Growth, mortality and spawning stock biomass of the striped red mullet Mullus surmuletus, in the Egyptian Mediterranean waters

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Abstract

Population parameters such as age, growth, mortality and maturity-at-age are crucial parameters for accurate stock assessment and management plans to ensure the sustainable development of fisheries. Also, they are essential for the calculation of spawning stock biomass (SSB) and equilibrium yield as well as biological reference points including F_{max}, $F_{0.1}$ and $F_{30\%SSB}$. Age and growth parameters were estimated for the striped red mullet, <u>Mullus surmuletus</u>, sampled from commercial landings of the trawl fishery in the Egyptian Mediterranean waters, using the otolith reading technique. <u>M. surmuletus</u> has a longevity of 5 years, but over 70% of fish were less than 2 years old. The growth parameter estimates were $K= 0.47$ yrs^{-1}, $L\infty= 31.74$ cm, and $t_o= -0.3$ yrs. Natural mortality (M) was 0.43 yrs^{-1}, fishing mortality (F) was 0.73 yrs^{-1}, survival rate (S) was 0.31 and exploitation ratio was 0.63 yr^{-1}. Length-at-50% maturity was estimated at 15.1 cm TL, while the length at first capture was estimated at 11.6 cm TL. SSB analysis showed that effort reduction is strongly recommended such that F be reduced by 40% to rebuild spawner biomass to acceptable levels. Per-recruit analysis revealed that F should be reduced by about 27% to achieve the maximum Y/R. All approaches point to the need for drastic reduction in fishing pressure by about 30-40% in the Egyptian Mediterranean fisheries.

Keywords: *Mullus surmuletus;* Age composition; Mortality; Spawning stock biomass; Reference points; Management.

Introduction

The red mullets (*Mullus surmuletus* and *M. barbatus*) are major target species of Mediterranean demersal fisheries and are exploited by more than one gear type (STERGIOU *et al.* 1992; RENONES *et al.* 1995; DEMESTRE *et al.* 1997). They are mainly exploited at depths of 3-90 m on sandy or muddy bottoms but also at times on rocky ground. These species are benthic carnivores and feed on small invertebrates (crustaceans, molluscs, polychaetes) that live on or within the bottom substrates (GHARBI & KTARI, 1979; GOLANI & GALIL, 1991; N Da, 1992; LABROPOULOU & ELEFTHERIOU, 1997; VASSILOPOULOU *et al.* 2001).

Red mullet are among the most valuable and highly priced fish species in Egypt, though widely distributed along the entire coast of Mediterranean, their major fisheries are located in the area from Alexandria to Port Said. Red mullet are mainly exploited by the trawl fishery and contribute about 10% of the total trawl landings in the Mediterranean (GAFRD annual reports). The catch is composed mainly of two species; *Mullus surmuletus* and *M. barbatus,* although some species of Red Sea origin have been recorded in the eastern Mediterranean. The striped red mullet, *Mullus surmuletus* is the most common species in the catch and constitutes about 65% of the red mullet landings. Several aspects of red mullet biology have been studied, including feeding, reproduction, age and growth (ANDALORO, 1982; MORALES-NIN, 1986; GONZALES PAJUELO & LORENZO NESPEREIRA, 1993; RENONES *et al.* 1995; LABROPOULOU *et al.* 1997; LOMBARTE *et al.* 2000; VASSILOPOULOU *et al.* 2001; MENDES *et al.* 2004; BARNES, 2008), but information on its dynamics and management is very limited. The only previous study concerning the biology of *Mullus surmuletus* in the Egyptian Mediterranean waters was that of HASHIM (1973).

The aim of this study is to assess the exploitation status of the striped red mullet *Mullus surmuletus* in the Egyptian Mediterranean waters and to define some precautionary reference points for its management.

Materials and Methods

Collection of fishery statistics

Data concerning the total and red mullet catches in the Egyptian Mediterranean, as well as the fishing effort expressed as the number of vessels were obtained from the General Authority for Fish Resources Development (GAFRD) annual reports. The data collection involved also interviewing of skippers at selected fishing harbors. These data include the vessel characteristics, type and size of fishing gears, number of fishing days and the fishing sites of special target species. Because of there is no catch statistics by fishing gear in the Egyptian Mediterranean, the author sorted the species according to the fishing gear and estimated the catch by gear for the previous years. The collected data were analyzed to estimate the catch per unit of fishing effort (CPUE) which reflects the relative abundance of this stock.

