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Research Article

POPULATION DYNAMICS OF ROUND SARDINE *SARDINELLA AURITA* IN EL-ARISH WATERS, SOUTHEASTERN MEDITERRANEAN, EGYPT

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ABSTRACT
The population dynamics of the round sardine, *Sardinella aurita*, in El-Arish waters, Southeastern Mediterranean, was studied based on monthly samples collected between January 2008 and December 2009 from El-Arish landing site. Age and growth studies based on sagittal otoliths revealed that this species has a maximum lifespan of three years and the mean back-calculated total lengths were 13.13, 18.41 and 21.45 cm at the ages I, II, and III respectively. Growth was described by the von Bertalanffy growth model as $L_t = 25.58\ (l\text{-}e^{-0.55(t+0.3)})$. Estimates of total, natural and fishing mortality were 2.53, 0.64 and 1.89 $year^{-1}$, respectively. The high value of exploitation ratio (E= 0.75) indicated that this species was harvested at a higher level than the optimum fishing mortality and this fishing pressure should be reduced to obtain MSY. The yield per recruit analysis suggested that the *S. aurita* stock in the El-Arish waters needs regulatory measurements to achieve its sustainable development.

Key Words: *Mediterranean Sea, El-Arish, Sardinella Aurita, Age and Growth, Population Dynamics, Management*

INTRODUCTION
The Egyptian Mediterranean coast is about 1100 km extending from El-Sallum in the West to El-Arish in the East and yielding about 55 thousand ton annually (GAFRD annual reports). The fishing grounds along the Egyptian Mediterranean coast are divided into four regions; Western region (Alexandria and El-Mex, Abu-Qir, Rasheed, El-Maadiya and Mersa Matruh), Eastern region (Port Said and El-Arish), Demietta region and Nile Delta region (Fig. 1). El-Arish fishing ground constitutes 6% of the total fish production in the Egyptian Mediterranean (GAFRD annual reports, 1995-2009).

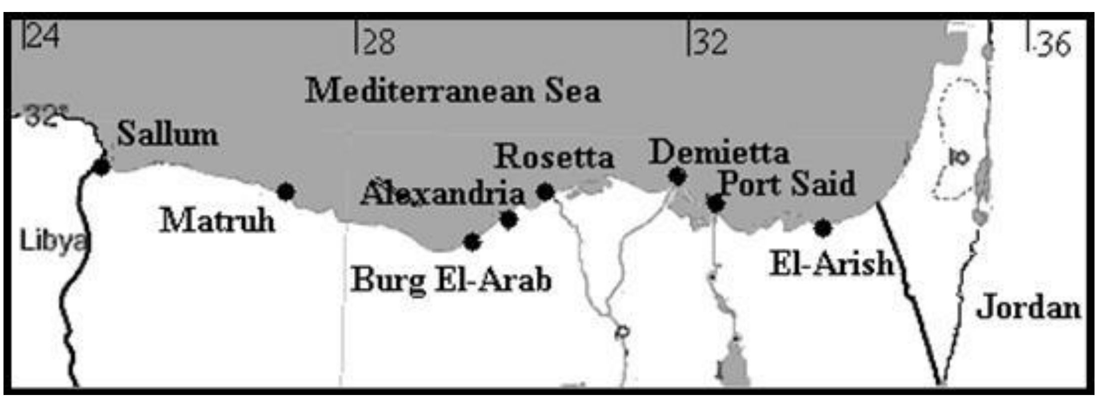

Figure 1. Egyptian Mediterranean coast

The round sardinella, *Sardinella aurita* (family: Clupeidae) is a marine pelagic fish that is widely distributed throughout tropical and subtropical seas including the entire Mediterranean and black seas (Froese and Pauly, 2003). It is one of the most important fishes in the Egyptian sector of the Mediterranean Sea contributing about 30% of the total fish production from Egyptian Mediterranean waters. In El-Arish waters, it is the most important fish group and represents about 85% of the total fish production. However, during the last twenty years a considerable decline in sardine landing along the Egyptian Mediterranean coast has been observed. In the last year the catch of sardine severely declined to only 50% of the El-Arish catch as the crabs invade the area and become the main catch.

