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A Preliminary Assessment and Management of Gilthead Bream *Sparus aurata* in the Port Said Fishery, the Southeastern Mediterranean, Egypt

Sahar Fahmy Mehanna[1,] *

[1] National Institute of Oceanography and Fisheries, P.O. Box: 182, Suez, Egypt.

* Corresponding Author: Tel.: +2062 336 00 15; Fax: +2062 336 00 16;
E-mail: sahar_mehanna@yahoo.com

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Abstract

A total of 1714 gilthead bream *Sparus aurata* was collected from the Port Said fishery between January 2004 and February 2005. Total length ranged from 10 to 35.5 cm while total weight varied from 18 to 650 g. The length-weight relationship parameters were a = 0.0123 and b = 3.0284. The age distribution covered age groups 0 to IV. The parameters of the von Bertalanffy growth function in length were K = 0.5 year^{-1}, L_∞ = 37.98 cm and t_0 = -0.6 years. The rates of total (Z) and natural mortality (M) were 1.95 and 0.62 year^{-1}, respectively. The fishing mortality (F) was 1.33 year^{-1} and exploitation rate (E) of 0.68 indicated that the population has been heavily exploited. The estimated total length at first capture (L_c) was 11.1 cm, while the total length at 50% maturity (L_m) was 25.77 cm. The reproductive activity of gilthead bream in the Port Said fishery took place between November and February, with the greatest intensity in December. Yield per recruit analysis revealed over-fished stock conditions particularly due to small fish being effectively unprotected by the current minimum size regulations.

Key Words: Mediterranean, Port Said, *Sparus aurata*, population dynamics, spawning, stock assessment, management.

Introductıon

Porgies (family: Sparidae) are among the most abundant demersal fishes inhabiting the Egyptian Mediterranean, especially the Port Said region (Figure 1). They are caught by two different fishing methods; trawl and hand line and constituted 6.5% of the total trawl catch and 29.9% of the total artisanal catch in Port Said (Mehanna *et al.,* 2005).

Gilthead seabream, *Sparus aurata* (Linnaeus, 1758) is common throughout the Mediterranean and considered as one of the most popular porgies for food. It is a bottom dwelling species and usually lives solitary or in small and loose groups. It is an expensive luxury food so; it is a target for intensive fishing. Recently, it has been widely cultured in many countries including Egypt. In the wild it spawns in the winter months but in aquaculture farms it is conditioned to breed all year round under controlled methods (Moretti *et al*., 1999 and Lloris, 2005).

Gillthead seabream *S. aurata* is locally known as "denis" and exploited by the trawl fishery. It contributed about 3% of the total trawl landings in the Port Said fishery. Its biology in the Egyptian Mediterranean was studied by Wassef (1978 & 1990), Ben-Tuvia (1979 & 1985), Ameran (1992), Khalifa (1995), Tharwat *et al.* (1998) and Abd–Alla (2004).

The present work is the first to provide a preliminary assessment and management of *S. aurata* in the Port Said fishery. It is aimed to estimate the biological and population parameters required for proposing a future plan to sustain and manage this valuable fish resource.

Material and Methods

A total of 1714 individuals of *S. aurata* (10–35.5 cm TL) were randomly collected from the commercial catch of the trawl fishery in Port Said from January 2004 to February 2005. Samplings were carried out twice every month through the period of study. The samples were grouped into 1 cm length classes and 925 specimens representing all lengths were sub-sampled for age determination and estimation of length-weight relationship.

Each fish was measured to the nearest mm for total length and weighed to the nearest 0.1 gram total weight, and then the sex and maturity were determined macroscopically. The weight of the gonads was recorded to the nearest 0.01 gram. Otoliths were taken for each specimen, cleaned and stored dry for later age determination. Annual rings on otoliths were identified and counted using an optical system consisting of Nikon Zoom - Stereomicroscope and Heidenhain's electronic bidirectional read out system V R X 182, under transmitted light. The total radius of each otolith and the radius of each annulus were measured to the nearest 0.001 mm. Regression analyses of otolith maximum radius on total length was calculated by the method of least squares. Back-calculated lengths-at-age were computed by using the Lee method (Lagler, 1956).

