Population dynamics and fisheries management of Gilthead sea bream, *Sparus aurata* (f. Sparidae) from Bardawil lagoon, North Sinai, Egypt

Mohamed S. Ahmed
Faculty of Environmental Agricultural Sciences, Suez Canal University, Egypt.

ABSTRACT

Population dynamics of Gilthead sea bream, *Sparus aurata* was studied from a small scale fishery of Bardawil lagoon. 3262 specimens ranged between 11 and 32.9 cm TL and 20 to 592 g total weight, were collected from April, 2009 to November, 2010. The relationship between length and weight was estimated as $W = 0.025\ L^{2.813}$. Age was determined using scales' reading technique for 865 individuals and the longevity of this species was found to be 4 years. Growth in length and weight at the end of each year was estimated. The growth parameters of the von Bertalanffy equation were calculated as $L_\infty = 36$ cm, $K = 0.39\ yr^{-1}$ and $t_0 = -1.68$ yr. Total, natural and fishing mortality rates were 1.02 yr^{-1}, 0.21 yr^{-1} and 0.81 yr^{-1}, respectively. The current exploitation rate ($E = 0.79$) indicates that the stock of seabrea in Bardawil lagoon was heavily exploited. The length at first capture L_c was estimated as 15.54 cm. The length at first maturity L_m of males and females were estimated as 20.5 and 22.8, respectively. The maximum allowable limit of exploitation (E_{max}) was 0.61 while that at maximum economic yield ($E_{0.1}$) was 0.499 and maintains 50% of stock ($E_{0.5} = 0.37$). The raised L_c to the first sexual maturity (22.5 cm as Lt) would be associated with an increase of Y′/R by 15 % from the current Y′/R at exploitation rates equal $E_{max}= 0.74$. Also, raised L_c to 24.5 cm at current exploitation rate $E_{max}=0.79$. The results indicate that, for proper management of sea bream catch on Bardawil lagoon, the effort should be reduced or the length at first capture should be raised.

Key words: Population biology, Fisheries regulation, *Sparus aurata*, Bardawil lagoon, Egypt.

INTROUDACTION

The Gilthead sea bream, *Sparus aurata* is an important species in the Egyptian coasts of Mediterranean Sea and the Bardawil lagoon fisheries. It was found in a wide variety of marine habitats, from rocky to sandy bottoms, at depths between 0 to 500 m, although it is usually more common at less than 150 m deep (Abecasis *et al.*, 2008). In Bardawil lagoon, *Sparus aurata* is mainly exploited by two fishing techniques; trammel nets and hand line. This species is common as a discard and by-catch of trawl and gill-nets fisheries operating in the lagoon. All previous studies agreed that during the last twenty years, the stock of sea bream shows a serious decline in Bardawil lagoon (Bebars *et al.,* 1986&1992; Khalifa, 1995; Khalil and Sheltout, 2006; Mehanna, 2006; Salem *et al.,* 2008). This work was carried out to supplement information about biological aspects and exploitation rates of *S. aurata* in Bardawil lagoon that could be useful for management of this important species.

MATERIALS AND METHODS

STUDY REGION

The study was carried out in the Bardawil lagoon (Fig. 1).The lagoon covers an area of 693 km^2, in an arid area in the northern part of Sinai Peninsula, Egypt. It is separated from the Mediterranean Sea by a long narrow sandbar that varies in width between 100 m and 1 km. The lagoon communicates with the Mediterranean Sea water by two artificial and one natural narrow channels. The lagoon is considered as a natural depression with a depth of 0.5-3 m.

