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Population structure and fisheries characteristics of the striped red mullet *Mullus surmuletus* from Matrouh fishing area, Mediterranean Sea, Egypt

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ABSTRACT

Population dynamic parameters of the striped red mullet, *Mullus surmuletus* caught by trammel nets operating in Matrouh fishing area, Mediterranean Sea, Egypt were studied. Samples (n = 1153) were collected between May 2020 and April 2021 and ranged from 9.1 to 30 cm in total length and from 15 to 325 g in weight. The length and weight relationship was $W = 0.011 L^{3.028}$ with $r^2 = 0.98$. Growth parameters of the von Bertalanffy model were $L\infty = 34.91$ cm, $K = 0.26$ year^{-1} and $t_0 = -0.77$ year. Estimates of total (Z), natural (M) and fishing (F) mortalities were 1.48, 0.55 and 0.93, respectively and the estimated exploitation ratio was 0.63 indicating that the resource is being overexploited in this area. The estimated length at first capture (Lc = 13.74 cm) was found to be less than the estimated length at first sexual maturity (Lm = 15.35 cm), indicating that this species didn't have the chance to spawn at least once in the fishery before being fished. It's our suggestion, that according to first-maturity length results, the minimum legal size MLS regulation should be revised to be at least above 16 cm.

INTRODUCTION

The Egyptian Mediterranean coast is about 1100 km extending from El-Salloum in the West to El-Arish in the East. The mean annual fish production from this vast area did not exceed 60 thousand tons (GAFRD; 2000 - 2020). The fishing grounds along the Egyptian Mediterranean coast are divided into four regions, 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 (GAFRD, 2020; Mehanna, 2021).

The red mullet (Family: Mullidae) are major target species of Mediterranean demersal fisheries. Red mullet are among the most valuable and highly priced fish species in Egypt, though widely distributed along the entire coast of Mediterranean Sea, 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 8% of the total trawl landings

in the Egyptian Mediterranean (**GAFRD annual reports 2000-2020**). The family Mullidae consists of 15 genera of which only *Mullus, Upeneus* and *Pseudopeneus* inhabit the Mediterranean Sea (**Hureau, 1986; Golani *et al.*, 2006**). The genus *Mullus* is represented by two species *Mullus barbatus* and *Mullus surmuletus* and one subspecies *Mullus barbatus ponticus*. *Mullus surmuletus* (Linneaus, 1758) is a benthic fish inhabiting mainly rocky substrates, seagrass beds and sandy soft bottoms showing the highest abundances at depths less than 100 m (**Hureau, 1986; Lombarte *et al.*, 2000; Bautista-Vega *et al.*, 2008**). It is distributed throughout the Mediterranean Sea, in the Atlantic, from Norway to the Canary Island, in the Black Sea and in the north-western coasts of Africa. It is one of the most important coastal resources in the Egyptian Mediterranean Sea, and is one of the main target species for fishers operating with trawls, trammel and gillnets. This species has been extensively studied in the Mediterranean Sea and some few studies were carried out in the Egyptian Mediterranean waters (**Hashem, 1973; Mehanna, 2009; Hassanien, 2017**).

Population dynamics models used for fish stock assessment and fisheries management are usually require the data on the age-length relationship and median age at first reproduction. This basic information was lacking in the Matrouh fishing area where there is no any study undertaken to evaluate the fishery status of different fish species in this area. Therefore, fishery managers may benefit greatly from an increased knowledge of this species biology and dynamics. The aim of the present study was to investigate for the first time, the population parameters of striped red mullet (*Mullus surmuletus*) in the western Egyptian Mediterranean (Matrouh fishing area) and verify how they may differ from the other fishing grounds in the Egyptian Mediterranean waters.

