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Age, Growth, Mortality and Reproductive Dynamics of the Red Mullet *Mullus barbatus* in the Delta Adjacent Waters, Mediterranean Sea, Egypt

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ABSTRACT

The age and growth, reproductive biology, and mortality of the red mullet *Mullus barbatus* were addressed in the Delta adjacent area, the Mediterranean Sea, Egypt. Length frequency of 12 months from January to December 2020 was used to study the population dynamics of this species which is exploited by trawling. The examined samples were 522 (46.9%) males, 510 (45.8%) females and 81 (7.3%) unsexed. Growth pattern was determined as isometric for males and positive allometric for females. Fitting the von Bertalanffy growth model gave the following growth parameters: $L\infty$=^ 22.66 cm TL, K= 0.39 year^{-1}, t_0 = -1.02 year for males, $L\infty$=^ 23.75 cm TL, K= 0.39 year^{-1}, t_0= -0.97 year for females and $L\infty$=^ 24.22 cm TL, K = 0.34 year^{-1}, t_0 = -0.77 year for combined sexes. Based on the estimated total, natural and fishing mortality coefficients, the exploitation rate for males, females and pooled data were around 0.65. The estimated fishing mortality rate (1.35, 1.14 and 1.18 year^{-1} for male, female and combined sexes, respectively) and exploitation rate (E = 0.65) obtained in this study indicate a high fishing pressure on the *M. barbatus* stock in the Egyptian Mediterranean waters. Monthly variation in both mean gonado-somatic index and maturity stages showed that this species breeds once a year from March to July for males and from February to June for females. From the analysis of probability of capture, the length at first capture was estimated at 11.76 and 11.54cm for males and females, respectively, which was smaller than the length at first sexual maturity (12.29cm for males and 12.91cm for females). Thus, the red mullet species in the Delta adjacent area, the Mediterranean Sea is overexploited.

INTRODUCTION

The red mullet, a member of family Mullidae, is a valued food species of high economic importance in Egypt. There are five mullet species in the Egyptian Mediterranean waters, two of them are native, and three are exotic species. These species are *Mullus surmuletus*, *M. barbatus* (native), *Upeneus pori*, *U. moluccensis* and *Parupeneus forskalli* (Red Sea origin) **(Mehanna *et al.*, 2016; Hassanien, 2017; Mehanna, 2020, 2021; Hassanien & Mehanna, 2022)**. The red mullets are heavily exploited and caught by different types of fishing gears but mainly by trawlers. The

annual production of the red mullet from the Egyptian Mediterranean experienced a severe decline from up to 4000 ton (2011) to only 550 ton in 2020 **(GAFRD annual statistical book, 2020)**.

The red mullet, *Mullus barbatus* (Linnaeus, 1758) is a benthic species living mainly on sandy and muddy bottoms of the continental shelf, with a widespread distribution along the Mediterranean coasts **(Hureau, 1986; Özbilgin *et al.*, 2004)**. It is a major target species of the Mediterranean demersal fisheries, exploited by more than one gear type **(Demestre *et al.*, 1997)**. They are mainly exploited at depths of 3- 90m on sandy or muddy bottoms but also at times on rocky ground. This species is carnivore and feeds on small invertebrates, mainly on Crustacea, Polychaeta, Mollusca, Echinodermata and small fishes that live on or within bottom substrates. In Egypt, *M. barbatus* has great commercial value and is one of the main target species of small and large scale fishery. Knowledge of parameters on growth, mortality, gear selectivity, biomass, spawning season contributes to properly estimating resources and managing marine fishery on principles of sustainable development. Some studies have been made on the aspects of biology and dynamics of the species **(Gharbi & Ktari, 1981; Çelik & Torcu, 2000; Kinacigil *et al.*, 2001; Arslan & İşmen, 2014; Genç, 2014; Talet *et al.*, 2016; Kurtul & Özaydın, 2017)**; however, in the Egyptian waters, very limited studies were achieved **(Hashem, 1973; Mehanna, 2009; Hassanien, 2017)**.

The biology and ecology of *M. barbatus* in the Delta adjacent area is poorly known. The main goal of this study was to generate sufficient information to improve future stock management and sustainable fishing of this species. The study described the age, growth, mortality and reproductive biology of *M. barbatus* in the Egyptian Mediterranean waters, the Delta region.

MATERIALS AND METHODS

Samples collection and sampling area

A total of 1113 *M. barbatus* fish idividuals (522 male, 510 female and 81 unsexed) were monthly collected between January and December 2020 from the trawl catch in Izbet El-Borg landing site, the Mediterranean Sea, Egypt (Fig. 1). Izbet El-Borg (31°30′11″N 31°50′28″E) is the most productive area in the Egyptian Mediterranean, producing a bulk of red mullet catch. It is a coastal city with a large fishing industry in Damietta Governorate, Egypt and the base of Egypt's largest fishing boat fleet, where more than 53% of the trawl fleet belong to this city. Furthermore, Izbet El-Borg is the landing site for all fishing operations taken place in the Delta adjacent area.

Samples were collected twice per month, and their length frequencies were grouped with 1cm length intervals. Total length (TL) (to the nearest 0.1cm) and the total weight (to the nearest 0.1g) of each specimen were measured before dissecting to weigh fish gonads (g). Based on the macroscopic investigation and relative dimensions of the gonads, the maturity stages of *M. barbatus* were detected.