Collection of samples

From July 2007 to April 2008, except for May and the first half of June 2007, the period when all fishing operations are prohibited, length measurements were obtained in three fishery terminals along the Egyptian sector of the Mediterranean; from west to east: Alexandria, Demietta and Port Said (Fig. 1). A total of 1385 striped red mullet, collected from the trawl fishery, were individually processed in order to obtain data on the total length (TL), in centimeters, and total weight (W), in grams. Sex and sagittal otoliths were taken for each specimen. This sample is represented of all lengths recorded in the landing sites and exploited by the trawl fishery.

Age determination

Sagittal otoliths were used for age determination of *M. surmuletus.* Otoliths were withdrawn carefully from the chambers of the inner ear of each fish and any adhering tissues were removed from the otolith by rubbing them gently between the fingers under water. They were stored dry in special envelopes with full information for fur-

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ther reading. Annual rings on the whole otolith were counted in glycerin under a Nikon Zoom- Stereomicroscope with Heidenhain's electronic bidirectional read-out system V R X 182. The total otolith radius and the radius of each annulus were measured to the nearest 0.001 mm. The total radius of each otolith was plotted against the total fish length to determine the body length-otolith radius relationship. The total lengths of the previous ages were back - calculated using Lee's (1920) equation.

Length-weight relationship

The general power equation ($W = a L^b$) was applied to estimate the length-weight relationship, where a and b are constants whose values were estimated by the least square method. Confidence intervals of 95% were calculated for the slope (b) to see if these were statistically different from 3.

Growth parameters

Growth was expressed in terms of the von Bertalanffy equation: $Lt = L\infty (1-e^{-K(t-to)})$, where $L\infty$ is the asymptotic total length, Lt the total length at age t, K the growth curvature parameter and to is the theoretical age when fish would have been at zero total length. The back - calculated lengths were applied to the Ford (1933) - Walford (1946) plot to estimate $L\infty$ and K, while to was estimated from the equation: $-\ln [(L\infty - L_t) / L\infty] = -Kt_o + Kt$. In the Ford-Walford plot the equation of von Bertalanffy can be rearranged as follows: $L_{t+1} = L\infty (1- e^{-k}) + e^{-k} L_t$, where L_t and L_{t+1} are the fish lengths at age t and t+1, respectively. This method was applied by fitting L_t against L_{t+1} which gives a straight line with a slope (b) equal to e^{-k} and an intercept (a) equal to $L\infty(1-e^{-k})$. Based on von Bertalanffy growth parameters, the performance index ($\emptyset$) was calculated as

$\emptyset = \log10 K + 2 \log_{10} L\infty$ (Pauly and Munro, 1984).

Mortality and exploitation rates

Catch curve method as described in Ricker (1975) was used to estimate the total mortality coefficient (Z), this method expressed as: $\ln (N_t) = a + bt$ where N_t is the number of fish at age t, then $Z = -b$. The natural mortality coefficient (M) was estimated using the method of Djabali *et al.,* 1993 as follows: $\text{LogM} = -0.0278 - 0.1172 \text{LogL}\infty + 0.5092 \text{LogK}$, while the fishing mortality coefficient (F) was computed as $F = Z - M$. The survival rate (S) was estimated as: $S = e^{-Z}$ and the exploitation rate (E) was calculated from the ratio F/Z (Gulland, 1971).

Length at first capture and Length at first sexual maturity

The length at first capture (L_c) was estimated by the analysis of catch curve using the method of Pauly (1984). The length at first sexual maturity L_{50} 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 interval. Then L_{50} was estimated as the point on X-axis corresponding to 50% point on Y-axis.

Spawning stock biomass and yield per recruit

Spawning Stock Biomass (SSB) and Yield per Recruit (Y/R) were estimated using the VIT program (Lleonart and Salat, 1997).

All these calculations were done for sexes combined as any management measures were planned for sexes combined.