In spite of great importance of this species to the economy of the Egyptian fisheries, their dynamics and management were sparsely studied. On the other hand, there were many studies concerning the biology of sardines in Egypt of which were those of Rifeat (1960), El-Maghraby (1960), Botros *et al*. (1970), Soliman *et al.* (1970), Hashem *et al.* (1979), Bebars (1981), Hashem and Faltas (1982), Faltas (1983), Wadie (1998), El-Aiatt (2004), Haggag (2005), Mehanna *et al.* (2008), Salem *et al.* (2010).

For the rational exploitation and management of *S. aurita* stock in the Southeastern Mediterranean (El-Arish waters, Egypt) information on its dynamics and biology is essential. The present study was carried out to discuss and estimate the basic parameters required for assessing and managing the stock of *S. aurita* in El-Arish.

MATERIALS AND METHODS

Samples of *S. aurita* were collected monthly (Fig. 2) from the commercial catches of purse-seine fishery at El-Arish landing site during two years (January 2008 until December 2009). All collected fishes (4870 fish) were measured to the total length and weighed to the nearest 0.1 g total weight. Sex, maturity stage and otoliths were taken for each specimen of *S. aurita*.

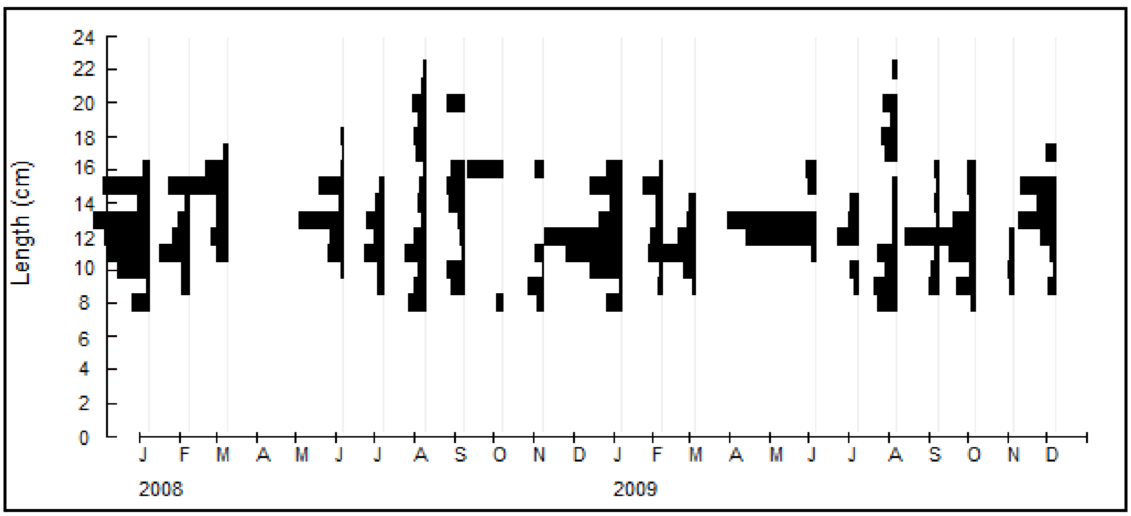

Figure 2. Length frequency of *Sardinella aurita* from El-Arish landing site

Annual rings on otoliths were counted using optical system consisting of Nikon Zoom - Stereomicroscope focusing block, Heidenhain's electronic bidirectional read out system V R X 182, under transmitted light. The total radius of the otolith "S" and the distance between the focus and the successive annuli were measured to the nearest 0.001 mm. Lengths by age were back - calculated using Lee's (1920) equation.

The relation between the total length (L) and total weight (W) was computed using the formula $W = a L^b$ where "a" and "b" are constants whose values were estimated by the least square method. Confidence intervals (CI) were calculated for the slope to see if it was statistically different from 3.

