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Some biological parameters of the red mullet, *Mullus barbatus* L., 1758, from the Gulf of Tunis

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The red mullet, Mullus barbatus L. *1758 is one of the main target species of the trawl fishing industry along the continental shelf off the Tunisian Gulf. The reproductive biology of this species has been studied based on statistical sampling conducted between February 2003 and January 2004. Length frequency distribution according to sex revealed that the females were highly represantative in the majority of size classes. Monthly variations in the gonadosomatic index (GSI) showed that males spawn from April to July, whereas the reproductive activity of the females occurs in the late spring and summer (May and July). The estimated lengths at maturity (Lm50) were 13.87 cm for males and 13.94 cm for females. According to the length-weight relationship, positive allometry was confirmed for males, females and pooled sexes.*

Key words: *Mullus barbatus*, Gulf of Tunis, reproductive cycle, sex-ratio, spawning season, size at first maturity

INTRODUCTION

The absence of currently gathered biological data on reproduction and growth of the red mullet (*Mullus barbatus*) in Tunisia has constituted an obstacle. This update study on stock assessment was conducted in order to adopt an adaptive management focus designed to help prevent the exploitation of this resource. In fact, the stock assessment models, paticularly the analytical models, required these parameters as input data. Therefore, the present study is in this context and aims to update, for the first time, the estimation of the reproduction parameters of this specie in order to allow for update stock assessment and resources management implications. The red mullet (*Mullus barbatus*) and the striped red mullet (*Mullus surmuletus*) are the only species of mullet in Tunisian waters. The current catch level of *Mullus barbatus* is estimated at 2000 tons annually which comprises of approximately

55% of the total catch of this family and only comprises contributes approximately to 4% of estimated Tunisian demersal fisheries (ANONYMOUS, 2004b).

Because of red mullet commercial importance a number of research studies have been carried out on this specie in Tunisia as well as in other Mediterranean regions. Various aspects of its biology and population dynamics have addressed its special characteristics including studies of reproduction, age determination, growth, stock identification and stock assessment (BOUGIS, 1952; HASHEM, 1973; GHARBI, 1980; FISHER *et al.,* 1987; LIVADAS, 1988; MORALES-NIN, 1992; SAHIN & AKBULUT, 1997; LOMBARTE *et al.,* 2000; GENÇ, 2002; METIN, 2005; SAYGUN *et al.,* 2006; LLORET *et al.,* 2007). However, biological studies of this specie in Tunisia coast are very limited. The only relevant studies addressing this specie in Tunisia where conducted a long time ago, by GHARBI (1980) and GHARBI & KTARI (1981a, b).

MATERIAL AND METHODS

Data was collected during twelve monthly trawl surveys conducted between February 2003 and January 2004 in the Gulf of Tunis located on the North East of the Tunisian coast (the SE Mediterranean Sea) (Fig. 1). This area is characterized by a small continental shelf more or less broken. The depth limits were approximately 150m.

A total of 144 hauls were organized in the study area, repeatedly at the same general location. These experimental hauls were operated monthly on professionally equipped boat, covering an area of 570 km² ranging between 40 and 100m of depth. The depth limits managed to cover at best the distribution areas of the main exploited, or potentially exploitable, species. Locations of stations were selected randomly within each stratum at the beginning of the trawl surveys. The vessel used was equipped with a Tunisian shrimp's trawl (modified Gulf of Mexico trawl) with 52 mm stretched mesh in the wing and 40 mm in the cod-end. Each haul lasted 120 min at an average speed of 3 km.