MATERIALS AND METHODS

Study area and sampling

Mersa Matrouh is 240 km west of Alexandria and 222 km east of El-Sallum the last point on the Egyptian – Libyan border (31° 20" N, 27° 13" E) (Fig. 1). It considers unexploited fishing ground due to its rocky bottom with annual average yield of 350 ton. A total of 1153 specimens of *M. surmuletus* (9.1 – 30 cm TL), were collected randomly from Matrouh landing site in the western Mediterranean Sea, Egypt during the period from May 2020 to April 2021. It was captured among the other species using the trammel nets which are the main fishing method due to the hard bottom in this area. The total length (TL) of each specimen was measured to the nearest millimeter and the body weight (W) was recorded to the nearest 0.1 g. Fish were sexed and assigned a maturity stage based on macroscopic examination of the gonads.

Fig. 1. Egyptian coast of Mediterranean Sea showing the main fishing grounds

Length-weight relationship LWR

The length–weight relationship of the striped red mullet was described by the power equation: $W = a\ TL^b$ **(Ricker, 1975)**, where **a** and **b** are constants whose values were estimated by the least square method. Confidence intervals CI of 95% were calculated for the slope (b) to see if it was statistically different from 3. The Student's t-test determines the growth as isometric (b = 3) or allometric (b > or <3).

Age determination

Sagittal otoliths were prepared and examined for age determination of red mullet. 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 fingers under water. Two readers were read the otoliths in order to get the most precise evaluation of the fish age. Annual rings on the whole otolith were counted in glycerin under a binuclear Stereomicroscope with reflected light. The total otolith radius and the radius of each annulus were measured. The relationship between the otolith radius (S) and the total length was fitted to estimate the necessary parameters for back calculations.

Growth parameters

The von Bertalanffy growth model (1938) was applied to describe the growth of the striped red mullet. Von Bertalanffy growth in length equation can be expressed as:

$$L_t = L_\infty [1 - e^{-k(t-to)}]$$

Where: L_t = mean length at age t, L_∞ = asymptotic length, K = growth coefficient that determines the rate at which L_∞ is attained, t_0 = age at which the length is theoretically equals zero. The growth parameters were determined using the formula of Chapman (1961) as: $L_{t+1} - L_t = L_\infty (1 - e^{-k}) - (1 - e^{-k}) L_t$

By plotting $(L_{t+1} - L_t)$ against (L_t), it gives a straight line has a slope (b) equals to $(1- e^{-k})$ and an intercept (a) equals to $(L_\infty (1-e^{-k}))$. Thus, the value of K and L_∞ can be estimated. The $\mathbf{t_0}$ was estimated from the following rearranged formula of the von Bertalanffy equation: $- \ln [1 - (L_t/L_\infty)] = - kt_0 + kt$

This is a straight line equation relating the age (t) and -ln (1-(L_t/L_∞)), having a slope (b) equals to (k) and an intercept (a) equals to (-k*t_0) then: t_0 = - a/b

Growth Performance Index (Ø)

To compare the growth rates in this study with those of other authors, the standard growth index (φ') was used as a measure of overall growth performance (**Pauly and Munro, 1984**). The index is defined as ϕ'= Log (K) + 2 Log (L∞).

Critical lengths

The length at recruitment (L_r) was determined as the smallest fish in the catch, The length at first capture (L_c) was estimated by the analysis of catch curve using the method of Pauly (1984), The data on the proportion mature in each size class were used to fit logistic curves and to estimate the length at first sexual maturity (L_m).

Mortality and Exploitation rates

Two different methods were applied to estimate the total mortality rate of red mullet; **Jones and Van Zalinge, 1981** (Analysis of the cumulative catch curve) and **Pauly, 1983** (Analysis of the length converted catch curve). While the natural mortality coefficient was estimated as the geometric mean of three different methods; **Taylor's** method (1960) as M = $3/t_{max}$ where t_{max} = maximum age attained, **Rikhter and Efanov (1976)** as M = $(1.52/t_{mass})$^0.72 – 0.16 where t_{mass} is the age at massive maturation. The **Djabali *et al.* (1994)** equation was also used for estimating the instantaneous natural mortality rate (M). **The Alagaraja (1984)** criterion was used in this study in order to choose the best estimate of natural mortality. The Alagaraja (1984) equation is expressed as: longevity (Te) = 4.605/M (year). Also, the validity of estimates of M can be judged by the M/K ratio as this ratio has been demonstrated to be within the range of 1.12–2.50 for most species around the world (**Beverton and Holt, 1957**).