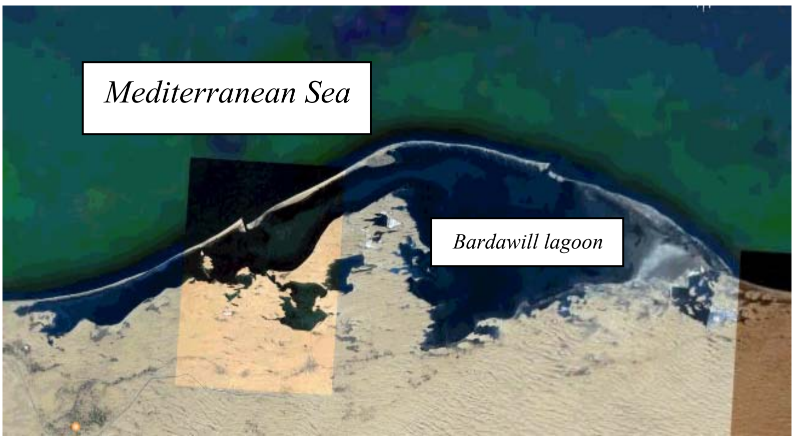

Fig. 1: The Bardawil lagoon

SAMPLING

Random samples were collected from well mixed catches of small boats (it with an overall length of 6 m and 9.9 horse power outboard engine) which worked with trammel nets and hand lines between April, 2009 and November, 2010. The boats were equipped with 500 – 1000 m trammel net (mesh size 3.5 cm) or two to four hand line. The line is often 5-10 m long and containing one hook. The hooks are often 2-3 cm long containing life bait. One to three fishermen worked on each boat. The fishing boats work in night from a static position. The boats work at depths ranging from 1 – 3 m. The total length of the collected fish was measured to the nearest mm and there total weight was recorded to the nearest 0.1 g.

For age determination, the scales were removed from the left side from 865 specimens behind the tip of the pectoral fin. In the laboratory, the scales were cleaned and stored dry in envelopes for the subsequent study. Later on, scales were soaked overnight in 10% ammonia solution. 5-7 scales were placed between two glass slides, and examined by 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.

DATA ANALYSIS

The back-calculated total length at the end of each year was determined from scale measurements using Lea's, 1910 equation as $L_x = L_p (S_x/S_P)$, where: L_x equals length of fish at age (x), L_p equals the fish length at capture, S_x equals the scale radius at annulus x and S_p equals total scale radius.

The relationship between length and weight was described by the potential equation ($W = a*L^b$, Ricker, 1975), where W is the total weight (g), and L is the total length (cm), a and b are constants. The calculated weight at the end of each year was estimated by applying length-weight equation.

The von Bertalanffy growth equation (VBGE): $L_t = L_\infty (1- e^{-k (t - t_0)})$ was used to describe growth in size, where L_t 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 $L\infty$ and K were estimated by plotting L_t vs L_{t+1} using the Ford, 1933 – Walford, 1946 plot, while t_0 was estimated by Gulland and Holt plot, 1959. For comparison of the growth parameters with previous studies, the growth performance index was calculated from the equation of Munro and Pauly (1983) as $(\Phi') = Ln\ K + 2Ln\ L_\infty$.

The length-converted catch curve method (Pauly, 1984_a) was used to estimate the instantaneous rate of total mortality (Z) by using the FiSAT program. The instantaneous rate of natural mortality (M) was obtained by Ursin (1967) formula as $M = W^{-1/3}$ 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 $F = Z - M$, while the exploitation rate $E = F/Z$.

The length at first maturity (L_m) was determined by examination of gonads to determine the sex and the stage of maturity, where 50% of fish reach their sexual maturity. It was estimated by fitting the maturation curve between the percentage maturity of fish corresponding to each length class interval. Then L_m was estimated as the point on the X-axis corresponding to 50% point on the Y-axis.

The probability of capture was estimated from length-converted catch curve, using the running average technique to determine L_{50} (Pauly, 1984_b).

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 $Y`/R = EU^{M/K} [1 - (3U/1+m) + (3U^2/1+2m) - (U^3/1+3m)]$ where, $U = 1- (Lc / L\infty)$, $m = (1-E)/ (M/K) = (K/Z)$: 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 (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. Also, the yield contours were plotted to assess yields on changes in E and Lc / L∞.