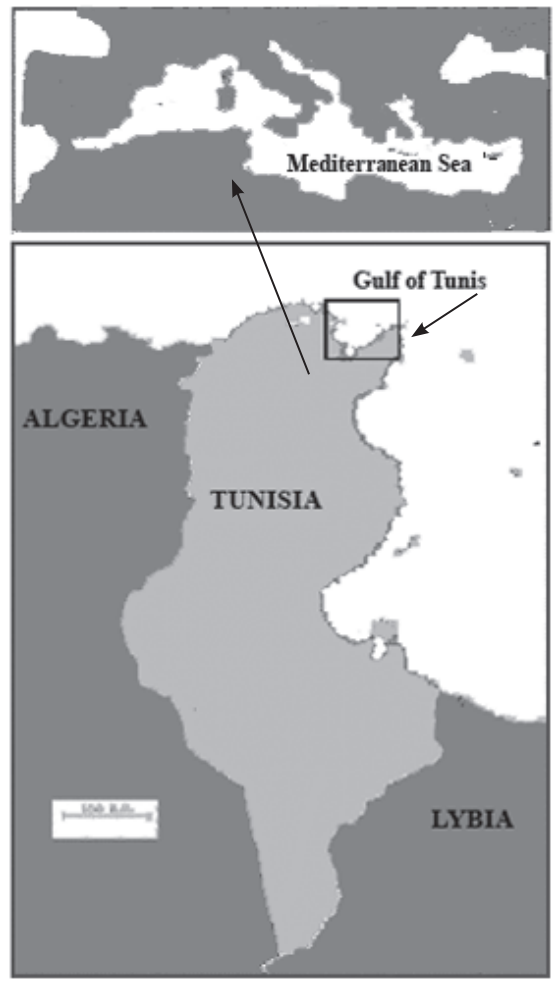

Fig. 1. Map of the Gulf of Tunis

A total of 1036 *Mullus barbatus* specimens (263 males and 773 females) were subjected to biological analysis. For each fish, were recorded the total length (*TL*), measured to nearest millimeters with an ichthyometer (precision of 1 mm), the total weight (*WT*), eviscerated weight (*We*) and gonad weight (*Wg*) using a top-loading digital scale (precision of 0.01g). The biological analyses were performed utilizing fresh specimens, while damaged individuals were systematically discarded.

Sex-ratio

The sex-ratio was estimated monthly during the study period, being expressed as the percentage of females in the various size classes:

$$SR = \frac{N_f}{N_f + N_m} \times 100$$

In order to detect statistically significant deviations from a balanced sex-ratio of 1:1, the chi-square (X^2) test was used (SOKAL & ROHLF, 1987).

$$x_c = \sum_{i=1}^{r} \frac{(f_{iobs} - f_{th})^2}{f_{th}}$$

Sexual cycle and period of spawning

For the description of the sexual cycle of *Mullus barbatus*, the maturation scale developed for this species was adopted (HOLDEN & RAITT, 1974), being based on the macroscopic aspect and relative dimensions of the gonads.

The spawning period of *Mullus barbatus* was determined by analyzing the monthly evolution of the gonado-somatic index (GSI). Formally we have:

$$GSI = \frac{W_g}{W_e} \times 100$$

where: *GSI* – gonado-somatic index; *Wg* – gonad weight; *We* – eviscerated weight.

Size at first sexual maturity

In this study, size at first sexual maturity (*Lm50*) was defined as the size class at which 50% of individuals are mature. Specimens were grouped in 5 mm size classes and the proportion of mature and immature individuals was recorded. The percentage of mature individuals in each size class was calculated by fixing the threshold of maturity starting from the maturation stage III, which corresponds to the phase of ovary development (FONTANA, 1969; CONAND, 1977). The total length at which 50% of the specimens were mature was estimated by a method based on a logistic non-linear least-squares regression (KING, 1995):

$$\mathrm{Pr} = \frac{1}{1 + \exp\left[-b(L - Lm\,50)\right]}$$

Where, (*Pr*) is the proportion of mature individuals at length (*TL*), *b* is a parameter determining the slope of the maturity curve and *Lm50* is the total length at which 50% of the fish are mature.

Length-weight relationship

The relationship between total length and weight was thereby determined, using the equation $W=aL^b$ (HUXLEY, 1924). *W* is defined as the weight in grams, *TL* is the total length of the fish in cm, and parameters (*a*) and (*b*) are estimated, defining *b* as coefficient of allometry. The degree of association between the variables was computed by the determination coefficient, r^2. Student's t-test was used to determine if the coefficient *b* was significantly different from 3 (TEISSIER, 1948).