Results and Discussion

Description of fishery

The Egyptian Mediterranean coast is

about 1100 km extending from El-Salloum in the West to El-Arish in the East (Fig. 1). The mean annual fish production from this vast area did not exceed 50 thousand tons (GAFRD; 1991 - 2007). The main fishing gears operating in this region were trawling, purse - seining and lining, especially long and hand lining. The fishing grounds along the Egyptian Mediterranean coast are divided into four regions, namely: the Western region (Alexandria and El-Mex, Abu-Qir, Rashid, El-Maadya and Mersa Matrouh), the Eastern region (Port Said and El-Arish), the Demietta region and the Nile Delta region. *M. surmuletus* is exploited mostly by trawl fishing vessels, but unfortunately one of the major obstacles to management and development of the fish resources in Egypt is the lack of reliable catch statistics, on an area and species basis, on catch, different units of fishing effort, age composition and size composition, as well as no statistics concerning the catch by species for different fishing gears operating in Mediterranean fishery. The number of trawl vessels which operated in the Egyptian Mediterranean ranged between 1135 and 1170 during 2000-2007 (Fig. 2). The vessel length varied between 18 and 22 m and its width varied from 4 to 6 m. Each vessel is powered by a main engine of 100 to 500 hp, some of them are equipped with echo-sounders. The annual red mullet landing increased from 1002 tons in 1992 to 2727 tons in 1999; thereafter, the

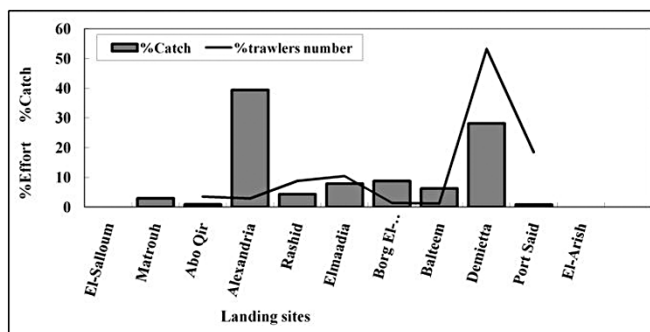*Fig. 1:* Egyptian Mediterranean coast.

Fig. 2: Catch of red mullet and number of trawlers (%) according to the landing sites along the Egyptian Mediterranean coast (2000-07).

relative abundance of these species showed a declining trend. Red mullet landings contributed to about 10% of the total trawl catch from the Egyptian Mediterranean, from which about 40% were recorded in Alexandria and 28% in Demietta during 2000–2007 (Fig. 2). The striped mullet size ranged from 5 cms to 29.1 cms TL, the size between 11 cms and 21 cms forming the bulk of the fishery. Recruitment of juveniles, ranging from 5 cms to 10 cms TL was generally observed during August–November. The length range recorded for trawl fishery did not differ from that of other gears, so the length frequency used in this study is representative of all length groups in the area.

Age and growth

Sagittal otoliths were used for age determination of *M. surmuletus* collected from the Egyptian Mediterranean waters. Otoliths have been proven as a reliable and valid method for ageing *M. Surmuletus* (MORALES NIN, 1991; RENONES *et al.* 1995; KONAN *et al.* 2006). Body length – otolith radius relationship revealed the existence of a strong correlation between these two parameters (Fig. 3). Also, the increase of fish size is accompanied by an increase in the number of annuli on the otoliths.

Moreover, back-calculated lengths accord with the observed lengths for the different age groups (Table 1). The results showed that the maximum life span of *M. surmuletus* is five years and age group one was the most frequent group in the catch where it constituted about 60% (Fig. 4). The greatest incremental growth in length occurred during the first year of life and declined rapidly thereafter (Fig. 5). The present observed maximum age of striped red mullet is lower than that previously estimated in the same area by HASHEM, 1973 (10-years old; length range 11-29 cm), but it agrees with that off Majorca, where the length range of the striped red mullet catch was 10-32 cm and the maximum age was six years old (RENONES *et al.* 1995).

Length - weight relationship

A total of 1385 individuals of *M. surmuletus* have been collected from the commercial landings in three different landing sites of the Egyptian Mediterranean waters. Their total lengths varied from 5.0 to 29.1 cm, while their weights ranged between 1.8 and 300 g. The length - weight relationship equation (Fig. 6) was: $W = 0.0104 L^{3.0617}$. The allometry coefficient of the length-weight relationship (b = 3.0617; CI = 3.1252

Table 1
Average back-calculated lengths (cms) of *Mullus surmuletus*
from the Egyptian Mediterranean waters.