RESULTES AND DISSCUTION

Age and growth

Scales reading for 865 individuals showed five age classes of *Sparus aurata* in Bardawil lagoon during the study period from April, 2009 to November, 2010. The percentage occurrence of these groups was 55.3, 29.9, 11.9, 1.9 and 1.0% for 0, 1, 2, 3 and 4 age groups respectively. This indicated the dominance of the young fish (0-group fish, illegal size), while the age group four was the least age group in the catch (1.0 %).The maximum estimated age (6 years) for *S. aurata* in Bardawil lagoon was recorded by Khalifa (1995). Age groups and growth in length (average back – calculation lengths) were identified for *S. aurata* as 23.38, 27.51, 30.21 and 32.15 cm for 1st, 2nd, 3rd and 4th years, respectively. The growth rate of *S. aurata* is particularly high during the first year of life, especially in this study. After the first year, the annual growth rate drops rapidly. Table (1) summarized the back-calculated lengths of the present study compared with the other studies for the same species.

Table 1: The length at the end of each life year of *S. aurata* given by different authors

Region	Sex	Age (years)	N	Total length at the end of life year						References
				1	2	3	4	5	6	
Bardawill lagoon, fishing season 1985/86	M	1–2	106	16.39	18.85					Bebars, 1986
	F	1–3	148	16.97	20.15	22.7				
Bardawill lagoon, fishing season, 1986	M+F	1–3	---	19.5	23.67	26.89				Ameran, 1992
Bardawill lagoon, fishing season, 1986	M+F	1–6	---	19.36	23.67	26.29	28.39	---	32.16	Khalifa, 1995
Bardawill lagoon, fishing season 2000	M+F	1–5	1826	19.36	23.83	28.45	31.54	32.84		Salem, 2004
Bardawill lagoon, fishing season 2001	M+F	1–5	1835	20.2	25.2	27.6	29.8	32.3		
Port Said	M+F	1–4	1714	21.26	27.8	32.25	34.3			Mehanna, 2007
Bardawill lagoon, fishing season, 2008	M+F	1–4	3483	22.82	27.09	30.03	31.5			Salem, 2010
Bardawill lagoon	M+F	1–4	3262	23.38	27.51	30.21	32.15			Present study

The observed total length ranged from 11 to 32.9 cm and the observed total weight varied from 20 to 592 g. The length – weight relationship (Fig. 2) was described by the power equation as: $W= 0.025*L^{2.813}$ (R^2 = 0.93). The differences in length-weight relationship of *S. aurata* in different rejoins (Table 2) might be interpreted as being due to differences in growth and morphometry between regions (Barnabè, 1976) and it is a practical index of the condition of fish, and varies over the year according to factors such as food availability, feeding rate, gonad development and spawning period (Bagenal and Tech, 1978).

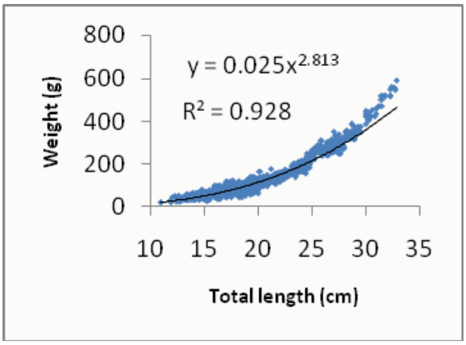

Fig. 3: Length – weight relationship of *S. aurata* in Bardawil lagoon.

Growth parameters of von Bertalanffy were calculated as L_∞= 36 cm, K = 0.39 year^{-1} and t_0 = -1.68 year and the obtained equation was $L_t = 36*(1-e^{-0.39(t+1.68)})$. Mcllwain *et al.*(2005) mentioned that the differences in growth parameters were due to age, sex, maturity and sampling period for the same species. The value of growth performance index (Φ') was calculated as 6.22. That results showed a lower of growth performance index than in the previous studies, which may be due to the lower value of *K*. Constant of length-weight relationship and growth parameters for *S. aurata* in Bardawil lagoon were summarized in Table (2).