RESULTS

Sexual cycle and spawning period

The gonado-somatic index (GSI) was used to determine the reproductive period, which was calculated from samples taken monthly

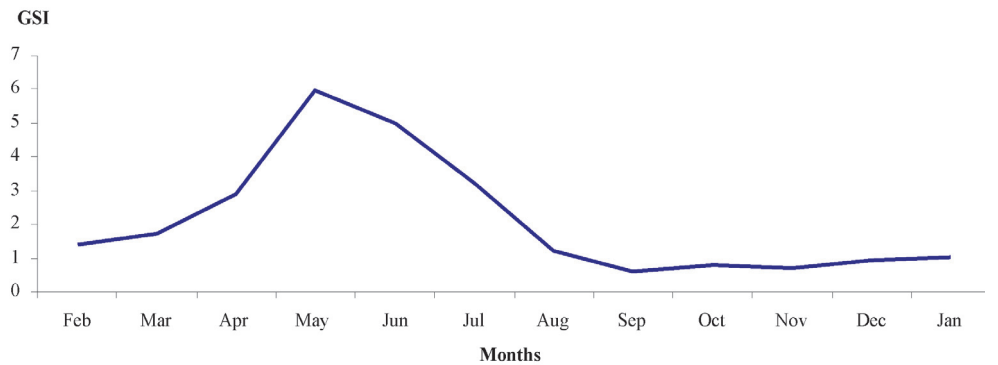

Fig. 2. Monthly changes in the gonadosomatic index (GSI) of Mullus barbatus *(female)*

from males and females. The maximum GSI value was 5.97 in females in May. In July, the GSI value decreased because all samples had presumably dispensed of their eggs (Fig. 2).

After August, the gonads began to develop and the values of GSI again started to gradually increase until January. Our findings suggest that the reproductive period of this species occurs regularly between May and July.

Spawning period for the males was overlapped the females' one, (Fig. 3), according to a cyclic development study. However, highest testis development occurred one month before that of the ovaries. Hence, males' sexual maturity lasted four months from January to April when the maximum GSI value was calculated at 2.77. Additionally, the spermatozoa emission period initiated in April and ceased in July or August, like that of the females. The maximum emission rate appeared to occur in June. During the six months (from August to January corresponding to autumnal and winter seasons), the testis remained inactive.

This study showed that, throughout the year, the period of spermatozoa availability is longer than that of oocytes, which is not an exception in Teleosteans. In fact, HICKLING (1930) stated that males of *Merluccius merluccius* had sperm almost all the time, whereas female sexual activity was limited to a shortened period within the year. In the same way, BOUGIS (1952) found that male sexual maturity of *Mullus barbatus* precedes the female one.

Sex-ratio

With reference to the distribution of males and females in the *Mullus barbatus* samples, the females predominate in all months (Fig. 4). The overall sex-ratio value estimated as 68 %

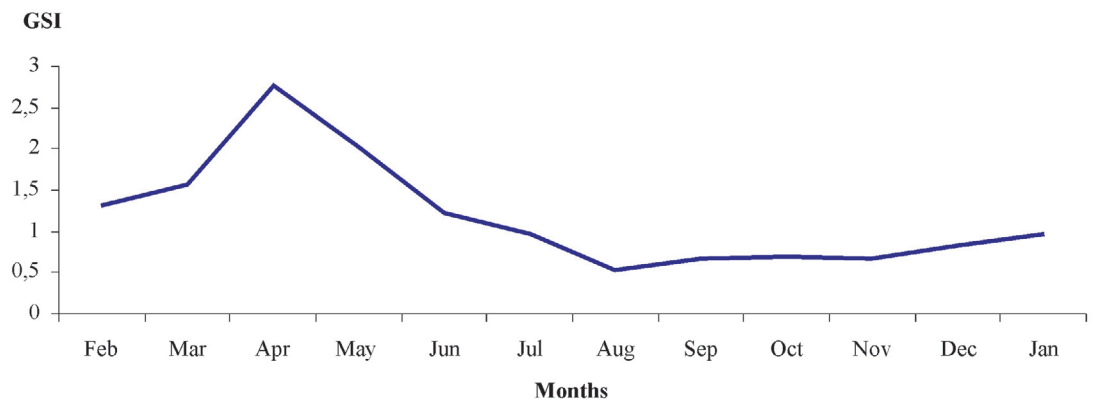

Fig. 3. Monthly changes in the gonadosomatic index (GSI) of Mullus barbatus *(males)*

