the increase of t_c. Griffiths (1997) and Booth & Buxton (1997) came to the same conclusion as the present study.

Virtual population analysis (VPA) has been widely used in fish stock assessment during the last 30 years (Sparre & Venema, 1998 and Nash, 1998).

The results in the present study which were obtained from VPA analysis could be considered as a base for future studies that help to predict the future catch. These results indicate that, the fish which died by natural mortality are always more than those which die by fishing mortality. It could also be seen that, the increase in fishing mortality as the fish increases in age was accompanied by a decrease in the population numbers of the species understudy. On the other hand, the natural mortality decreases as the fish gets older. These results are in agreement with Lehtonen (1984) and Abd Elbarr (2004).

From the above discussion, it could be stated that the fisheries status of *D. sargus sargus* in Abu Qir Bay reached the target reference point ($F_{0.1}$) but did not reach the overexploited phase. Although fishing effort is more based on age groups I and II which might suggest recruitment overfishing yet, the overfishing of this species according to the present data is not currently a concern.

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بيـولـوجيــة أسـمـاك الشرغوش الحر (*SARGUSDIPLODUS SARGUS*) وتقييـم حالـة مصـــايدها بخليـج أبوقيـــر,مـصـــر.

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الكلمات الدالــة على البـحـث: أبوقـير، مـعدلات النفوق، عـائـد الـوزن الـحـيوي، تطـويـر مصـايـد، أسمـاك الشرغوش الحـر .

أهتمت هذه الدراسة بدراسة بيولوجية مصايد أسماك الشرغوش الحر (*Diplodus sargus sargus*) في خليج أبوقير بمصر. وقد ظهرت في هذه الدراسة نتائج علاقة طول السمكة بوزنها, التوزيع الديموجرافي في المصيد, معامل الحالة, العلاقة بين طول السمكة وقطر قشرتها, الحسابات الرجعية لطول السمكة ووزنها عند نهاية كل سنة من عمرها الفائت, كما تم الوصول إلى معاملات معادلة فون برتالانفي.

تمثلت الأعمار في المصيد بسبع مجموعات عمرية (من المجموعة العمرية ماقبل سنة حتي المجموعة العمرية للسنة السادسة من العمر) حبث يتمثل أغلب المصيد في المجموعة العمرية الأولي و الثانية. وكذلك تم تحديد معدلات النفوق الطبيعي والنفوق بالصيد والنفوق الكلي ومعدل الاستغلال ومعدل البقاء والطول والعمرعند أول تعرض للصيد.

هذا وقد تم تطبيق معادلة بيفرتون وهولت لسنة 1957 للحصول على قيمة العائد من وحدة الأفراد الجديدة وعائد الوزن الحيوي والعائد من وحدة الأفراد الجديدة بالنسبة للوزن الحيوي عند نقطة معدل صيد مستهدفة عند ($F_{0.1}$) والقيمة العظمى للعائد من الأفراد الجديدة (F_{max}) وتم تحديد معدلات النفوق بالصيد المقابلة لهذه القيم وكذلك نسبة عائد الوزن الحيوي بالمقارنة بالوزن الحيوي البكري. كما تم تتبع قيم النفوق الطبيعي والنفوق بالصيد للأسماك خلال السنوات الستة الماضية وكذلك تحديد أعداد الأسماك المتبقية في كل سنة للعام التالي وأظهرت الدراسة أن المصيد يعتمد أساسا على المجموعات العمرية I ، II , III.

وقد خلصت الدراسة إلى أن حالة مصايد هذا النوع من أسماك الشراغيش الموجود في خليج أبو قير قد وصل إلى نقطة العائد المستهدف الأولى، ولكنه لم يصل بعد إلى حالة الصيد الجائر لأن معدل صيده لم يصل إلى نقطة الحد الأقصى حتى الآن.