To evaluate growth, back-calculated lengths-at-ages were fitted to the von Bertalanffy growth model (Ricker, 1975). Gulland and Holt (1959) plot was applied to estimate the von Bertalanffy growth

Figure 1. Egypt and the Egyptian Mediterranean coast.

parameters (L_∞ and K). A likelihood ratio test (Kimura, 1980; Cerrato, 1990) was then used to test for significance.

To estimate the relation between total length (L) and total weight (W), the variables were log-transformed to meet the assumptions of normality and homogeneous variance. A linear version of the power function:

$$W = a*L^{b}$$

was fitted to the data. Confidence intervals (CI) were calculated for the slope to see if it was statistically different from 3. Analysis of residual sums of squares (Chen *et al.,* 1992) was used to determine whether a significant difference existed between the sex-specific length-weight relationships.

The growth performance index (φ') was computed according to the formula of Pauly and Munro (1984) as:

$$\varphi' = \text{Log}_{10} K + 2 \text{Log}_{10} L_\infty.$$

The total mortality coefficient Z was estimated using the method of Pauly (1983). The natural mortality coefficient M was estimated using Taylor's (1960) equation as:

$$M = 3/t_{max}$$

where t_{max} is the maximum age attainable by individual specimens in the given population, while the fishing mortality coefficient

$$F = Z – M$$

and the exploitation rate E was estimated as:

$$E = F/Z \text{ (Gulland, 1971).}$$

The length at first maturity L_{50} (the length at which 50% of fish reach their sexual maturity) was estimated by fitting the maturation curve between the observed points of mid-class interval and the percentage maturity of fish corresponding to each length class interval. Then L_{50} was estimated as the point on the X-axis corresponding to 50% point on the Y-axis. The length at first capture L_c (the length at which 50% of the fish at that size are vulnerable to capture) was estimated by the analysis of catch curve using the method of Pauly (1984a & b).

The spawning season was detected by following the monthly variation in both gonado-somatic index (GSI) and maturity stages. GSI was determined as:

$$GSI = W_g*100/W_t.$$

Where W_g is the gonad weight and W_t is the total body weight in grams.

Gonads were staged macroscopically according to a five-stage maturity index as a modification of the Hjort (1910 & 1914) key.

The relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)' were estimated by using the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986) and defined by:

$$\left(\frac{Y}{R}\right)' = E \times U^{\frac{M}{K}}\left[1-\left(\frac{3U}{1+m}\right)+\left(\frac{3U^2}{1+2m}\right)+\left(\frac{U^3}{1+3m}\right)\right]$$

$$\left(\frac{B}{R}\right)' = \frac{\left(\frac{Y}{R}\right)'}{F},$$

where;

$$m = \frac{(1 - E)}{\frac{M}{k}} = \frac{k}{Z}$$

$$U = 1 - \frac{L_c}{L_\infty}.$$

Results And Discussion

Age Validation

Knowledge of growth and growth variability is essential to the understanding of a stock's population dynamics. To achieve an accurate assessment of these characteristics, several issues need to be addressed. Foremost, is a rigorous approach to the validation and precision testing of age estimates (Campana, 2001). Besides, fishery management plans rely on accurate age determinations; if age estimations are not validated, errors in age determination could result in inaccurate mortality estimates, underestimation of strong year classes and longevity (Beamish and McFarlane, 1983). Ages of *S. aurata* were determined by interpreting growth increments on sagittal otoliths. The sagittal otoliths of sparid species proved to be easy to read, with clearly identifiable bands (Paul, 1976; Ben-Tuvia, 1979 & 1985; Beamish and McFarlane, 1983 & 1987; Djabali *et al*., 1993; Sarre, 1999; Sarre and Potter, 2000; Erzini *et al.,* 2001). Marginal increment analysis showed that a single annulus was formed during January each year. This finding is in accordance with that of Cassie (1956), Paul (1976), Wassef (1978 & 1990), Ameran (1992), Khalifa (1995) and Abd-Alla (2004). All of them concluded that the annulus was formed during the winter between November and February. The maximum life span of *S. aurata* in Port Said fishery was four years and age group one was the most frequent group in the catch and constituted 56% while the age group four was the least age group and formed 2.3% of the catch.