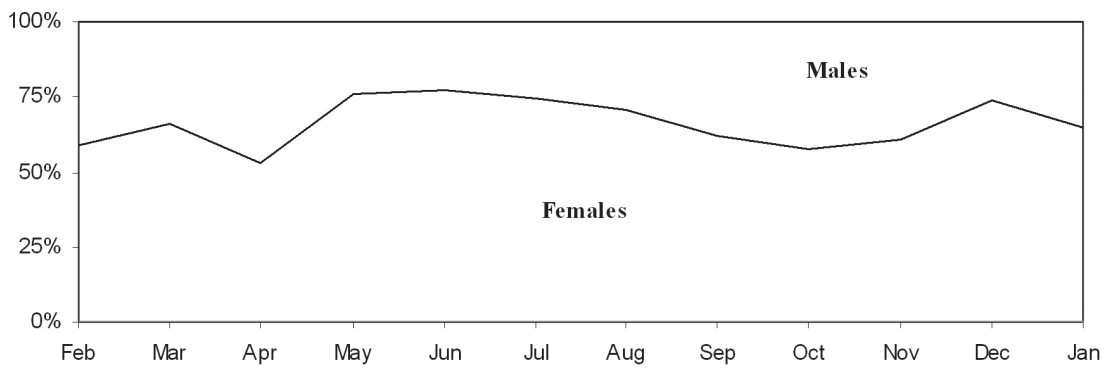

Fig. 4. Sex ratio monthly evolution for Mullus barbatus *in Tunisian Gulf*

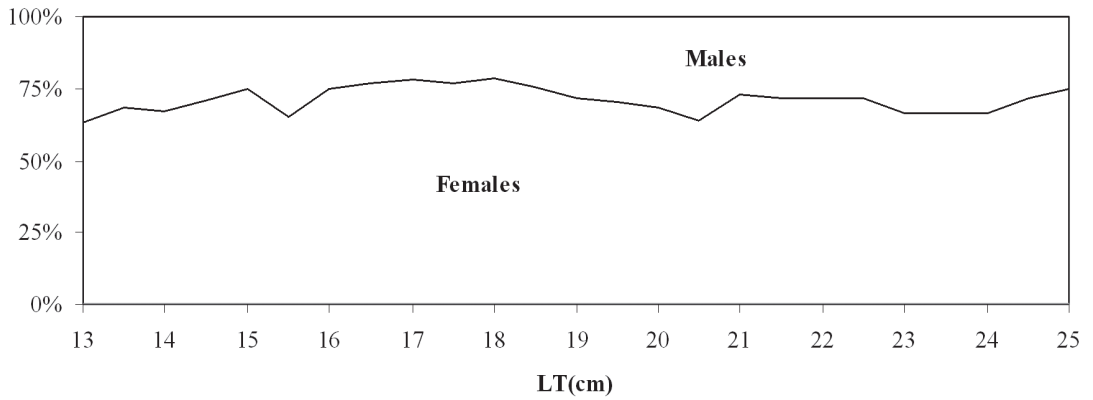

Fig. 5. Sex ratio evolution by size class in Mullus barbatus

in favour to females. Chi-square test showed a significant difference (X^2 obs = 12.33 >> X^2 th = 3.84; P<0.05). Further, females were dominant in all size classes (Fig. 5).

Size at first sexual maturity

The smallest mature female observed during the present study was 11.5 cm *TL*, whereas the smallest mature male was 11 cm *TL*. The