Table 2: Constants of length weight relationship and the growth parameters of *S. aurata* in Bardawil lagoon

Regions	Age (years)	N	Constants of length-weight relationship and growth parameters						References
Egypt			a	b	L∞	K	t_0	φ'	
Bardawil lagoon	4	3262	0.025	2.813	36	0.39	-1.68	6.22	Present study
	6	-	0.014	2.98	38	0.34	-0.96	-	Khalifa, 1995
	5	1537	0.013	3.035	38.5	0.297	-1.08	-	Tharwat *et al*., 1998
	4	1835	0.014	3.017	35.2	0.58	-0.74	6.58	Salem, 2004
Port said	4	1714	0.012	3.028	38	0.5	-0.6	-	Mehanna, 2007
	4	1947	0.027	2.79	32.7	0.81	-	6.765	Salem *et al*., 2008
	4	3483	0.030	2.76	34.2	0.48	-0.78	6.33	Salem , 2010
Other regions									
Thau (France)	4	713	0.0226	2.886	62	0.221	-0.077	6.745	Lasserre & Labourge, 1974.
Ebro (Spain)	7	611	112*10^{-7}	3.055	62.1	0.171	-0.63	6.494	Suau and Lopez, 1976
Mirna (Croatia)	12	314	0.0112	3.052	59.8	0.153	-1.71	6.303	Kraljevic and Duleic, 1997
Mellah Lagoon (Algeria)	7	370	0.0129	3.067	55.3	0.513	-0.28	7.359	Chaoui, *et al*., 2006

Length at first sexual maturity (L_m)

The length at first sexual maturity was estimated as 20.5 and 22.8 cm which corresponding to an age of 0.47 and 0.83 year for male and female respectively (Fig. 3). This results is close to that of Salem (2004) who observed that, the value of L_m for *S. aurata* in the same lagoon was 20.6 and 22.1 cm for male and female, respectively. Anna *et al.* (2005) recorded that, in the Mediterranean Sea, this species is becoming mature at smaller lengths compared to the other regions.

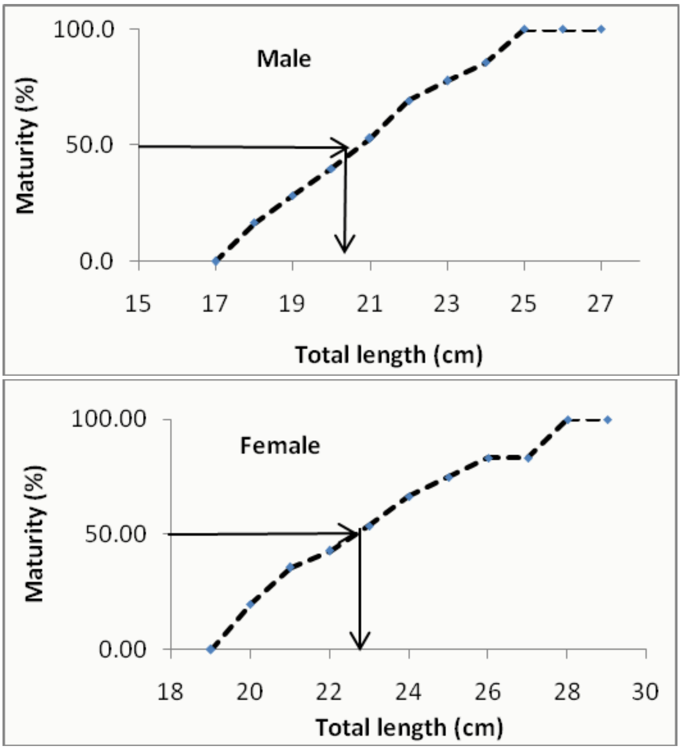

Fig. 3: The length at first maturity of *S. aurata* in Bardawil lagoon

Mortalities and exploitation rate

Total mortality (Z) from length-converted catch curves was estimated as 1.02 yr^{-1} (Fig. 4) while natural mortality (M) was estimated as 0.21 yr^{-1} and the fishing mortality rate (*F*) was 0.81 $year^{-1}$. From these results, the current exploitation rate (*E = 79.43 %*) 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 and more recently, Pauly (1987) proposed a lower optimum F that equal to 0.4 M. Patterson (1992) reported that an exploitation rate of about 0.4 is safe for the stock.