Body Length - Otolith Radius Relationship

Otolith radius of *S. aurata* was linearly related to total length (Figure 2) and can be described by the following relationship:

$$TL = 3.0753\ S + 1.5229 \quad (r^2=0.9622)$$

where S is the otolith radius in mm and r^2 is the determination coefficient. This linear relationship indicated that otolith growth was proportional to fish growth.

Back-Calculations and Growth in Length

The mean lengths at age were back-calculated for *S. aurata* as 21.26, 27.80, 32.25 and 34.30 cm for the 1st, 2nd, 3rd and 4th year of life, respectively. Observed lengths were consistently higher than the back-calculated lengths-at age for individual age groups, which indicated that seasonal growth had occurred since the formation of a new annulus. Differences between back-calculated lengths-at-age and observed lengths are in the range of observed seasonal growth (Table 1). The greatest incremental growth in length occurred during the first year and then declined rapidly thereafter. The back-calculated lengths from this study compared with those reported in the previous studies are given in Table 2. The results were relatively comparable with those of Lassere and Labour (1974), Wassef (1978) and Abd-alla (2004), while the back-calculated lengths of the present study were higher than those given by Ameran (1992) and Khalifa (1995) who reported different values for the same species during the three years of study at the Bardawil Lagoon.

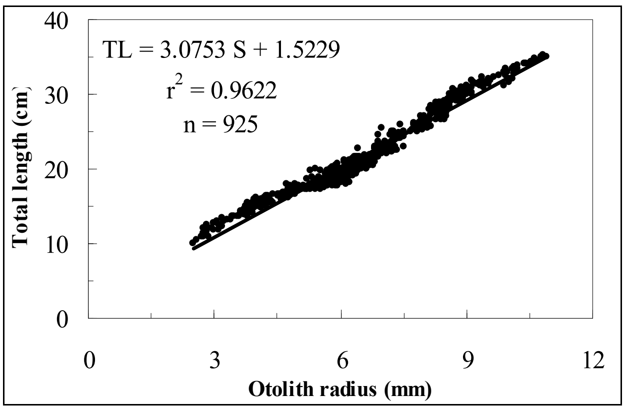

Figure 2. Total length-otolith radius relationship of *Sparus aurata* in Port Said fishery

Table 1. Back-calculated lengths (cm) at the end of each year for *Sparus aurata* from the Port Said fishery.

Age(year)	No. of fish	Observed length	Back-calculated lengths (cm)			
			1	2	3	4
0	90	13.15				
I	518	21.98	**21.26**			
II	180	28.43	21.21	**27.80**		
III	116	32.77	21.17	27.71	**32.25**	
IV	21	34.80	21.11	27.65	32.18	**34.30**
	Increment		21.26	6.54	4.45	2.05
	%		61.98	19.07	12.97	5.98

Table 2. Back-calculated lengths with age of *Sparus aurata* at different localities.

Locality	Total length at the end of each year of life (cm)						Author
	1	2	3	4	5	6	
France							Lassere & Labour (1974)
Basin of Arcachon	20.54	27.97	34.06	36.58			
Basin of Thau	20.08	28.43	35.05	40.58			
Sete	18.71	27.01	32.82	36.88			
Egypt							
Alexandria	17.67	26.16	32.31	39.8	44.11		Wassef (1978)
Bardawil Lagoon	25.15	27.29	28.66	30.05			Ben-Tuvia (1979)
Bardawil Lagoon							
1985	19.50	23.54	26.70				Ameran (1992)
1986	19.70	23.67	26.89				
1985	15.32	19.52	22.69	25.28			Khalifa (1995)
1986	18.36	21.31	23.51				
1987	19.36	23.67	26.29	28.39	--	32.16	
2000	21.44	27.02	30.05	31.88			Abd-Alla (2004)
2001	20.97	26.72	30.17	32.19			
Port Said	21.26	27.80	32.25	34.30			The present study

Length – Weight Relationship

Analysis of residual sums of squares indicated no significant difference between the sex-specific length-weight relationships of *S. aurata* in Port Said fishery (df=2, F=0.019, P>0.05); consequently a power regression was applied to the length-weight data of all individuals combined (Figure 3). The total length varied from 10 to 35.5 cm while the total weight ranged between 18 and 650 g and the resultant equation was:

$W=0.0123*L^{3.0284}$ (r^2=0.9831).

Isometric growth was observed for gilthead seabream, as the value of b was not significantly different from 3 (95% Confidence Interval = 2.895 - 3.105).