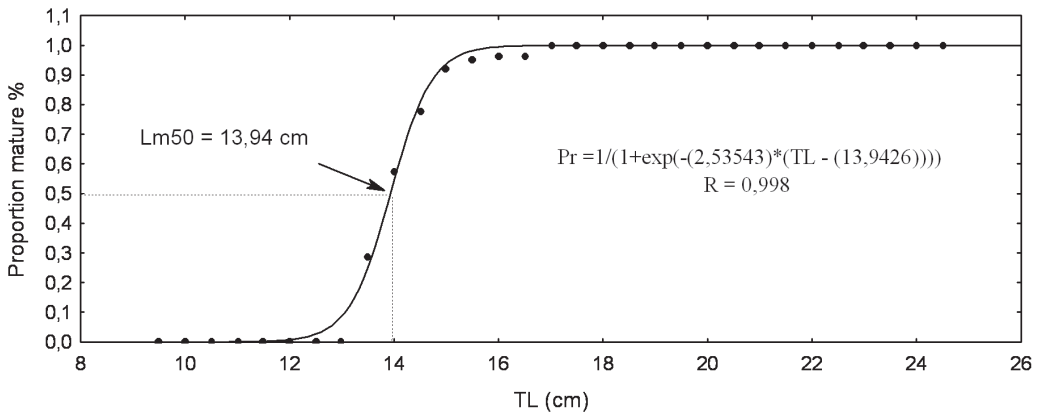

Fig. 6. Size at first sexual maturity of Mullus barbatus *(females)*

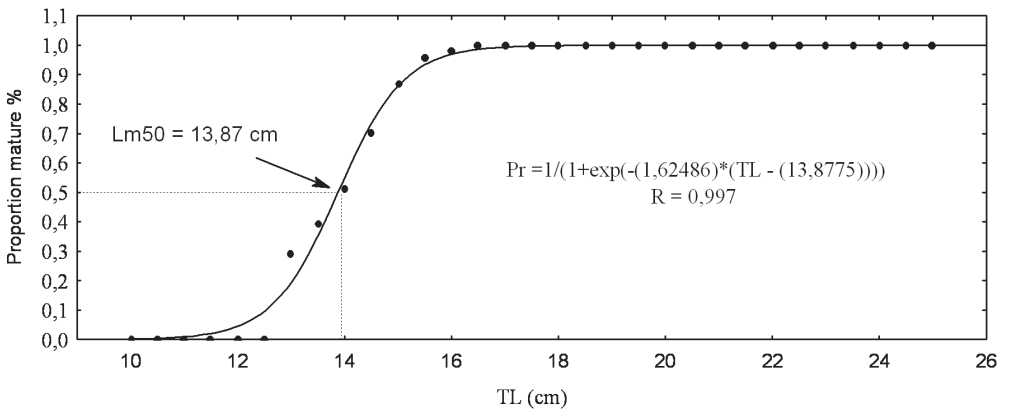

Fig. 7. Size at first sexual maturity of Mullus barbatus *(males)*

estimated mean size at which 50% of females were mature was 13.94 cm (Fig. 6), whereas the estimated mean size at which 50% of males were mature was 13.87 cm (Fig. 7).

Length-weight relationship

Of 1036 specimens captured, 773 were female and 263 were male. Females measured 9.7 to 25.1 cm *TL* ($\overline{X}$ *=16.37 cm TL*), males

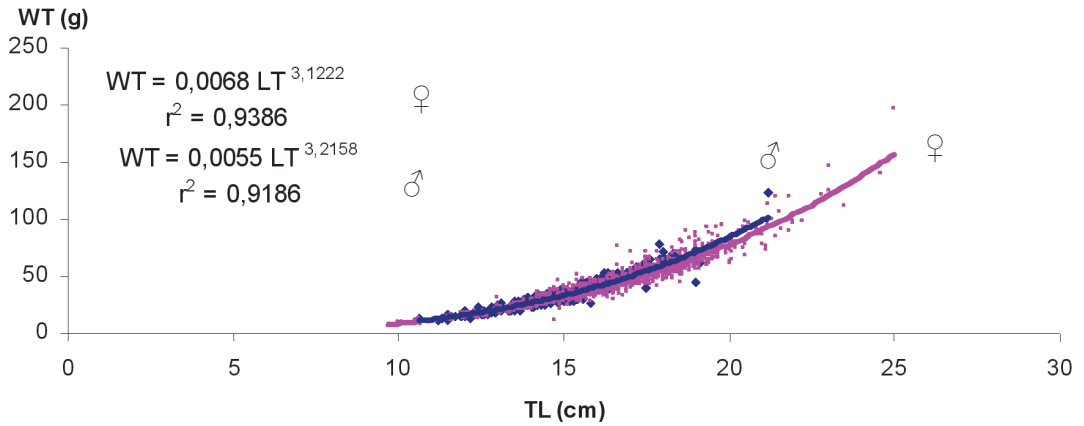

Fig. 8. Relationship between total length (TL) and total weight (WT) in Mullus barbatus *(sexes separated)*