The fishing mortality coefficient F was estimated as F = Z – M and the exploitation rate E was estimated as E = F / Z (**Gulland, 1971**).

RESULTS and DISCUSSION

1. Length frequency distribution

The total length of *M. surmuletus* in Matrouh fishing area ranged between 9.1 and 30 cm and the highest frequency was found at length groups from 14-14.9 to 18-18.9 cm with a peak at 15 cm (Fig. 2). The maximum observed length recorded in Matrouh fishing area was greater than that recorded in the previous studies. **Hashem (1973)** recorded a maximum length of 29 cm in Alexandria, **Mehanna (2009)** found a maximum observed length of 29.1 cm for samples collected from Alexandria to Port Said, while **Hassanien (2017)** recorded a maximum length of 26.8 cm from Alexandria.

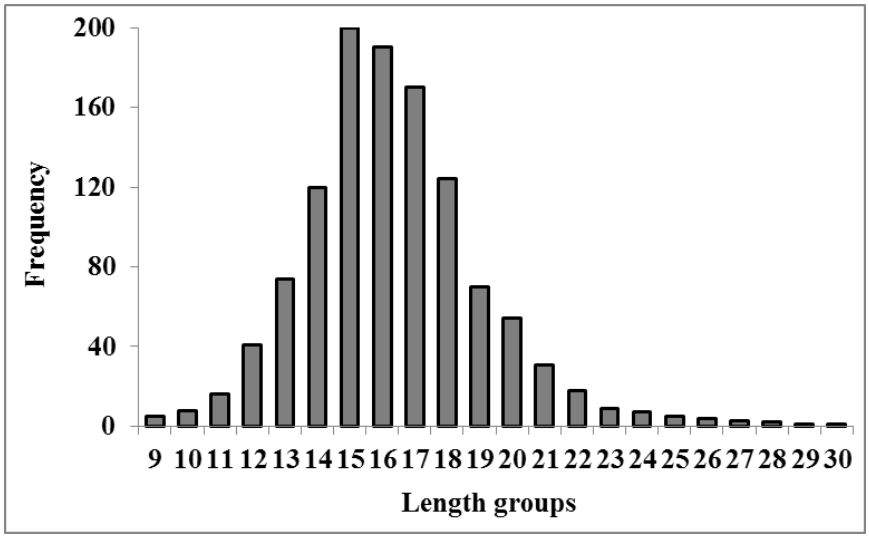

Fig. 2. Length frequency distribution of *M. surmuletus* from Matrouh, Mediterranean Sea

2. Length-Weight relltionship

Length-weight relationship is widely available for commercial fishes as they allow easy conversion of length in weight and vice versa (**Cherif *et al.* 2007; Mehanna and Farouk, 2021**). This relationship is useful for the comparison among geographic regions and for the application of stock assessment models (**Gonçalves, *et al.* 1996; Moutopoulos and Stergiou, 2002; Cherif, *et al.* 2007; Frose and Pauly, 2022**). The b value (3.028) of *M. surmuletus* showed isometric growth as this value not different significantly from 3 (CI= 2.963 – 3.093). The analysis of the LWR given by several authors show some differences in b values (Table 1). Such differences can be attributed to one or more of the following factors: salinity, temperature, sex, food, time of year and stage of maturity (**Pauly 1984; Cherif *et al.*, 2007; Mehanna and Farouk, 2021**).