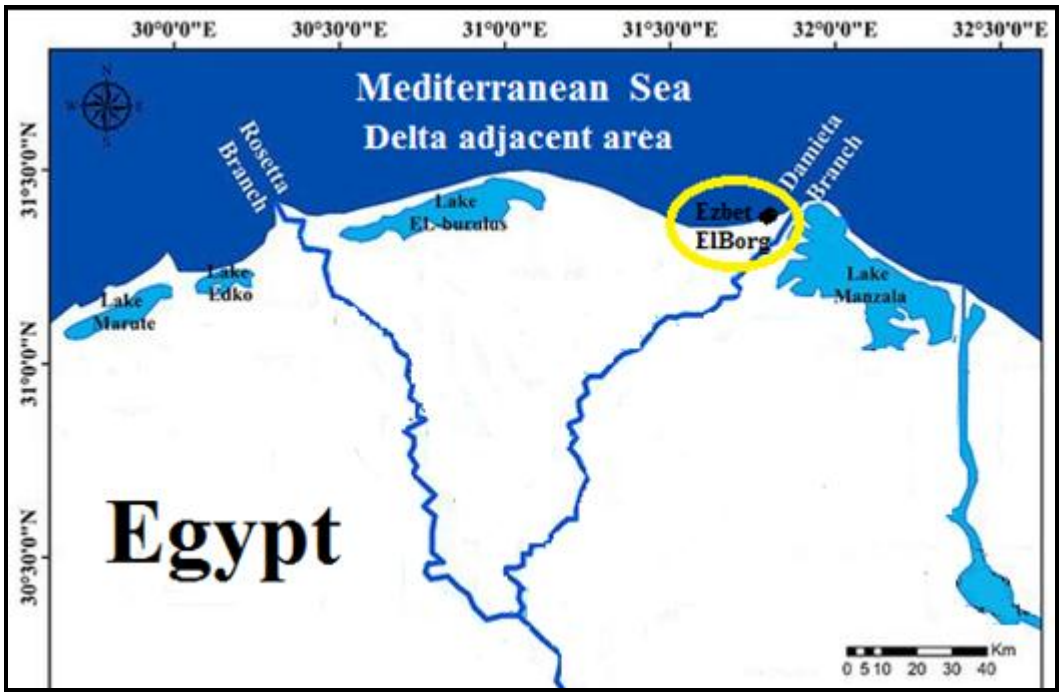

Fig. 1. The Egyptian Mediterranean showing the study area

Sex ratio

The overall and monthly sex ratio were determined, and the deviations from 1:1 hypothesis were statistically tested using chi-square analyses **(Sokal & Rohlf, 1981)**.

Length-weight relationship LWR

The length-weight relationship (LWR) was analyzed using the power equation: $W = aL^b$ **(Ricker, 1973)**, where W is the total weight (g), and L = total length (cm). The parameters a and b were estimated by the least squares method obtained by logarithmic transformation to correct the nonlinearity of the original curve and the heterogeneity of variances: Log W = b Log L + Log a. The null hypothesis for the isometric growth (H0: b = 3) was analyzed by t-test, using the following statistical formula: ts = (b -3)/Sb, where Sb is the standard deviation of the parameter b, for $\alpha = 0.05$ **(Morey *et al.*, 2003)**. Additionally, 95% confidence limits of b were estimated to show if the b-value was significantly different from 3. ANCOVA was used to determine if there was significant difference in LWR between sexes **(Zar, 1999)**.

Age and growth

The age was determined using the sagittal otoliths extracted through the dissection of the skull. Collected otoliths were cleaned and preserved in labeled Eppendorf tubes. Annual rings on the whole otolith were counted in glycerin under Olympus SZX16 Stereomicroscope. The total otolith radius and the radius of each annulus were measured to the nearest 0.001mm. The total radius of each otolith was plotted against the total fish length to determine the body length-otolith radius relationship. The back calculated lengths were obtained using the Fraser−Lee equation **(Lee, 1920)** as $Li = [Si (Lc – a)/Sc] + a$, where Si is the annulus radius corresponding to age i; Lc is TL of fish at catch; Sc is

the total otolith radius, and a is the intercept of linear regression between total length and total otolith radius. To validate the age determination, the otoliths were investigated by two readers to estimate the reading precision. Coefficient of variation (CV), absolute percent error (APE) and percentage agreement (PA) were used to estimate the reading precision **(Beamish & Fournier, 1981; Chang, 1982)**.

Growth parameters were estimated using the von Bertalanffy growth equation **(1938)** as $Lt = L\infty (1 - e^{-K(t - t_0)})$, where $L\infty$ is the asymptotic length; K is the growth coefficient; Lt is the length at time t, and t_0 is the age of fish at zero length. Likelihood ratio test was used to compare the von Bertalanffy growth parameters between sexes **(Kimura, 1980)**. The growth performance index **(Pauly & Munro, 1984)** was estimated to compare growth rate using the formula $Ø' = \log (k) + 2 \log (L\infty)$.

Spawning season

The spawning period of *M. barbatus* was determined via analyzing the monthly evolution of the gonado-somatic index (GSI), where GSI = [Gonad weight/ Body weight *100] and the monthly percentage of maturity stages. The monthly means values of GSI were statistically tested by the ANOVA.