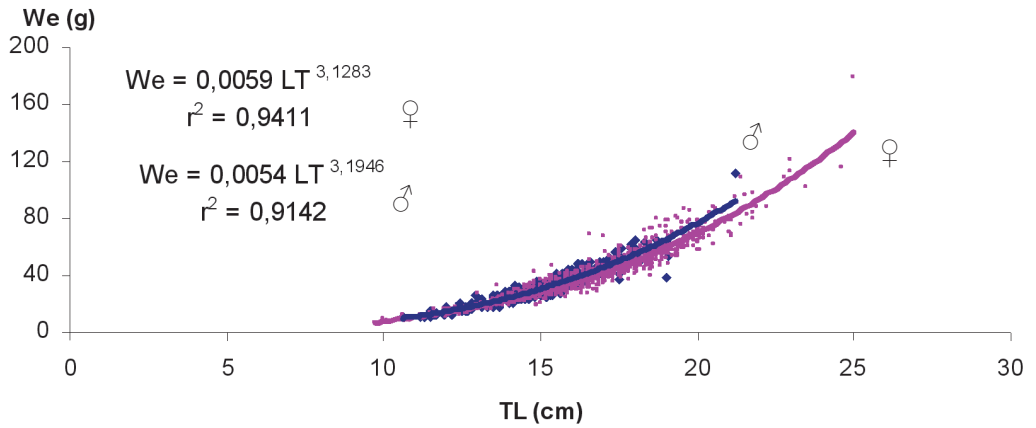

Fig. 9. Relationship between total length (TL) and eviscerated weight (We) in Mullus barbatus *(sexes separated)*

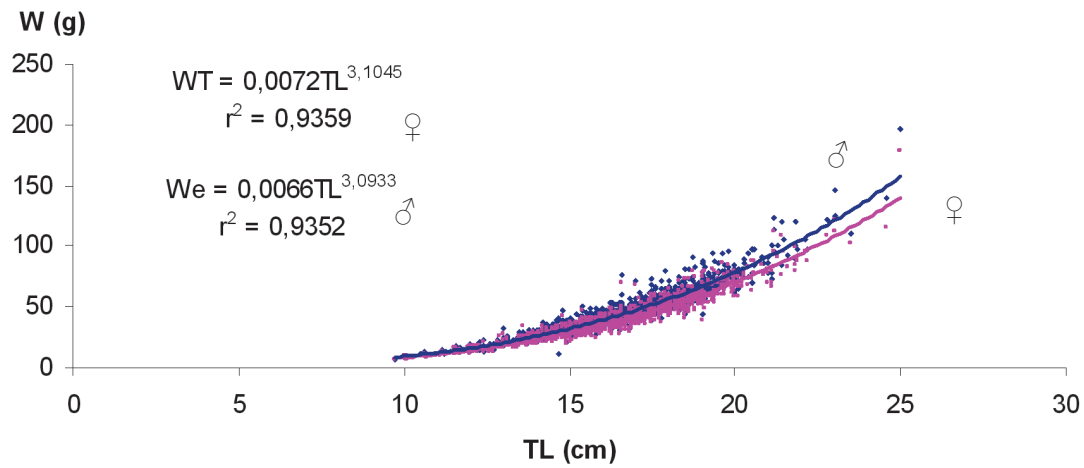

Fig. 10. Relationship between total length (TL) and total weight (WT) in Mullus barbatus *(sexes combined)*

Table 1. Values of the regression parameters (a, b, r²) of the length-weight relationship

Equations	Sex	*a*	*b*	r^2	t obs.	Significance	Alometry
$WT=aTL^b$	♀	0,0069	3,1222	0,9386	5,0683	+	Positive
	♂	0,0055	3,2158	0,9186	3,2198	+	Positive
	♂+♀	0,0072	3,1045	0,9359	4,6429	+	Positive
$We=aTL^b$	♀	0 ,0059	3,1283	0,9411	5,4298	+	Positive
	♂	0,0054	3,1946	0,9142	2,8466	+	Positive
	♂+♀	0,0066	3,0933	0,9352	4,1360	+	Positive