The back-calculated lengths were used to estimate the growth parameters ($L\infty$ & K) of the von Bertalanffy growth model by fitting the Ford (1933) and Walford (1946) plot. The growth performance (ø) of *S. aurita* population in terms of length growth was computed using the index of Pauly and Munro (1984) as $ø = \text{Log } K + 2 \text{ Log } L\infty$.

The data were then pooled monthly and subsequently grouped into classes of one centimeter intervals. The data were analyzed toestimate the total mortality (Z) using the length converted catch curve method

of Pauly (1983). Natural mortality by age was estimated according to the Caddy's formula using the PROBIOM Excel spreadsheet (Abella *et al.*, 1997). The fishing mortality coefficient F = Z – M and the exploitation rate E was estimated as E = F/Z.
Yield per Recruit analysis (Y/R) was conducted based on the exploitation pattern resulting from the XSA model and population parameters.

RESULTS AND DISCUSSION

Purse-Seine Fishery

The number of purse- seiners in El-Arish port varied between 50 and 60 vessels. The vessel's length ranged between 15 and 20 meter and its width of about 5 to 7 meter. They are powered by engines of 100 to 500 hp and equipped with a purse seine net of 8 mm mesh size. The purse-seiners are operated at night using lighted dinghies. This illumination leads to attract fish before setting the net. The purse-seine fishery in El-Arish contributed about 85% of the total fish production.
The dominant fish families in the purse-seine catch of El-Arish were family: Clupeidae which commonly known as sardines and herring and contributing about 97% of purse seine catch and 85% of the total fish production from El-Arish waters (Fig. 3); family: Scombridae (mackerels, bonitos and tunas) and family: Mugilidae (mullets). The species of lesser importance or unsorted species were grouped as "others". Sardine fisheries were highly important to the El-Arish economy where sardines are the most dominant and popular fish there and have a reasonable market price. Before the construction of Aswan High Dam, the sardine accounted for about 40% of the total landed catch of the Egyptian Mediterranean waters. By that time fisheries of Sardine were mainly operated during autumn (Faltas, 1983). This was due to the effect of arrival of Nile waters rich in nutrients and which therefore flourished the phytoplankton there (Halim, 1960), sardine aggregated in huge shoals on the coastal Egyptian waters for feeding where they were captured by gillnets. After the construction of High Dam, a serious decline in sardine catch was observed.

Age and Growth

Overall 4870 fish were collected, 1200 of which were used for age determination. Age of *S. aurita* was determined based on the otoliths' readings and the results showed three age groups for *S. aurita* and the age group I was the most frequent one in the catch where it constitutes about 65%. The mean back-calculated lengths were 13.13, 18.41, and 21.45 cm at ages I, II and III respectively. The results showed also that the maximum growth rate in length of *S. aurita* in El-Arish was observed during the 1^{st} year of life after which the annual increment decreases with further increase in age. These results agree with the previous studies dealing with age and growth of this species at Mediterranean waters (Table 1). The differences between the present results and the previous ones for the same species and area (El-Aiatt, 2004 and Salem et al., 2010) may be due to the difference in the methods used as both studies were depended on the same data analyzed by the same authors using the same method (scale's reading).

Length-Weight Relationship

A subsample of 1200 specimens of *S. aurita* ranging in sizes from 7.8 to 22.7 cm total length and weighing 3 to 75 g were measured to estimate the length-weight relationship with the formula $W = a L^b$, where a and b are constants estimated by linear regression of the log transformation varieties (Fig. 4). The regression takes the form:
$\text{Log } W = -1.8261 + 2.7454 \text{ Log } L \quad (r^2 = 0.94)$
Corresponding to $W = 0.0149 L^{2.7454}$
A negative allometric growth was observed for this species as the value of (b) was deviated significantly from the value 3 (95% CI was 2.724 – 2.767).