Length at maturity and length at first capture

Length at maturity (Lm), the size at which 50% of the individuals were mature, was estimated by means of a logistic function fitted to the proportion of sexually mature individuals by size class, using a nonlinear regression **(King, 1995)** as follows:

$P = 1/(1+\exp[-b(L-Lm)])$

Where, P is the proportion of mature fish in each length class; b is a parameter determining the slope of the maturity curve, and Lm is the total length at which 50% of the fish individuals are mature.

Length at first capture (Lc) was calculated by selection ogive method determined by applying the probability of capture to the length frequency distribution **(Pauly, 1984)**.

Mortality and exploitation rates

To estimate the total mortality (Z), the mean of two different methods were considered. The first was the analysis of length converted catch curve **(Pauly, 1983)** as $\ln(N\Delta/t) = a + bt$, where N is the frequency of each length class; Δt is the time needed to grow from t1 to t2 of a given length class; t is the relative age corresponding to the mid-point of the length class, and a and b are the regression constants. The second method was that of **Beverton and Holt (1956)** using the following equation:

$$Z = \frac{K\,(L\infty - \bar{L})}{\bar{L} - \acute{L}}$$

Where, $L\infty$ and K are the von Bertalanffy growth parameters; $\bar{L}$ is mean length of fish in the catch (cm), and L' is the smallest length of fish in the catch (cm). Natural mortality (M) was determined using the formula of **Djabali *et al.* (1994)** as follows:

$\text{LogM} = -0.0278 - 0.1172 \text{ Log } L\infty + 0.5092 \text{ Log K}$

in addition to the formula of **Rikhter and Efanov (1976)**. Fishing mortality (F) was calculated to determine the difference between the total and natural mortality: F = Z – M. Exploitation rate (E) was estimated as E = F/Z **(Gulland, 1971)**.

Statistical analysis

The data obtained from the length, weight and annual rings of the *M. barbatus* were analyzed using SPSS v. 21 and Microsoft Excel program.

RESULTS

A total of 1113 specimens of *M. barbatus* were collected of which 522 were males (46.9%), 510 were females (45.8%) and 81 were unsexed (7.3%). The sex ratio was in favor of males 1:0.98 male:female. The χ^2 test showed that there is no significant difference from the ideal one 1:1 ($P > 0.05$). Males were dominant in lengths from 9-9.9 to 12-12.9cm and 15-15.9cm, while females were the most abundant in larger lengths from 16-16.9 to 20-20.9cm and in the smallest length group (8- 8.9cm) (Fig. 2). The monthly sex ratios fluctuated among months with the domination of males during March through June and during November, while October showed 1:1 ratio (Fig. 3).

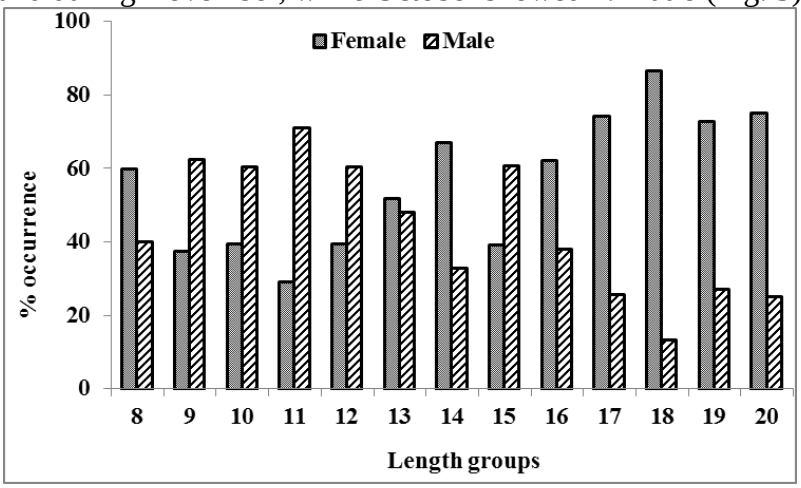

Fig. 2. Sex ratio by length groups of *Mullus barbatus* from Delta region, the Mediterranean Sea

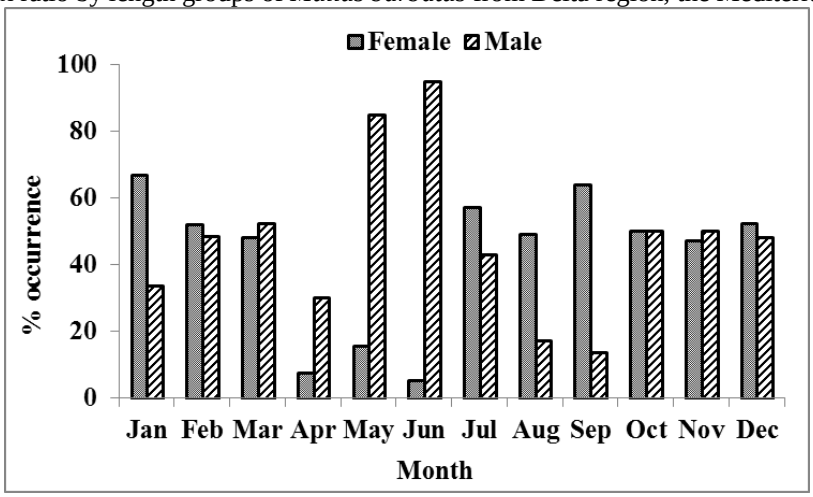

Fig. 3. Monthly sex ratio of *Mullus barbatus* from Delta region, the Mediterranean Sea

The TL of males ranged between 8.8 and 20.0cm, while their weight fluctuated from 7.3 to 105g. On the other hand, the TL of females ranged between 8.7 and 20.7cm and their weight from 7.2 to 134g. The length frequency distribution of male, female and the whole population of *M. barbatus* (Fig. 4) show that the highest number of individuals was observed in 11- 11.9 and 12– 12.9cm for males and in 12- 12.9 and 13- 13.9cm for females. The least number was recorded in the terminal length groups for both sexes (Fig. 4). The number, minimum, maximum, mean and SE values of the total length and weight for males, females and whole sample are presented in Table (1).