The calculated weights by age groups were 128.91, 290.44, 455.34 and 548.77 g for the 1st, 2nd, 3rd and 4th year of life, respectively. The growth rate in weight was much slower during the first year of life, and then the annual growth increment in weight increased reaching its maximum at the end of the third year of life (Figure 4).

Growth parameters

A likelihood ratio test (LRT) showed no significant difference between male and female VBGFs growth curves (χ^2=7.82, df=3, P>0.05). The obtained equations for pooled data were as follows:

For growth in length $L_t = 37.98\ (1 - e^{-0.5\ (t+0.6)})$, and for growth in weight $W_t=747.19(1-e^{-0.5\ (t+0.6)})^{3.0284}$

Growth Performance Index (φ')

The growth performance index (φ') of *S. aurata* was computed as 2.87. This value is consistent with other estimates (Table 3).

Mortality and Exploitation Rates

The total mortality coefficient Z was estimated as 1.95 year^{-1} (Figure 5). The natural mortality coefficient M was 0.62 year^{-1}, while the fishing mortality coefficient F was 1.33 year^{-1}. The exploitation rate E was computed as 0.68. Gulland (1971) suggested that the optimum exploitation rate for any exploited fish stock is about 0.5, at F_{opt} = M.

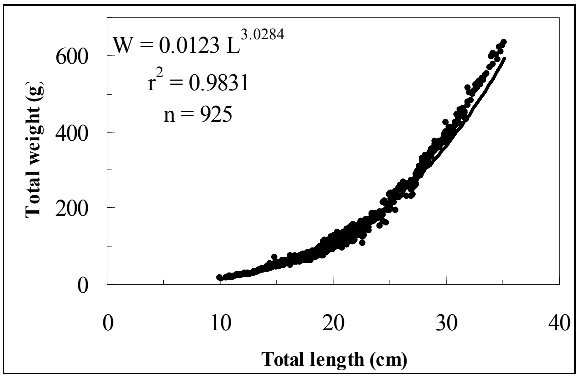

Figure 3. Length-weight relationship of *Sparus aurata* in Port Said fishery.

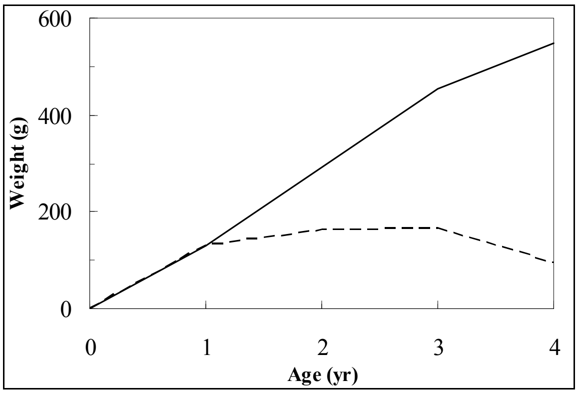

Figure 4. Growth in weight and growth increment of *Sparus aurata* in Port Said fishery

Table 3. Growth parameters and growth performance index of *Sparus aurata* in Egypt.

Locality	L_∞ (cm)	K (yr^{-1})	t_o (yr)	φ'	Author
Alexandria	70.62*	0.17*	--	2.93*	Wassef (1978)
Bardawil lagoon					
1985	38.05	0.25	-1.92	2.56*	Ameran (1992)
1986	40.71	0.21	--	2.54*	
1985	34.55	0.24	-1.41	2.46*	Khalifa (1995)
1986	29.96	0.29	-2.23	2.42*	
1987	38.97	0.21	-2.41	2.50*	
1997	38.50	0.30	-1.08	2.65*	Tharwat *et al.* (1998)
2000	34.08	0.58	-0.70	2.83*	Abd-Alla (2004)
2001	35.18	0.52	-0.74	2.81*	
Port Said	37.98	0.50	-0.60	2.86	The present study