Maximum length and Growth parameters

The maximum observed length of *S. aurita* was 22.7 cm and the maximum predicted one estimated using FiSAT software was 23.04 cm with 95% confidence interval of 20.23 - 24.45 (Fig. 5). Growth parameters of the von Bertalanffy growth formula for *S. aurita* were estimated as $L\infty = 25.58$ cm, $K = 0.55$ yr^{-1} and t_o

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Table (1). Length (cm) at age of *Sardinella aurita* from Egyptian Mediterranean coast.

Locality	L_1	L_2	L_3	L_4	L_5	L_6	L_7	Author
Alexandria	12.4	14.7	16.4	18.1				El-Maghraby (1960)
Alexandria	13.2	18.2	20.8	22.8				El-Maghraby *et al.* (1970)
Alexandria	12.3	16.2	19.3	22.3	23.8			Soliman *et al.* (1982)
Alexandria	12.4	16.0	19.2	21.9	23.8	25.6	27.2	Faltas (1983)
El-Arish								El-Aiatt (2004)
2000	12.38	15.91	18.77	20.54				
2001	12.18	15.23	18.56	20.02				
Port Said								Haggag (2005)
2001	12.56	16.31	18.95	20.77				
2002	12.28	15.95	18.86	20.52				
Port Said	13.48	18.22	21.85	23.76				Mehanna *et al.* (2008)
El-Arish	11.7	15.3	18.5	20.3				Salem *et al.* (2010)
El-Arish	13.13	18.41	20.45					Present study

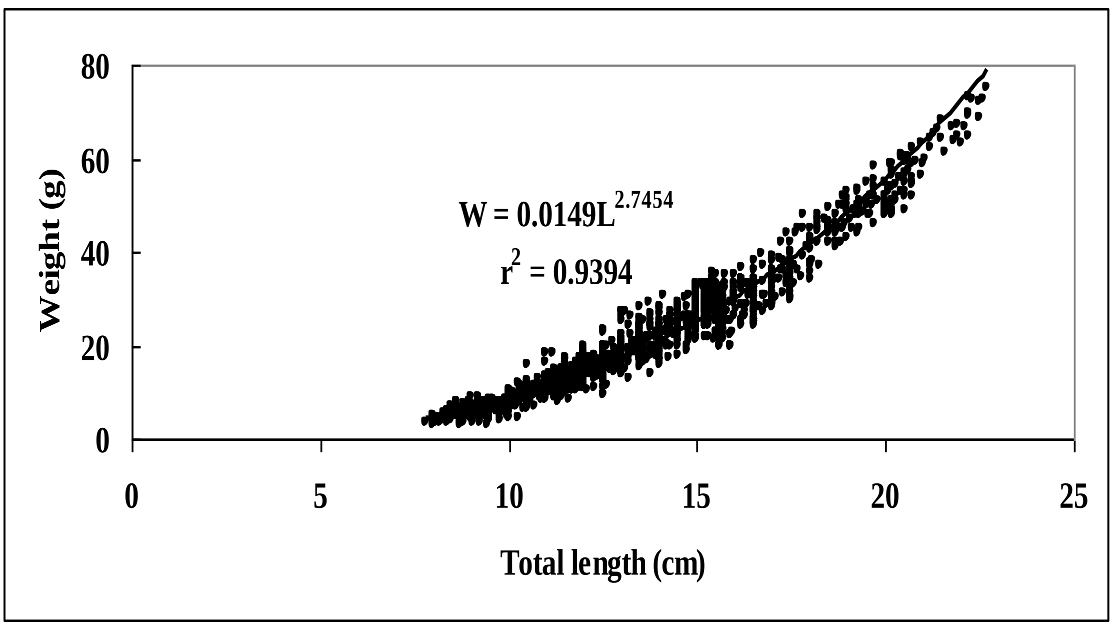

Figure 4. Length-Weight relationship of *Sardinella aurita* from El-Arish waters

= -0.3 yr. Calculated growth performance index (ø) was found to be . These values did not show much difference when compared to the $L\infty$ and K values estimated by the other authors for the same species of Mediterranean waters (Table 2).