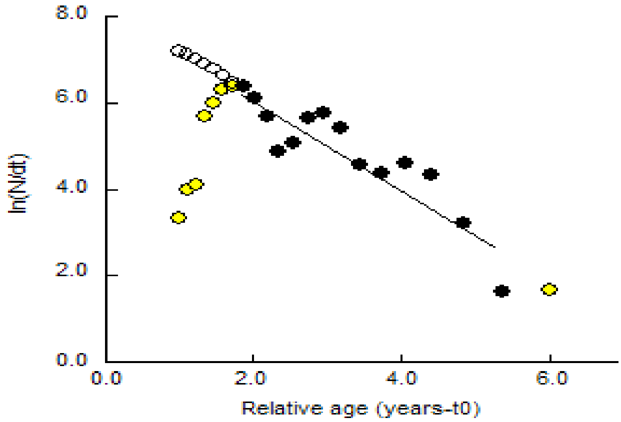

Fig. 4: length-converted catch curve of *S. aurata* in Bardawil lagoon.

Length at first capture *(L_c)*

The length at first capture (The length at which 50% of fishes retained by the gear is the mean selection length, *Lc*) was estimated to be 15.54 cm, also, 25 % of all fish were caught at 14.38 cm TL, and 75 % at 16.79 cm TL (Fig. 5). In this study, the value of L_c was considerably smaller than the length at first sexual maturity (L_m) for male (20.5 cm) and female (22.8 cm). The current sea bream catch in Bardawil lagoon was mostly below the length at first sexual maturity (immature fish). Therefore must have a chance to spawn 2–3 times before capture according to Grandcourt *et al*. (2005) by increasing the mesh size of trammel nets.

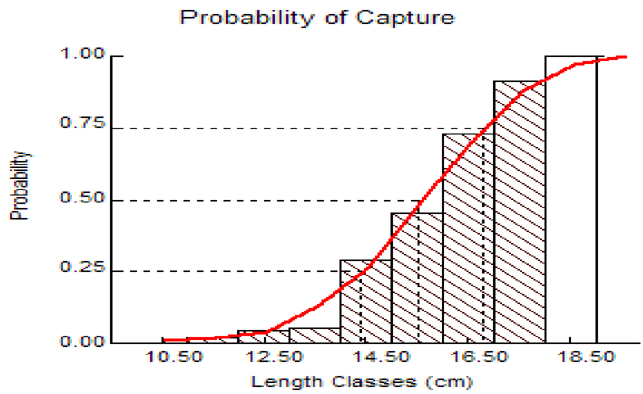

Fig. 5: Analysis of capture probability for *S. aurata* in Bardawil lagoon.

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

The Knife Edge selection procedure (Fig. 6.) for the analysis of relative yield–per-recruit (Y′/R) and biomass per-recruit (B/R) of *S. aurata* vs. the exploitation rate in Bardawil lagoon gave an E_{max} = 0.61, $E_{0.1}$ = *0.5* and

$E_{0.5}$ = *0.37*. Therefore, the computed current exploitation rate E (0.79) was higher than the predicted maximum sustainable yield (E_{max} = 0.61), the predicted maximum economic yield ($E_{0.1}$ = 0.5) and maintains 50% of stock ($E_{0.5}$ = 0.37). From this result, the stock of sea bream in Bardawill lagoon was a heavily exploitation. In this study, The value of L_c (whish is a proxy of mesh size) and the current exploitation rate (whish is a proxy of effort) indicated that the small fish are caught at higher effort level. Hence the fishery requires reduction in effort or increase in length at first capture. May be is not easily to balance between the reduction in effort and socio-economic needs of the fishermen however, applying optimum mesh size may be not difficult and allowing increase of L_c to different values.