*The values were calculated by the author

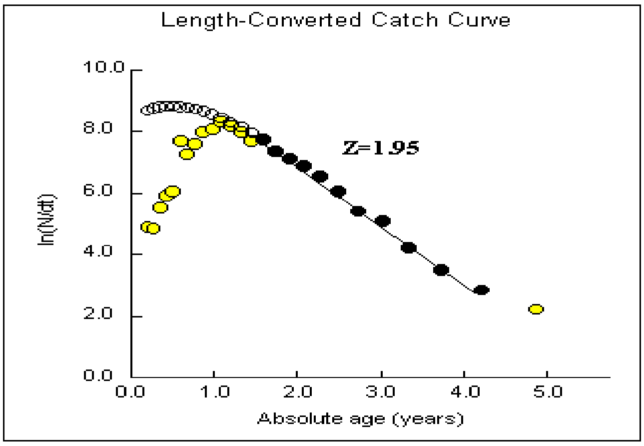

Figure 5. *Z*-estimation for *Sparus aurata* from Port Said fishery.

More recently, Pauly (1987) proposed a lower optimum F that equal to 0.4 M. In the present study, F was higher than the two values of F_{opt} given by both Gulland (1971) and Pauly (1987) indicating that the stock of *S. aurata* in Port Said is overexploited.

Length and Age at First Capture

The length at first capture was estimated as 11.1 cm which corresponding to an age of 0.25 year.

Length and Age at First Maturity

The gilthead seabream from Port Said is a protandrous hermaphrodite. Thus, males were dominant in the lower length classes of 10-17 cm. Sex inversion was observed at lengths between 15 and 27 cm and all fish over 32 cm were females.

Length at first sexual maturity L_{50} is of great importance when determining the optimum mesh size. No statistically significant difference was found between sexes (likelihood ratio test; $P>0.5$), so the L_{50} of *S. aurata* in the Port Said fishery was estimated for pooled data and found to be 25.77 cm. The corresponding age was 1.67 yr, which means that the exploited *S. aurata* must be protected till their second year of life in order to be able to spawn at least once. Wassef (1978) gave L_{50} = 20 cm for males and 23 cm for females *S. aurata* in the Alexandria fishery, while Tharwat *et al.* (1998) estimated L_{50} = 20 cm for pooled data in the Bardawil Lagoon, this difference from the results of this study may be due to the length range used.

The smallest mature male and female fish in the present study were 17 cm in total length which was greater than both estimated L_c and the lengths of fish captured, indicating growth and recruitment over-fishing. In the light of these results, a minimum size limit should be implemented for *S. auratus* in Port Said.

Spawning Season

The monthly variation in GSI values (Figure 6) and the distribution of different maturity stages (Figure 7) revealed that the spawning activity continued from November to February peaking in December. These results are in accord with those

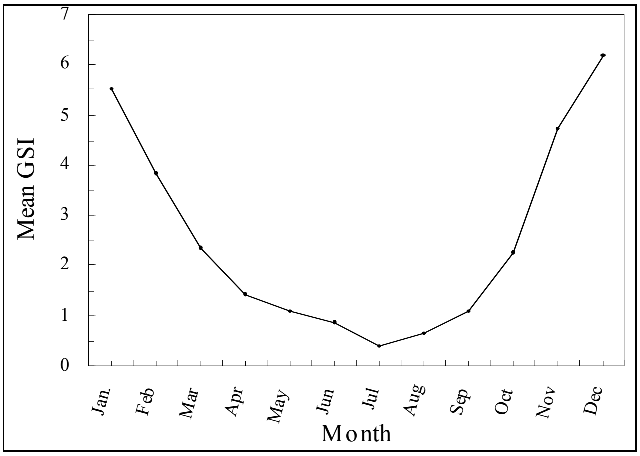

Figure 6. Monthly variation in GSI for *Sparus aurata* from Port Said fishery.

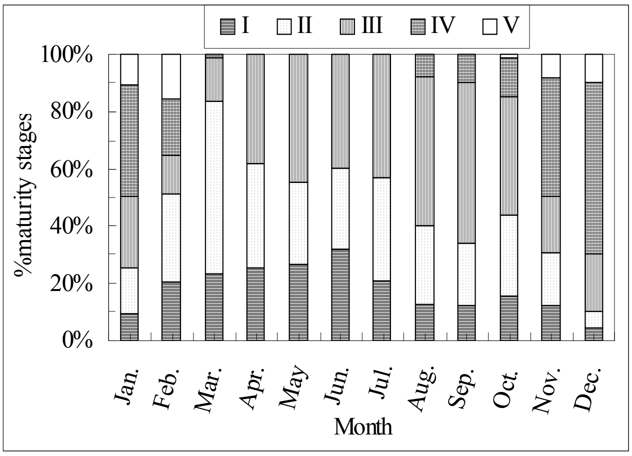

Figure 7. Monthly distribution of maturity stages for *Sparus aurata* in Port Said fishery.

reported in previous studies (Cassie, 1956 in NewZealand; Wassef, 1978 in Alexandria; Ben-Tuvia, 1979&1985 in Lake Bardawil and Tharwat *et al.,* 1998 in the Bardawil Lagoon).