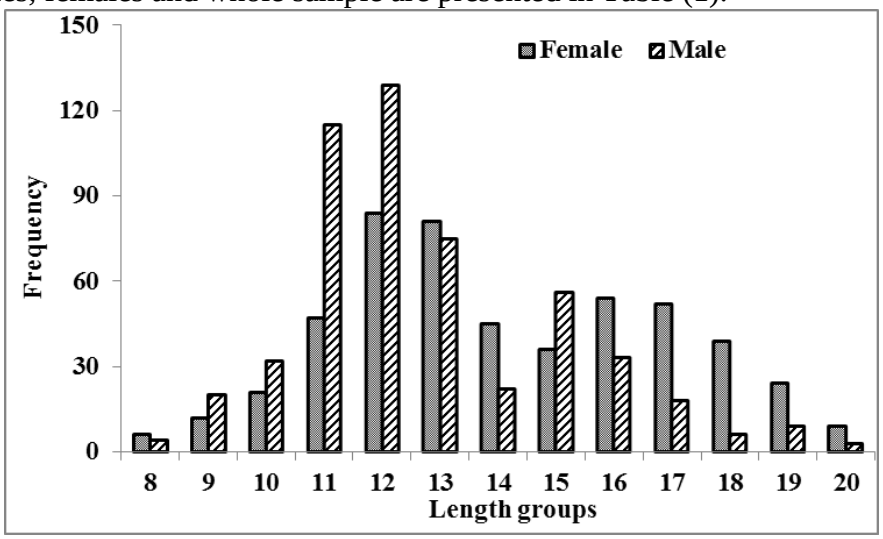

Fig. 4. Length frequency of *Mullus barbatus* from the Delta region, the Mediterranean Sea

Table 1. Length and weight range, mean and standard error of *Mullus barbatus* from Delta region, the Mediterranean Sea

Sex	No	Total length (cm)		Total weight (g)	
		Range	Mean ± SE	Range	Mean ± SE
Male	522	8.8 – 20.0	12.95 ± 0.14	7.3 - 105	22.57 ± 1.02
Female	510	8.7 – 20.7	14.01 ± 0.18	7.2 - 134	31.05 ± 1.21
All individuals	1113	7.0 – 20.7	13.21 ± 0.13	3.5 - 134	28.25 ± 0.98

The whole otoliths were used for age determination of *M. barbatus* from the Delta region, the Mediterranean Sea, and the use of sagittal for age estimating was proven, with distinct opaque and translucent bands surrounding a white opaque nucleus (Fig. 5). The ages of *M. barbatus* ranged from 0 to 4 years for males and females. The age group one was dominated in the catch (49% in males and 36% in females), and the age frequency distribution of female and male *M. barbatus* in different ages is presented in Fig. (6). The mean body length for both male and female fish showed an increasing trend with age, while the proportion of individuals decreased with the increase in fish age (Fig. 7).

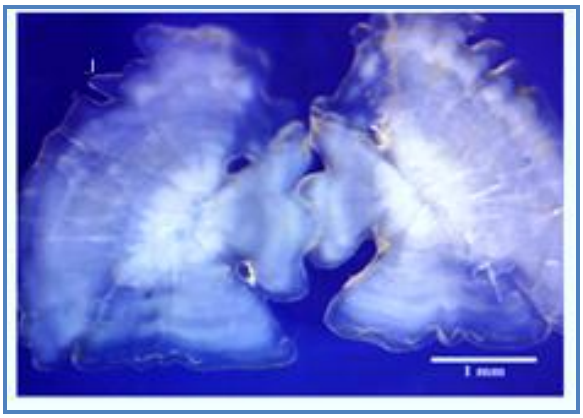

Fig. 5. Otolith of *Mullus barbatus* from the Egyptian Mediterranean waters

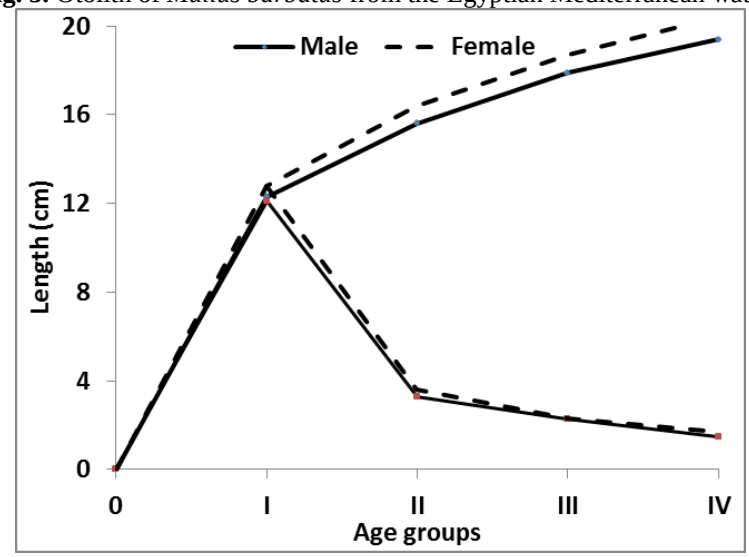

Fig. 6. Growth in length of *Mullus barbatus* from the Egyptian Mediterranean waters