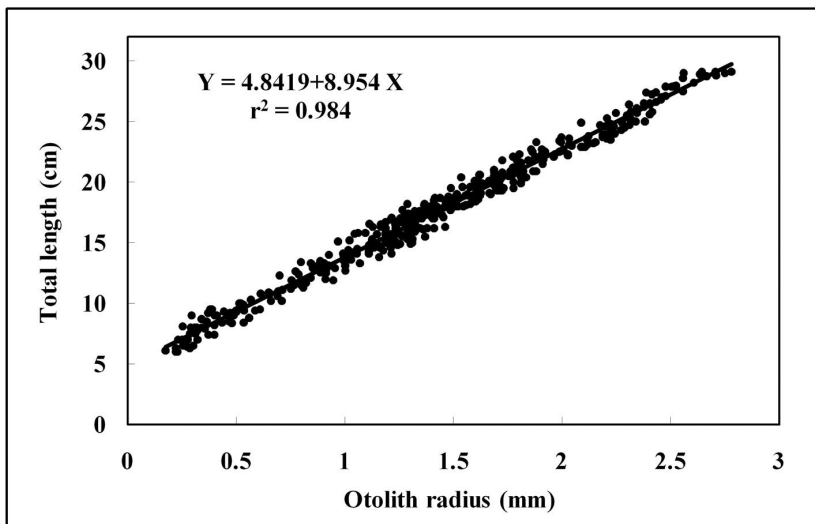| Age group	Empirical length	Back-calculated lengths (cms)				
		1	2	3	4	5
I	15.18	14.55				
II	21.35	14.36	20.87			
III	25.22	14.33	20.76	24.93		
IV	28.00	14.24	20.63	24.82	27.90	
V	29.06	14.15	20.51	24.77	27.79	29.00
Increment		14.55	6.32	4.06	2.97	1.10

Fig. 3: Total length-otolith radius relationship of *Mullus surmuletus* from the Egyptian Mediterranean waters.
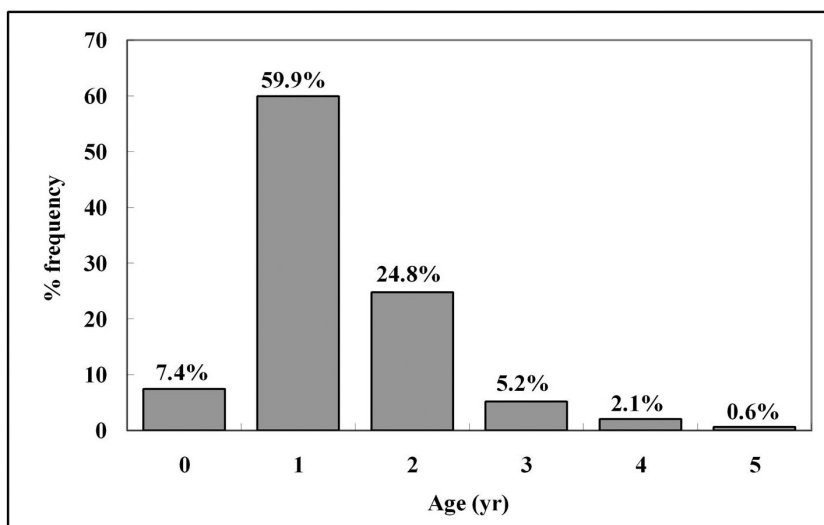

Fig. 4: Age composition of *Mullus surmuletus* from the Egyptian Mediterranean waters.

- 2.9982) indicates isometric growth. This value is close to the one recorded by HASHEM (1973), he gave b= 3.192 for sexes combined of the same species in Alexandria and Abo Qir Bay.
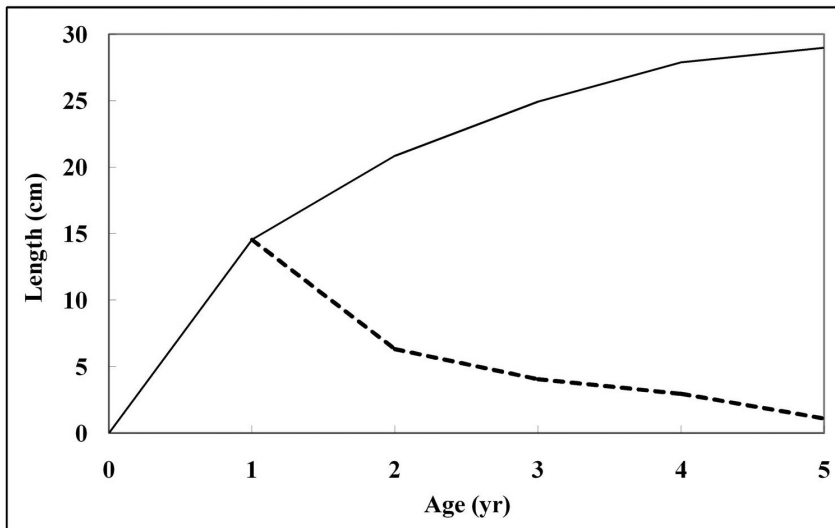
Growth parameters