Maximum length (L_{max}) to the asymptotic length ($L\infty$) is an important parameter of the life history as a recorded by Stergiou (2000), where founded the mean value of $L_{max}/L\infty$ for marine fish ranged between 0.56 and 1.34 with a mean value of 0.90. Maximum length (L_{max}= 22.52 cm) and the value of $L_{max}/L\infty$ (0.89) very close to the mean value which reported by Stergiou *et al.* (2006) for 383 Mediterranean marine fish ($L_{max}/L\infty \approx 0.89$).

Table 2: Growth parameters of *Sardinella aurita* from Mediterranean waters

Locality	Method	L∞	K	t_o	Ø	Author
Alexandria		26.0	0.53	---	2.55	El-Maghraby *et al.* (1970)
Alexandria		36.5	0.54	-0.35		Abdalla & El-haweet (2000)
Tunisia		31.32	0.24	---	2.27	Gaamour *et al.* (2001)
El-Arish 2000 2001	Scale	25.68 25.61	0.318 0.293	-1.04 -1.08	2.32 2.28	El-Aiatt (2004)
Port said 2001 2002	Scale	25.01 24.81	0.359 0.36	-0.94 -0.89		Haggag (2005)
Greece	Scale	24.9	0.51	-0.88		Tsikliras *et al.* (2005)
Senegal	LF	26.91	0.57		4.28	Goudiaby *et al.* (2008)
Port Said	Otolith	28.14	0.4	-0.6	2.51	Mehanna *et al.* (2009)
El-Arish	Scale	25.83	0.3	-0.88	2.29	Salem *et al.* (2010)
El-Arish	Otolith	25.58	0.55	-0.3	2.56	Present study

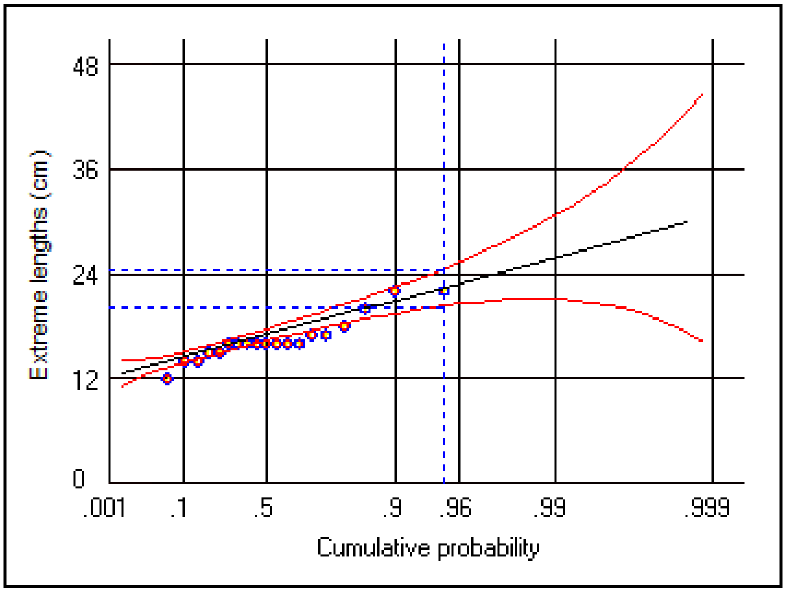

Figure 5: Maximum predicted length of *Sardinella aurita* from El-Arish waters.

Mortality and Exploitation rate

The computed annual mortality rates Z, M and F were 2.53, 0.64 (Fig. 6) and 1.89, respectively. The rate of exploitation (E) was estimated as 0.75 which indicate over fishing during the period of study. This assumption is based on Gulland (1971), he stated that suitable yield is optimized when F = M i.e., when E is more than 0.50, the stock is generally considered to be overfished. More recent, Pauly (1987) proposed a lower optimum F that equals to 0.4 M. In the present study, F was higher than the two values of F_{opt} given by Gulland (1971) and Pauly (1987) indicating that the stock of *S. aurita* in El-Arish waters is heavily exploited.