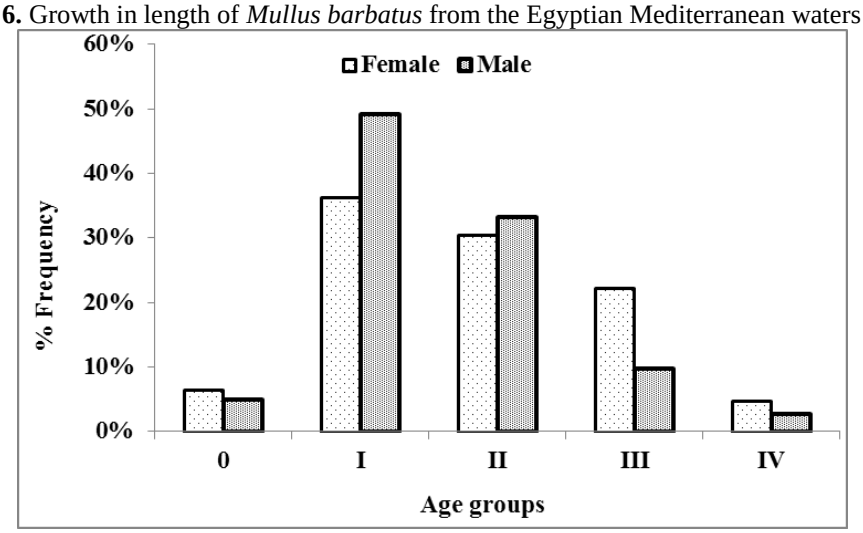

Fig. 7. Age composition of *Mullus barbatus* from the Egyptian Mediterranean waters

By computing the LWR (Fig. 8), it was noticed that, males exhibited an isometric growth pattern (b = 3.0856, CI= 2.9862 – 3.1850), while females had a positive allometric growth (b = 3.2249, CI = 3.1544 – 3.2955). Generally, all samples showed positive allometric growth (b = 3.1421, CI = 3.0899 – 3.1950).