Growth parameters of the von Berta-

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Fig. 5: Growth in length of *Mullus surmuletus* from the Egyptian Mediterranean waters.
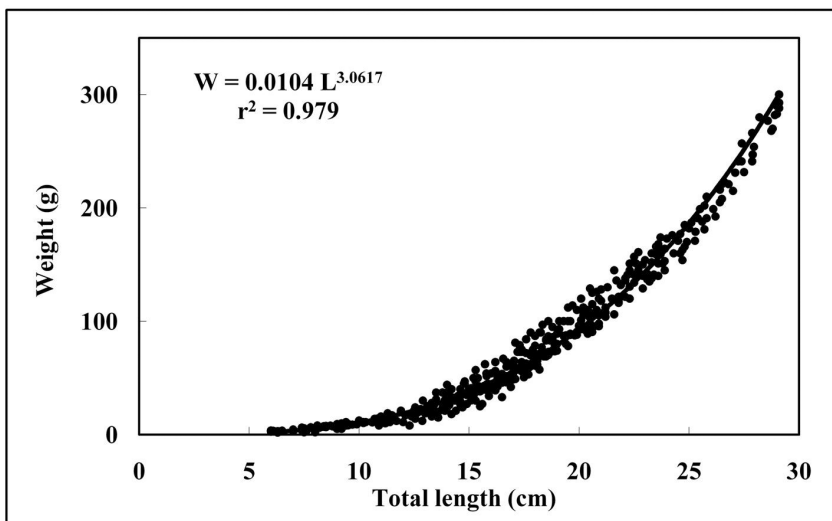

Fig. 6: Length-weight relationship of *Mullus surmuletus* from the Egyptian Mediterranean waters.

lanffy growth model (Fig. 7) for *M. surmuletus* were estimated as $L\infty = 31.74$ cm, $K = 0.47$ yr^{-1}, and $t_o = -0.3$ yr. The calculated growth performance index ($\varnothing$) was found to be 2.67. The estimates of the growth parameters are similar to values calculated in the frame of other studies (Table 2).

Table 2
Growth parameters (L$_\infty$ and K), growth performance index ($\varnothing$) and the allometry coefficient (b) of *Mullus surmuletus*.

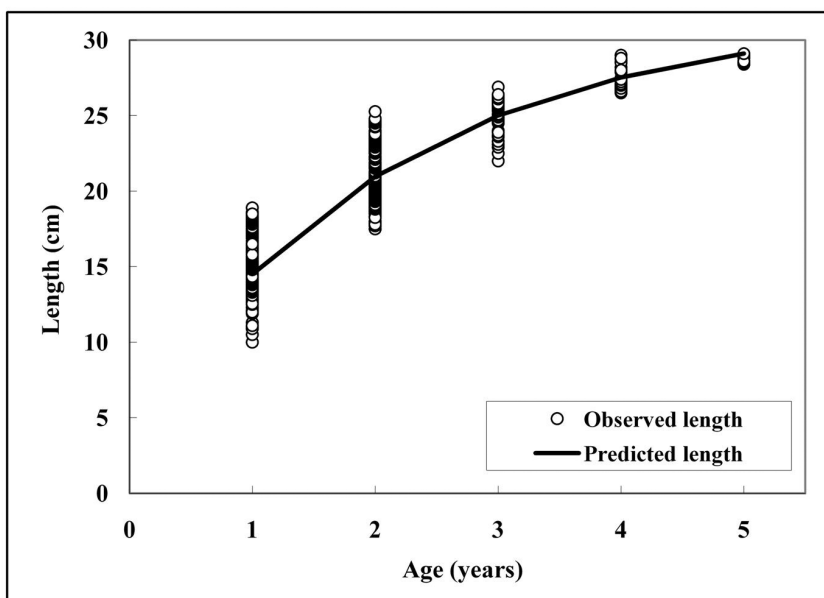| Locality	L$_\infty$	t$_0$	K	$\varnothing$	b	Author
Tunisia	19.95 SL	-0.025	0.49	2.29	3.283	Gharbi & Ktari, 1981
Italy	31.1 TL	-2.68	0.24	2.34		Andaloro, 1982
Spain	34.5 TL	-3.82	0.137	2.21	2.925	Morales Nin, 1991
France	33.4 TL		0.43	2.68		Campillo, 1992
Spain	31.9 TL	-2.6	0.205	2.32		Renones *et al.* 1995
Spain, Majorca	31.28 TL	-2.35	0.211			Renones *et al.* 1995
Egypt	31.74 TL	-0.3	0.47	2.67	3.0617	Present study