10.6 to 21.2 cm *TL* ($\overline{X}$ *=14.98 cm TL*). The length-weight relationship of *Mullus barbatus* indicated a positive allometry (Fig. 8, 9 and 10) and was described by the following equation: $WT = 0.0072TL^{3.1045}$. The analysis by sex (males: $WT = 0.0055TL^{3.2158}$; females: $WT = 0.0069TL^{3.1222}$) showed a significant difference in the *b* coefficient (Table 1).

DISCUSSION

The spawning season of *Mullus barbatus* in the Mediterranean Sea, takes place between May and July in the gulf of Lion (BOUGIS, 1952), the Northern area of Tunisia (ANONYMOUS, 2002a) and in İzmir Bay (METIN, 2005). The maturity and spawner period of red mullet in Tunisian coasts covers three months for females (May-July) and four months for males (April-July) (GHARBI, 1980 and GHARBI & KTARI, 1981a). Similarly, in the Ligurian Sea, the Algerian and Egyptian coasts, red mullet had a short and earlier spawning period between April and June (ORSI RELINI & ARNALDI, 1986; LALAMI, 1971 and HASHEM, 1973). Whereas, in the Moroccan Mediterranean area the spawning period was spread out from April to August (SLIMANI *et al.,* 2003). Also, in the Aegean Sea (Edremit Bay), the reproduction of *Mullus barbatus* was longer and occurred between March and September (ÇELIK & TORCU, 2000). GENÇ (2002), reported the spawning period of the red mullet in the Black Sea during the period June-August for water temperature between 18 and 25 °C. All of these results indicate that *Mullus barbatus* prefer warm waters and seasons for spawning.

In fish, sex ratio varies considerably from species to species but in the majority of species it is close to 1:1. It differs from one population to another of the same species and may vary from year to year in the same population (NIKOLSKY, 1963). The sex ratios in this study were 32% for males and 68% for females in the gulf of Tunis. High ratio of females in the catch may be caused by several factors related to the physiology and the ethology of the specie, such as the age, a tendency for slower growth or a higher mortality rates in males (DESBROSSES, 1935 and KARTAS & QUIGNARD, 1984). Other possible reasons could be a different catchability between the two sexes and a fishing effort more aimed to females than to males due to the body shape dimorphism; females are heavier and fatter than males (DESBROSSES, 1933; HASHEM, 1973; N'DA *et al.,* 1993; JABEUR, 1999).

According to several authors in the Mediterranean Sea, JOKSIMOVIĆ (2005) and VRGOČ (2000) reported that the high ratio of females most probably because of different growth rates of males and females. This was confirmed by (ŽUPANOVIĆ & JARDAS, 1989) in the Jabuka Pit region. In the Aegean Sea (Edremit Bay), the proportions of *Mullus barbatus* individuals were 68.78% and 31.22% for females and males respectively (ÇELIK & TORCU, 2000). However, through the analysis of literature related to the eastern Mediterranean Sea, females predominate while an inverse situation is observed in the Western Mediterranean Sea (ŽUPANOVIĆ, 1963).

For the first sexual maturity, GHARBI (1980) reported that first sexual maturity of *Mullus barbatus* in the gulf of Tunis occurred between

12.9 and 14.4 cm, wich corresponds to the first age year. In the Izmir Bay, the mentioned size at first sexual maturity is 14.2 cm for females and 12.4 cm for males, at ages lesser than one year (METIN, 2005). In the Moroccan Mediterranean Sea, the size at the first sexual maturity is close to 11 cm *FL* for both males and females (SLIMANI *et al.,* 2003). In the Italian waters, the first sexual maturity is reached for most of the population during the first year of life, at sizes of 11.9 cm *TL* for males and 13.4 cm *TL* for females (FIORENTINO *et al.,* 1998). In the Greek Seas (Gulf of Saranikos and Gulf of Thermaikos) red mullet females attain sexual maturity during the second year of life while males at the end of the first year (PAPACONSTANTINOU *et al.,* 1981).