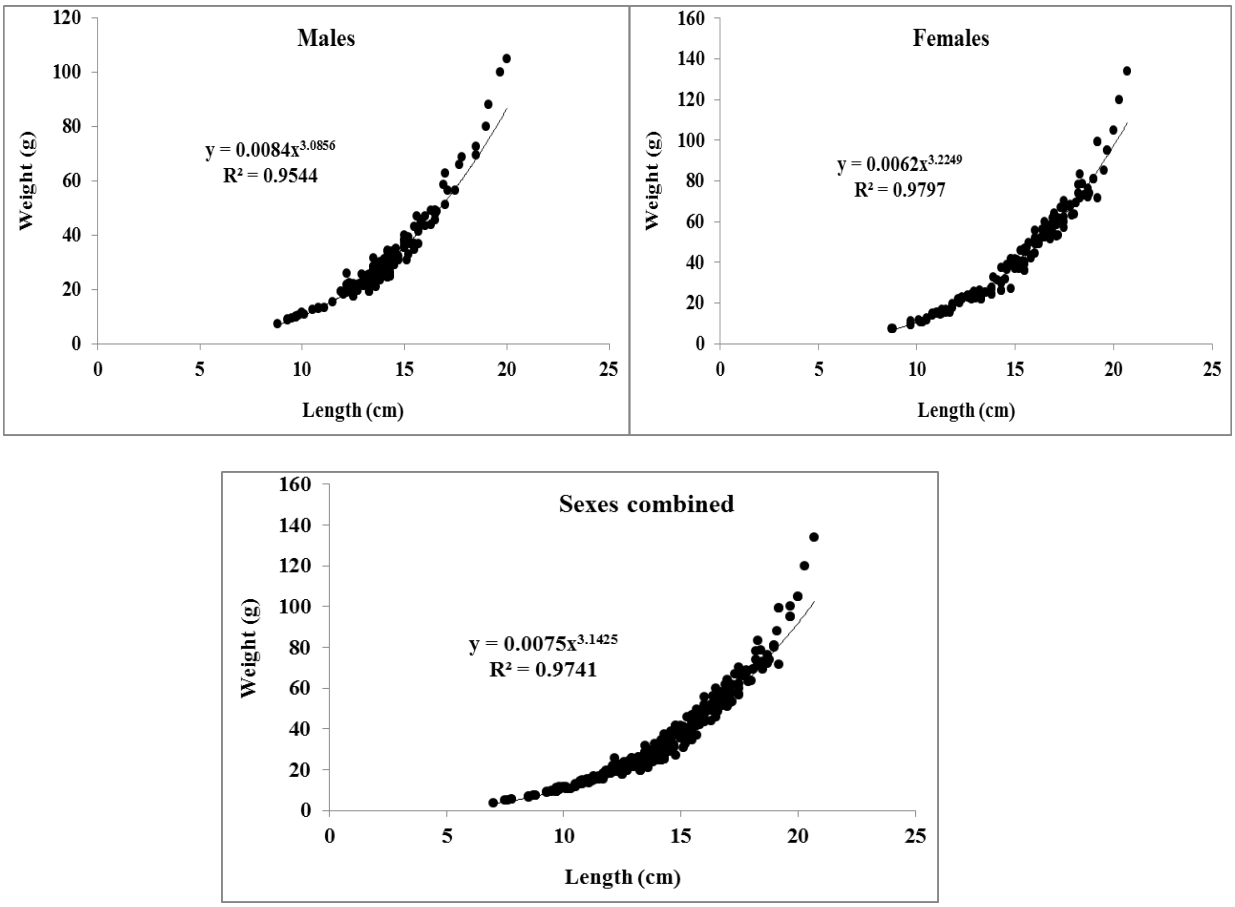

Fig. 8. Length-weight relationship of *Mullus barbatus* from the Egyptian Mediterranean waters

The back-calculated lengths at age were used to calculate VBGF growth parameters as $L\infty =\hat{}$ 22.66cm TL; K = 0.39 year^{-1}; t_0 = -1.02 year for males; $L\infty =\hat{}$ 23.75cm TL; K = 0.39 year^{-1}; t_0 = -0.97 year for females, while $L\infty =\hat{}$ 24.22cm TL; K = 0.34 year^{-1}, and t_0 = -0.77 year for sexes combined. No significant differences in growth parameters were found between sexes (P> 0.05)

Notably, the mean GSI increased from January and peaked in April and May and steadily declined until December (Fig. 9). The monthly percentage of maturity stages in females shows that the percentage of mature ovaries progressively increases from January to June, with a peak in April and May. The frequency of mature ovaries followed a similar trend observed with GSI and decreased from July till December. The mature/spawner females showed a peak lasting for two months, April and May, followed by the spent females starting to appear in the samples.

The males' percentage of maturity stages shows a reproductive period from March until July. The spent males appeared in July with an increasing trend to October. The ripe males appeared in the catch since March until July, showing a peak in June. spent males occur from July to December, with a peak in August and September. These results indicate that the spawning period of female *M. barbatus* ranges from February to June and for male, it extends from March to July.

The size and age at 50% maturity estimated by logistic regression were 12.29 and 12.91 cm for males and females, respectively. The comparison of the maturity ogives of males and females by the Chen test shows no significant differences ($p > 0.05$). The smallest mature male observed was 9 cm TL, while the smallest mature female was 9.5 cm TL; moreover, the first length class with 100% of adult specimens was 15-15.9 cm for males and females.

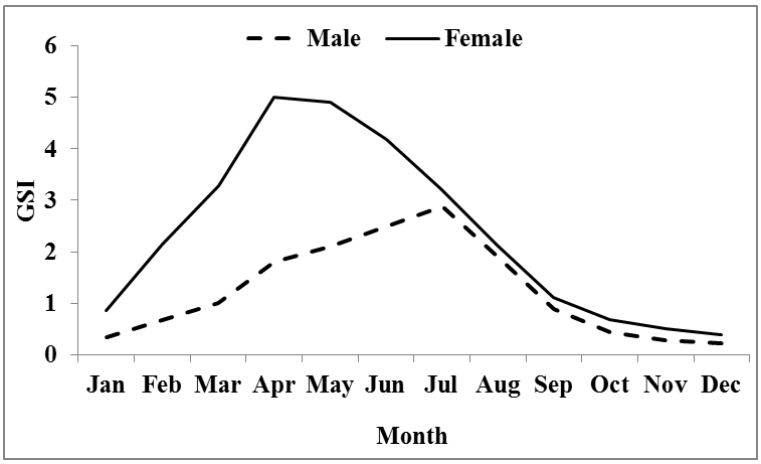

Fig. 9. Monthly mean GSI of *Mullus barbatus* from Egyptian Mediterranean waters

The length at first capture was estimated at 11.76 and 11.54 cm for males and females, respectively (Fig. 10). Total, natural and fishing mortality coefficients were estimated at 2.07, 0.72 and 1.35 year^{-1} for males, 1.75, 0.61 and 1.14 year^{-1} for females, 1.82, 0.64, and 1.18 year^{-1} for sexes combined, respectively. Accordingly, the exploitation rate was around 0.65 for red mullet in the Delta adjacent area, Mediterranean Sea.