Per - recruit Analysis and Reference Points

The plot of relative yield per recruit Y'/R and relative biomass-per-recruit (B'/R) of *S. aurata* from the Port Said fishery against the exploitation rate E (Figure 8) gives a maximum (Y'/R) at E= 0.51. The exploitation level which maintains the spawning stock biomass at 50% of the virgin spawning biomass $E_{0.5}$ was estimated as 0.31. This indicates that the current E and F values were higher than those giving the maximum Y'/R and maintains 50% of the unexploited stock biomass ($E_{0.5}$).

To predict the effects of increasing the length at first capture on the yield of *S. aurata*, the relative yield-per-recruit was estimated by applying a higher value of L_c (19 cm). The results indicated that an increase of L_c would be associated with an increase in yields at the existing exploitation rate (Figure 9). However, the existing E was nearly the same as that which maximize yield per recruit (E_{max}= 0.68). Also, the obtained value of $E_{0.5}$ was 0.36. This means that, the present level of L_c is not the optimum length at first capture of this fish species and it should be raised to about 20 cm.

It can be concluded that the *S. aurata* stock in the Port Said fishery is in a situation of overexploitation and to sustain this valuable fishery resource some management measures, including reduction of the present level of fishing effort and an increase in the length at first capture should be applied. To directly reduce the fishing effort seems impossible for socio-economic reasons, so instead, to propose a closed season, define closed areas and regulate mesh sizes of the nets used could be advised.

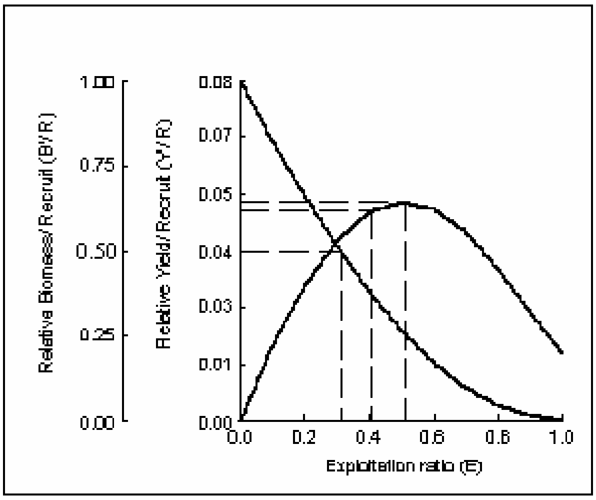

Figure 8. Yield per recruit analysis for *Sparus aurata* from Port Said fishery.

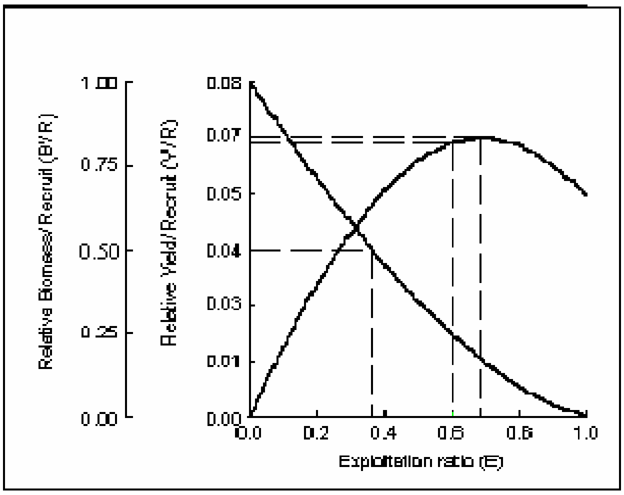

Figure 9. Yield per recruit analysis for *Sparus aurata* with different L_c (L_c/L_∞= 0.5).

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