CHAMPANAT *et al.* (1983) attributed differences in sizes at first sexual maturity to the geographic location of the studied areas and consequently to the different environmental conditions, such as temperature, salinity and food (JABEUR *et al.,* 2000; MAHE *et al.,* 2005; BASILONE *et al.,* 2006). Furthermore, some authors analysed samples coming from one single fishing gear, wile the red mullet resource can be caught by different "metiers" (trawling, gill netting, trammel netting, ect); thus, the fishing gear selectivity can affect the length distribution in the samples and the results related to the estimation of biological parameters (GOODYEAR, 1995; RICKER, 1969).

Length-weight relationships are very useful for fisheries research as it allow the easy conversion of length in weight and vice versa. The same equation is useful for the application of stock assessment models and for the comparison among geographical regions (KOLHER *et al.,* 1995; GONÇALVES *et al.,* 1996; FROESE & PAULY, 1998; MOUTOPOULOS & STERGIOU, 2002). In fact, the analysis of the length-weigth relationships given by several authors in the Mediterranean Sea shows some differences in (*b*) values (Table 2). Such differences in *b* values can be attributed to the combination of one or more of the following factors, such as temperature, salinity, food

Table 2. Parameters of the length-weight relationship $W=aL^b$ *[Weight (in g) and length (in cm)] of* Mullus barbatus *from the Mediterranean Sea*

Area	(a)	(b)	Reference
Cyprus waters	0,01288	2.94	LIVADAS, 1988
Aegean Sea	0,0096	3,179	VASSILOPOULOU & PAPACONSTANTINOU, 1992
North Aegean Sea	0,0145	3,085	PAPACONSTANTINOU *et al*., 1994
Gulf of Ewoikos (Greece)	0,0145	3,085	PETRAKIS & STERGIOU, 1995
Adriatic Sea	0.0125	3.015	MARANO, 1996
Edremit Bay (Turkey)	0,0157	2,98	ÇELIK & TORCU, 2000
Black Sea	0,0063	3,18	GENÇ, 2002
İzmir Bay (Turkey)	0,0070	3,29	KINACIGIL *et al.,* 2001
Egyptian coasts	0,0120	3,00	ABDALLAH, 2002
Kyclades (Ionian Sea)	0,0177	2,832	MOUTOPOULOS & STERGIOU, 2002
Moroccan Mediterranean	0,0116	3,099	SLIMANI *et al.,* 2003
Montenegro shelf	0.00767	3.102	JOKSIMOVIĆ, 2005
İzmir Bay (Turkey)	0.0102	3.176	ÖZAYDIN & TASKAVAK, 2007
Gulf of Tunis	0,0072	3,1045	This study

(quantity, quality and size), sex, time of year and stage of maturity (SHEPHERD & GRIMES, 1983; PAULY, 1984; WEATHERLEY & GILL, 1987; DULČIĆ & KRALJEVIĆ, 1996; JOBLING, 1997; MAHE *et al.,* 2005; GÖKÇE *et al.,* 2007; KLING *et al.,* 2007).

CONCLUSIONS

The stocks of red mullet in the Tunisia waters and in the Mediterranean Sea are considered to be heavily exploited (CADDY, 1993; BEN MERIEM *et al.,* 1996; SLIMANI *et al.,* 2003). Since the Gulf of Tunis is known to be a nursery for many species as well pelagic and demersal species (HATTOUR, 1991; ZARRAD *et al.,* 2003). From a management perspective, it has generally been assumed that closure of trawl fisheries during all year and in waters shallower would be an effective means of increasing the biomass of fish available to the fisheries, such protected area would allow a proportion of the stock to grow to a relatively large size at which overall fecundity is greatly increased (MACHIAS *et al.,* 1998). This management policy is necessary to protect the immature fraction of the population and adults during spawning. This might to generate a increase in recruitment by increasing the number of reproducing females. Much of what fisheries management tries to achieve is aimed towards maintaining a sufficient biomass of reproductively active fish to replenish stocks (ROBERTS, 1997).

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Neki biološki parametri trlje blatarice *Mullus barbatus* L., 1758, u tuniskom zaljevu

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