Table 1. Length-weight relationship parameters of *M. surmuletus* reported by various studies

Locality	Size range	a	b	Author
Majorca Island	10.0 - 32.0	0.0091	3.12	Reňones *et al*. (1995)
Portugal	21.5 - 38.0	0.029	3.08	Gonçalves *et al.* (1996)
Aegean Sea	13.8 – 32.0	0.014	2.95	Stergiou and Moutopoulos (2001)
Gökçeada Island	10.9 – 29.9	0.0069	3.19	Karakulak *et al.* (2006)
Mediterranean, Egypt	5.0 – 29.1	0.0104	3.06	Mehanna (2009)
Saros Bay	9.6 – 26.8	0.0084	3.12	Arslan and İşmen (2013)
Alexandria, Egypt	7.3 – 26.8	0.02	3.03	Hassanien, 2017
Mediterranean, Egypt	6.0 – 29.1	0.0104	3.062	Mehanna and Farouk, 2021
Matrouh, Egypt	9.1 – 30.0	0.011	3.028	Present study

3. Age and growth

Otolith readings are reliable and valid method for age determination of *M. surmuletus* (**Morales-Nin, 1991; Mehanna, 2009; Hassanien, 2017**). Sagittal otoliths (Fig. 3) were used for age determination of *M. surmuletus* in Matrouh and in all, 91% of the otoliths were readable, and a low APE value of 2.8% was achieved. Fish of ages 0-6 years were present in the samples and age groups I, II and III are the most frequent ones (Fig. 4). The growth in length was very fast in the early years of life and became slower with the further increase in age (Fig. 5).

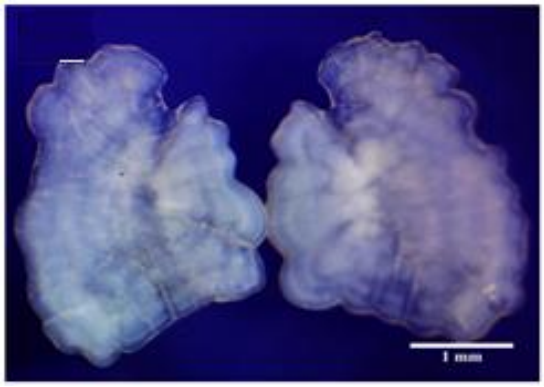

Fig. 3. Sagittal otolith of *M. surmuletus*

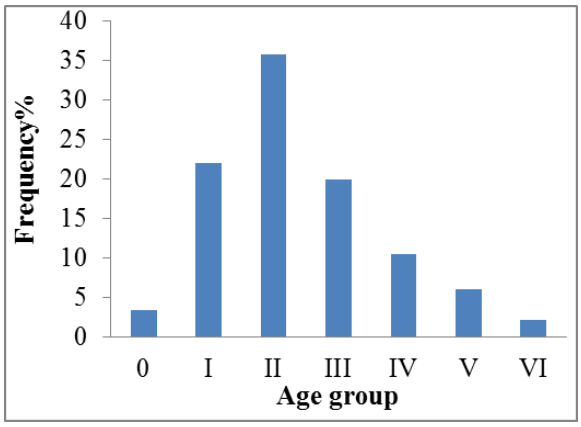

Fig. 4. Age composition of *M. surmuletus* from Matrouh, Mediterranean Sea

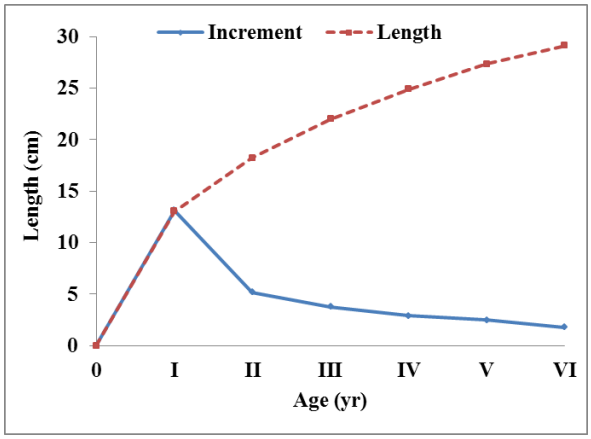

Fig. 5. Growth in length and growth increment of *M. surmuletus* from Matrouh, Mediterranean Sea

Andaloro (1981, 1982) and **Sanchez *et al.* (1983)** found that red mullet attain an age of 7 years. Morales-Nin (1986) used otoliths for age determination and reported that the age composition of *M. surmuletus* caught in the Katalan Sea ranged from 1 to 10 years. **Reiiones *et al.* (1995)** recorded fish up to 6 years old. **Moldur (1999)** and İlhan *et al.* (2009) reported a maximum of 5 and 6 years of age for *M. surmuletus* from the Marmara Sea and Aegean Sea، respectively. **Hashem (1973), Mehanna (2009), and Hassanien (2017)** recorded 10, 5 and 5 years old, respectively in the Egyptian Mediterranean off Alexandria. These differences between ages should be attributable to differences in the length of the largest fish sampled in the various studies.