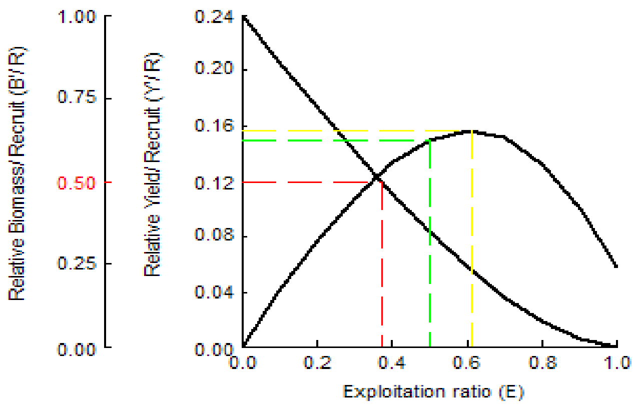

Fig. 6: The relative yield–per-recruit (Y'/R) and biomass per-recruit (B/R) *S. aurata* in Bardawil lagoon with Lc 15.54 cm.

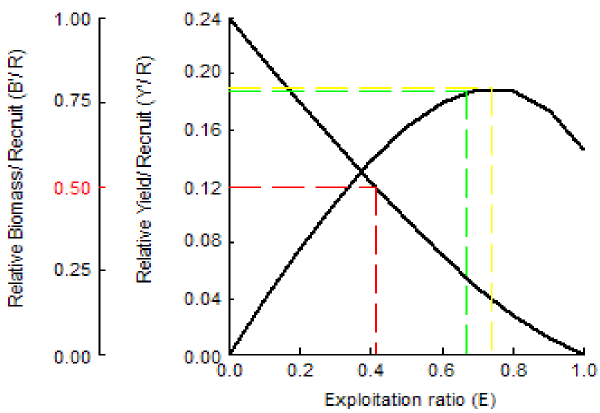

Fig. 7: The relative yield–per-recruit (Y'/R) and biomass per-recruit (B/R) *S. aurata* in Bardawill lagoon with Lc 22.5 cm.

The yield-per-recruit was calculated at different values of L_c (15.5, 22.5 and 24.5 cm), and exploitation rates. The raised L_c to the first sexual maturity (*22.5 cm as* L_t) would be associated with an increase of Y′/R by 15 % from the current Y′/R at exploitation rates equal E_{max} = 0.74, $E_{0.1}$ = 0.67and $E_{0.5}$ = 0.41 (Fig.7). Thus, for proper management of sea bream catch on Bardawil lagoon, the length at first capture (L_c) must increase from 15.54 to 22.5 cm with economic exploitation rate, $E_{0.1}$ = 0.67 or should be raised L_c to 24.5 cm at current exploitation rate E_{max} = 0.79 (Fig.8).

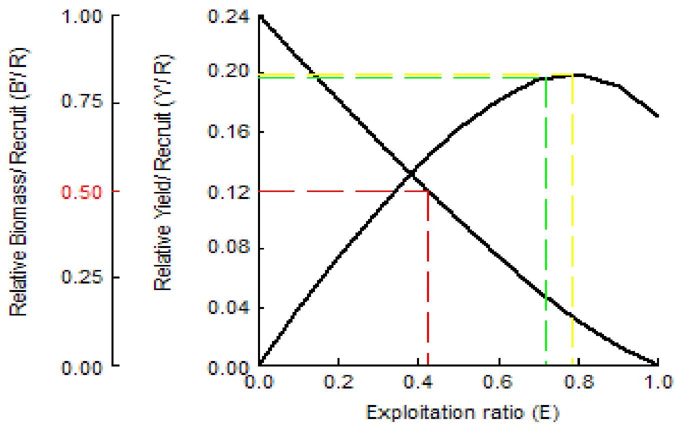

Fig. 8: The relative yield–per-recruit (Y'/R) and biomass per-recruit (B/R) *S. aurata* in Bardawil lagoon with Lc 24.5 cm.

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