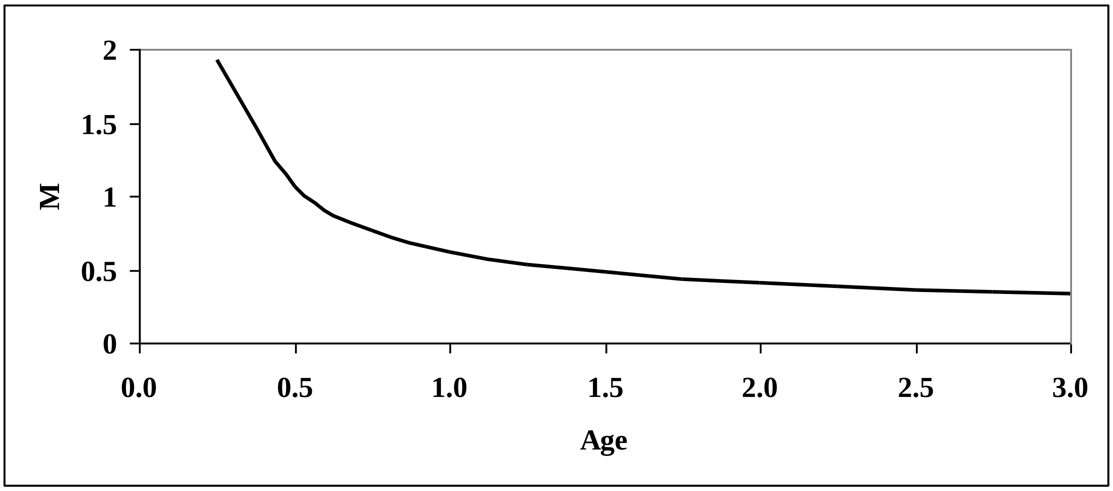

Figure 6: Natural mortality M at age of *Sardinella aurita* from El-Arish waters.

Yield per Recruit (Y/R)

The model of Beverton and Holt (1956) modified by Gulland (1969) was applied to estimate the yield per recruit of *S. aurita* in El-Arish waters.

The plot of (Y/R) against F was shown in figure (7). It was obvious that, the maximum (Y/R) was obtained at F_{MSY} = 1.1, as the fishing mortality rate increases beyond this value, yield per recruit decreases. The results indicated that the present level of F was higher than that which gives the maximum (Y/R). The obtained data indicated clearly that the present level of age at first capture was smaller than that produces the maximum (Y/R).

The results indicate also that, at the present level of fishing mortality coefficient (F= 1.89), age at first capture (T_c = 0.8 year) and natural mortality coefficient (M= 0.64), the yield per recruit was estimated to be 215.6 g. This means that, the present level of fishing mortality is higher than that which gives the maximum yield per recruit and to obtain the maximum yield per recruit (223.7 g), the fishing mortality coefficient must be reduced from 1.89 to 1.1 (41.8%).

To determine the most appropriate age at first capture "T_c" of *S. aurita* in El-Arish waters, the yield per recruit was estimated by applying $T_c = T_m$ (age at first sexual maturity) = 1.1 year. The results (Fig. 7) indicated that with the increasing of T_c a higher yield per recruit can be obtained. It is obvious also that if T_c is 1.1 instead of 0.8 year a maximum yield per recruit of 243.4g can be obtained at fishing mortality of 1.55 which is less than the present level. This means that, the present level of T_c is not the optimum T_c of this fish species in El-Arish waters and it must be in the range of 1.5 year.