4. Growth parameters

The results showed that females and males growth parameters are not significantly different (Max. likelihood test: Λ= 2.91, $\chi^2_{0.05,3}$ = 7.79, P>0.05). Accordingly, the parameters of the von Bertalanffy growth equation were determined for all individuals are shown in Table 2. The value of the growth performance index obtained for the whole population was 2.51. Our estimate of asymptotic length ($TL\infty$ = 34.9 cm) was higher than all those reported in Egyptian Mediterranean (Table 2).

Table 2. Growth parameters of *M. surmuletus* reported by various studies

Locality	**L∞**	**K**	**t_0**	**Ø**	**Author**
Spain	34.5	0.137	-3.82	2.21	Morales Nin (1991)
Majorca Island	32.5	0.11	-3.65	2.07	Reňones *et al*. (1995)
KritikoPelagos	35.4	0.225	-1.19	2.45	Machias *et al*. (1998)
Spain	40.1	0.164	-1.88	2.42	Quetglas *et al.* (2005)
Izmir Bay	27.9	0.103	-1.58	2.18	İlhan *et al*. (2009)
Mediterranean, Egypt	31.7	0.47	-0.30	2.67	Mehanna (2009)
Balearic Islands	40.1	0.16	-1.88	2.41	Colloca *et al*. (2013)
Alexandria, Egypt	31.57	0.31	-0.38	2.49	Hassanien (2017)
Matrouh, Egypt	34.91	0.26	-0.77	2.51	Present study

5. Mortality and exploitation rates

The mean rate of total mortality (Z) estimated from different methods was 1.48 $year^{-1}$, the mean natural mortality rate (M) was 0.55·$year^{-1}$, the fishing mortality (F) was 0.93·$year^{-1}$. Correspondingly, the exploitation rate was 0.63 which higher than the optimum one (0.4). The M/K ratio obtained in the present study (2.12) was well within the normal range of 1 – 2.5, as suggested by **Beverton and Holt (1957)**. Considering the calculated mortality parameter results, the exploitation rate is above the optimum value, the population have under the fishing pressure. The results obtained from this study will help fisheries scientists to enforce regulations on commercial fisheries concerning minimum landing size restrictions for *M. surmuletus*.

6. Critical lengths and ages

The length at first maturity Lm along with the length at first capture Lc are important tools that enable fishery managers to determine what should be the minimum size of the target species of a fishery. Length at recruitment (the smallest length in the catch) was 9.1 cm (0.41 year) while the length at first capture Lc estimated from the selection ogive was 13.74 cm (1.17 year). The results showed that *M. surmuletus* reached first maturity at around 15.35 cm TL (1.48 year) which is greater than Lc. Similarly, previous results in Mediterranean mentioned that this species attains sexual maturity between the first and the second years of life (**Hashem, 1973; Andaloro, 1982, Sanchez *et al*., 1983; MoralesNin, 1991; Mehanna, 2009; Hassanien, 2017**). It has been demonstrated that the capture of fish prior to attaining sexual maturity can result in a depletion of the spawner biomass and therefore recruitment. Given that the length at first capture reported herein is smaller than the length at sexual maturity, it may be necessary to change the current fishing strategy for red mullet in Matrouh fishing area in order to avoid recruitment overfishing. However, a study of the population dynamics of different fish species along with the evaluation of different fishing gears in this area is required to determine appropriate management recommendations via more sustainable local fishing management measures (e.g. using a larger mesh size to avoid harvesting immature individuals and/or reducing or eliminating fishing mortality in buffer or no-take areas, respectively).

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