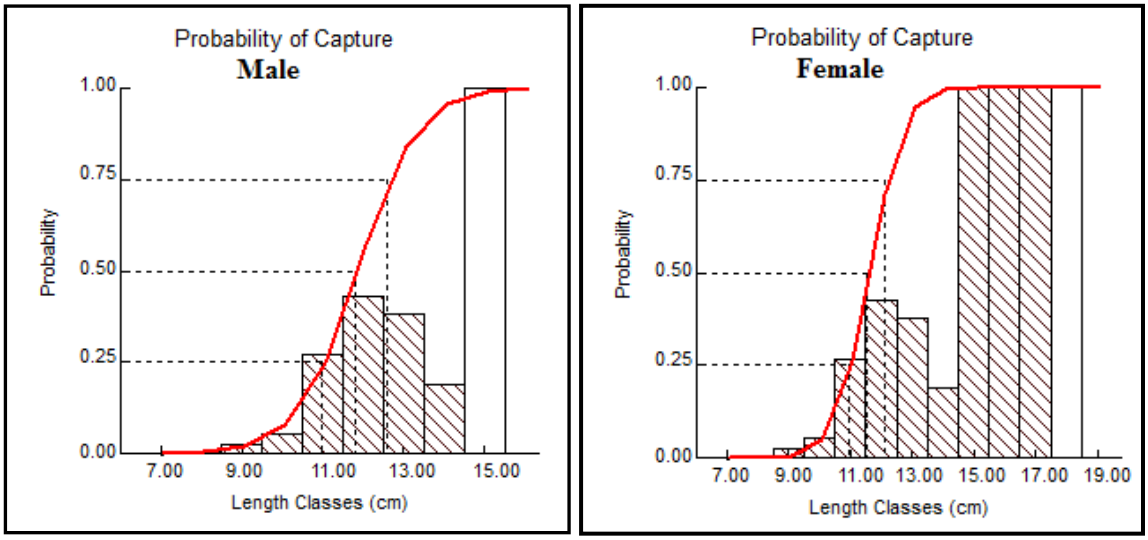

Fig. 10. Lc estimation for *Mullus barbatus* from Egyptian Mediterranean waters

DISCUSSION

Accurate estimates of life history parameters such as age and growth (length-at-age), length at first sexual maturity, mortality, and population variance in length-at-age are basic requirements for reliable stock assessment and effective fisheries management (Aires-da-Silva *et al.,* 2015; Zhu *et al.,* 2016). There are few studies regarding the biology and population dynamics of the red mullet species in the Egyptian Mediterranean waters especially in the Delta adjacent area. This study was undertaken to provide the basic parameters required for improvement the management strategy of *M. barabatus* like age, growth, maturation, and mortality .

Sex ratio based on trawl samplings showed the dominance of males and the overall sex ratio did not differ significantly from the theoretical 1:1. The dominance of red mullet males was reported in some studies (Genç, 2000; Süer, 2008), but females were generally dominant in the most studies. This is acceptable because the sex ratio differs from area to area and from time to time for the same area as it influenced by several factors such as reproduction, food availability and environmental conditions (Nikolsky, 1963; Vandeputte *et al.,* 2012).

The maximum fish length of the presently reported species was 20 and 20.7 cm TL for males and females respectively. The Student's t-test showed significant differences between males and females in mean length and weight ($p < 0.05$), with females having slightly bigger body sizes than males. Mehanna (2009) reported a maximum TL of 24.4 cm for *M. barbatus* collected from the trawl fleet operating in the eastern Mediterranean from Alexandria to Port Said, while Hassanien (2017) recorded smaller maximum size from Alexandria fishing area (19.8 cm). The maximum recorded length of this species ranged between 14 (Black Sea) and 38.2 cm TL (Agean Sea) but most of the previous studies reported maximum size range 19 – 24 cm TL (FishBase, 2022).

The growth pattern of red mullet was described using the LWR and it was isometric in males and positive allometric in females. The b-value of males was not significantly different from 3 (t-test, $P > 0.05$), while for females and all individuals the b-values were significantly different (t-test, $P < 0.05$). The b-values of the LWR were significantly different between the sexes (ANCOVA, $P < 0.05$). The growth type per sex of this species in the Egyptian waters did not studied before but Mehanna (2009) estimated the b-value of red mullet as 3.11 for pooled data and Hassanien gave different b-value as 2.88 from Alexandria. The previous studies worldwide reported b-values for red mullet ranged between 2.8 and 3.4 (FishBase, 2022). The parameter "b" in fish is affected by several factors such as habitat suitability, sex, season, gonad maturation, diet, stomach fullness, health, annual and seasonal differences in environmental conditions, food availability, sample size and the length range within different areas (Le Cren, 1951; Biswas, 1993; Morey *et al.,* 2003; Henderson, 2005; Nieto-Navarro *et al.,* 2010; Mehanna and Farouk, 2021).

The length-at-age data are fundamental in the application of analytical stock-assessment models (Ranfil *et al.,* 2002). In addition, the uncertainties in the age data for red mullet are a challenge to the proper management of this important resource (Lembo *et al.,* 2009). Age validation is necessary for all growth studies in order to improve accuracy and precision as well as to provide unbiased data for stock-assessment models. Thus, two readers were count the annuli on the whole otolith and the results indicated

good agreement between them (agreement = 93.21%, CV = 3.76% and APE = 2.79%). The maximum life span of *M. barbatus* was four years and age group one was the most frequent group in the catch for both males and females. The comparison of the mean length-at-age of males and females showed that there was no significant variation between mean length of different age classes in the two sexes ($p > 0.05$).

The estimates of the growth parameters are in the range of values calculated in the previous studies (Table 2). Since Hashem (1973), this is the first study considering the sex of red mullet in the estimation of different life history parameters. The differences in growth parameters among different areas are affected by physiological, environmental, geographical, and nutritional (Jobling, 1997). Also, the methods used to estimate the growth parameters and the sampling procedures can also cause differences within the species (Biro and Post, 2008; Pardo *et al.*, 2013; Pilling *et al.*, 2002; Taylor *et al.*, 2005).

The estimated growth performance (Ø) index for male and female of this species is comparable with the Ø values obtained previously (Table 2). The estimated values in the present study are slightly higher than the value estimated by Hassanien (2017) in Alexandria and lower than that estimated by Mehanna (2009) in the Egyptian Mediterranean waters.