It is worth mentioning that overfishing, illegal mesh sizes and constructive fishing techniques are not the only reasons for declining of sardine production in Egyptian Mediterranean waters. Besides, the quality and quantity of food and some environmental changes that greatly reduce the survival rate of sardine eggs and larvae affect the occurrence and abundance of sardine shoals (Mehanna et al., 2008). Before 1965, the river Nile discharge was the main reason for the high biological productivity of the shelf waters. This was due to the large amounts of organic substances and mineral particles through its two tributaries (Demietta and Rosetta). The regulation of the Nile flood by the construction of the Aswan high Dam (1964- 1966), resulted in a serious change of the ecological conditions in south eastern Mediterranean from Alexandria eastwards (AL-Kholy& El-Wakeel, 1975). This greatly affected the sardine fishery along the Egyptian Mediterranean coast and the catch declined from 18 thousand ton in 1962 (EL-Zarka &Koura,1965) to less than one thousand tons in 1972 (Hashem, 1972).

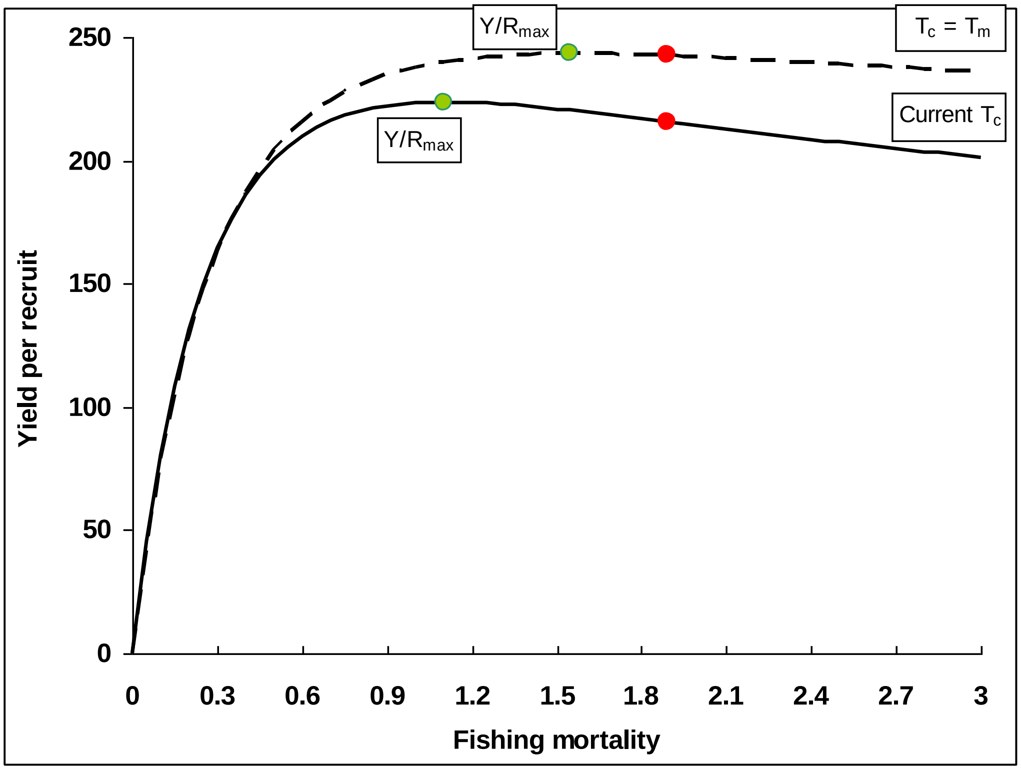

Figure 7: Yield per recruit analysis for *Sardinella aurita* from El-Arish waters.

The cessation of Nile flood after the construction of Aswan High Dam leads to the decrease of nutrients and sediment, which arrived to Mediterranean by the floodwater and this was the main factor that affected all small pelagic resources, especially sardine.

From the above results it could be concluded that *S. aurita* stock in El-Arish fishery is in a situation of overexploitation and to maintain this valuable fish resource, it is essential to reduce the present fishing pressure to obtain more sustained production. Also the mesh sizes should be increased.

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