Fig. 7: von Bertalanffy growth slope of *Mullus surmuletus* from the Egyptian Mediterranean waters.

Mortality, survival and exploitation rates

The total mortality coefficient, Z (Fig. 8), the natural mortality coefficient, M, and the fishing mortality coefficient, F, were estimated for pooled data as 1.16, 0.43 and 0.73 yr^{-1}, respectively. Survival rate (S) was computed as 0.31 and exploitation rate, E, was 0.63 yr^{-1}. The relatively high value of E indicates overfishing of this stock during that period. Gulland (1971) stated that suitable yield is optimized when F= M i.e., when E is more than 0.5, the stock is generally

considered to be overfished. More recently, Pauly (1987) proposed a lower optimum F that equals 0.4 M.

Length-at-50% maturation and length at first capture

Length at first sexual maturity L_{50} is of great importance when determining the optimum mesh size and SSB. The L50 of *M. surmuletus* in the Egyptian Mediterranean fishery was estimated for pooled data and found to be 15.1 cm TL (Fig. 9). The corresponding age was 1.39 yrs, which means that the exploited *M. surmuletus* must be protected till their second year of life in order to be able to spawn at least once. Hashem (1973) reported that L_{50} of males and females is 13 and 15 cm, respectively in the Egyptian Mediterranean, corresponding to the first and second year of life, respectively. He also mentioned that the spawning season extends from April until June, peaking in May. Off Majorca the L_{50} of males and females is reached at 15 and 16.8 cm, re-

spectively (RENONES *et al.* 1995) and off the Canary Islands at 16 cm (GONZALES PAJUELO *et al.* 1993).

The estimated length at first capture L_c in the present study was 11.6 cm TL. Both the estimated L_c and the observed lengths of fish captured indicated growth and recruitment overfishing. In the light of these results, a minimum size limit should be implemented for *M. surmuletus* in Egyptian Mediterranean waters.

Reference points and management

The Y/R and SSB analysis (Fig. 10) showed that the F_{MSY} was 0.53, so the current F should be reduced to this level (about 27%). This reduction will be accompanied by an increase of SSB by about 59%. Also, the surviving fraction of the SSB expressed as the rate between the current value (SSBc) and the same value for the stock in pristine (virgin) condition (SSBv) was 0.15, which is lower than the threshold value of 0.3. Therefore, the latter calls for im-
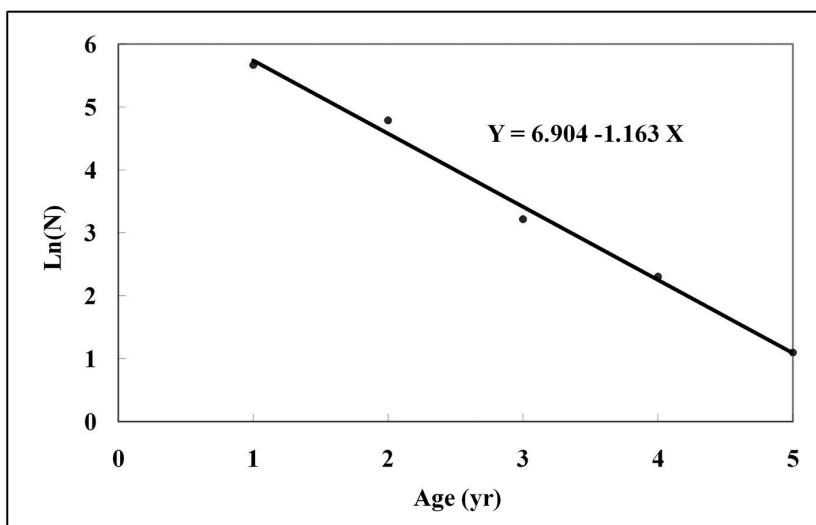