Table 2. VBGF parameters and growth performance index (ø) of *Mullus barbatus*

Locality	Sex	L∞	K	t_0	Ø	
Aegean Sea	♂	22.7	0.25	-1.85	2.11	Vassilopoulou, 1992
	♀	25.5	0.21	-2.13	2.14	
	Both	27.0	0.18	-1.51	2.13	
Aegean Sea (Saros Bay)	♂	28.3	0.14	-2.39		Arslan and Ismen, 2014
	♀	26.6	0.18	-1.75		
	Both	28.7	0.16	-1.92		
Ionian Sea	♂	22.4	0.28	-1.85	2.15	Tursi *et al.*, 1994
	♀	24.5	0.27	-1.98	2.21	
	Both	25.2	0.26	-1.71	2.22	
Tyrrhenian Sea, Sicily	♀	22.1	0.38	-0.94	2.27	Sieli *et al.*, 2011
Mediterranean Sea, Sicily	♂	20.2	0.57	-0.80	2.37	Gancitano et al., 2012
	♀	23.6	0.45	-0.80	2.40	
Mediterranean Sea, Algeria	♂	20.9	0.66	-0.14	2.46	Talet *et al.*, 2016
	♀	25.1	0.60	-0.15	2.58	
	Both	25.1	0.49	-0.19	2.49	
Mediterranean Sea, Egypt	♂	33.1	0.09	-2.66		Hashem, 1973
Abo Qir	♀	36.9	0.10	-2.71		
Egyptian Mediterranean	Both	27.1	0.66	-0.13	2.69	Mehanna, 2009
Alexandria	Both	22.4	0.39	-0.69	2.29	Hassanien, 2017
Delta adjacent area	♂	22.66	0.386	-1.02	2.30	Present study
	♀	23.75	0.394	-0.97	2.35	
	Both	24.22	0.345	-0.77	2.31	

Natural mortality (M) may vary within the species in different areas as it is dependent on density of predators and competitors whose abundance is influenced by fishing activities. Generally M/K is used as an index for checking the validity of M and K values estimated by different methods and it is known to range from 1 to 2.5 (Beverton and Holt, 1959). The M/K ratios obtained in the present study for males and females (1.85 and 1.56) were lie within this range. Only two earlier studies are available for red mullet mortality estimates in the Egyptian Mediterranean and estimated it for sexes combined only (Mehanna, 2009; Hassanien, 2017).

Also, the value of Z/K in this study was found to be 5.31 for males and 4.49 for females which indicated that the stock of M. barbatus is presently under a high level of exploitation (Z/K >2) in the Egyptian Mediterranean waters. The calculated exploitation rate (≈0.65) is above the optimum value indicating a high fishing pressure on the red mullet population. The results obtained from this study confirmed the urgent need to enforce the regulations on commercial fisheries concerning minimum landing size restrictions for *M. barbatus*.

The spawning period is a principal issue in fisheries biology, ecology, and management because of its importance for the recruitment (Beaugrand *et al.*, 2003), survival (Garvey *et al.*, 2002), stock biomass, and thus the fishery yield (Kjesbu and Witthames, 2007).

The monthly gonado-somatic index (GSI) and maturity stages were used to estimate the spawning period of red mullet. The monthly variations in GSI values showed an increase from January and peaked in May and June for males and in April and May for females. According to the gonadic maturation stages, the highest proportion of ripe gonads (stage IV) in females was observed in May and June for males and in April and May for females. These results indicated that the spawning period of female *M. barbatus* ranged from February to June and of male from March to July.

The length at first capture Lc was estimated at 11.76 and 11.54 cm TL for males and females, respectively while the estimated length at first maturity Lm was 12.29 and 12.91 cm for males and females, respectively. It was obvious that Lc is smaller than the Lm, which means that the exploited *M. barbatus* must be protected in order to share at least once in the spawning activity. Therefore, mesh sizes used should be increased to catch fish of about 14 cm length. Also, more than 44% of red mullet landed by trawlers had a TL < 13 cm (less than Lm), therefore it is important to adopt a minimum landing size corresponding, at least, to the length at first maturity.

In the previous studies that reported the reproduction of red mullet (Hureau, 1986; Stergiou *et al.*, 1997; Akyol *et al.*, 2000; Metin, 2005), they indicated that the length at first maturity is between 10.3 cm to 14.4 cm and reproduction period is from April to August. The differences in Lm estimates could be explained by the phenotypic response to some environmental variations or by the evolutionary consequence of some selective pressure such as fishery efforts (Barot *et al.*, 2004), as well as by the different estimation methods applied (ICES, 2008).

CONCLUSION

One of the main contributions of this work was to provide the basic data required for more effective fishery management of the red mullet in the Delta adjacent area, Mediterranean Sea. These results have important implications for the conservation of the

red mullet in the Egyptian Mediterranean Sea, as the values of F, E, Lc and Lm of *M. barbatus* indicating an overexploitation situation. The application of some regulatory measures such as fishery closures in some periods of the year and minimum legal size is required. Moreover, the monthly data of the GSI and maturity stage define a single reproductive season during the year extended from February to July with a bulk in May and June for males and in April and May for females. Thus, a fishing mortality reduction is necessary to avoid future loss in stock productivity and landings. Also, fishing effort should be controlled and decreased especially in the spawning time to maintain its spawning biomass.

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