$$Y = 6.904 - 1.163\ X$$

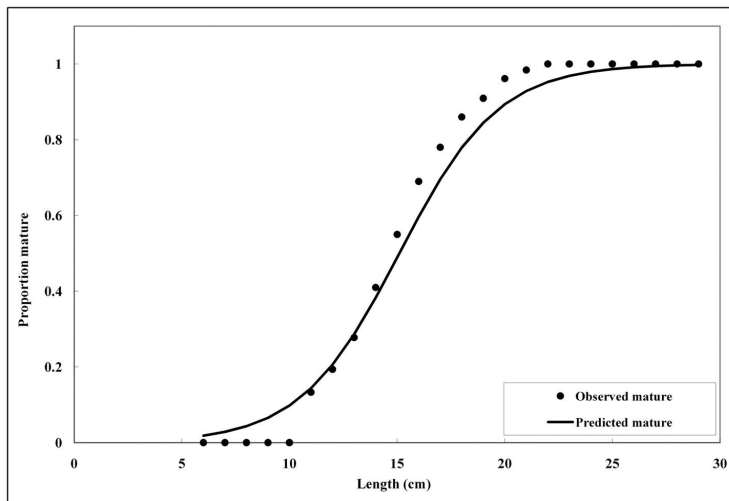*Fig. 8:* Catch curve for *Mullus surmuletus* from the Egyptian Mediterranean waters.

Fig. 9: Maturation curve for *Mullus surmuletus* from the Egyptian Mediterranean waters.
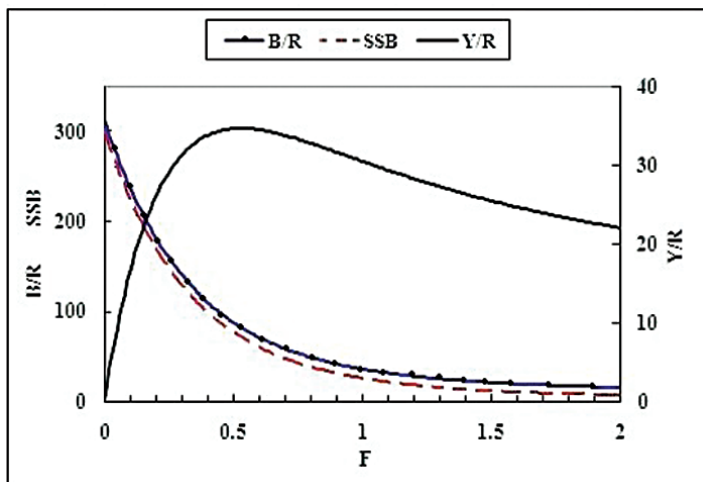

Fig. 10: SSB and Y/R analysis for *Mullus surmuletus* from the Egyptian Mediterranean waters.

mediate management action to prevent a possible stock collapse. Moreover, specific actions should be taken to conserve the spawning stock during March–July and the juveniles during August–November when they appear in shallow coastal waters.

It is worth mentioning that Egypt has implemented some regulatory measures: closed season for 45 days each year since 2006 (from 1st May to mid June), prohibition of any new licenses and prevention of any improvements to fishing vessels, but

these measures seem to be insufficient to prevent the decline of our marine resources.

In conclusion, the striped mullet seems to be highly exploited as the current F is higher than the defined values of reference points $F_{0.1}$ and $F_{30\%SSB}$ (0.32 and 0.44 respectively). The reducing of fishing pressure especially fishing of spawners and juveniles and defining specific critical areas such as nursery and spawning grounds is recommended. The necessity of constructing a data base with reliable fishery statistical records enabling stock assessment of higher precision is also emphasized. Finally, it is important to establish some form of cooperation among fishers, scientists, and government agencies for implementing sustainable management programmes. Education and creation of awareness among fishers on the negative impact of fishing and marketing spawners and juveniles may bring a subtle change in their attitude and incentives.

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