

## Original Article

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# Age, growth and mortality of the striped seabream *Lithognathus mormyrus* (Linnaeus, 1758) in the Gulf of Tunis (Central Mediterranean Sea)

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## Abstract

Despite the high commercial value of the striped seabream *Lithognathus mormyrus* (Linnaeus, 1758) in the Gulf of Tunis, biological data on its age, growth and exploitation rate are lacking. With the aim of estimating growth parameters, 516 individuals, ranging from 6–27.5 cm total length and from 3.5–293.5 g total weight, were collected from the artisanal fishing fleet between February 2014 and July 2016. The somatic growth presented a positive allometry and was described by the equation  $TW = 6.54 \cdot 10^{-3} TL^{3.213}$ . The monthly analysis of the marginal increment of the otoliths revealed that only one annulus was deposited per year. The estimated von Bertalanffy growth parameters were:  $L_{\infty} = 30.18$  cm,  $k = 0.303$  year<sup>-1</sup> and  $t_0 = -1.42$  years. Total and natural instantaneous rates of mortality were respectively  $Z = 0.784$  year<sup>-1</sup> and  $M = 0.698$  year<sup>-1</sup>. Exploitation rate ( $E = 0.1$ ) showed that the Gulf of Tunis stock of *L. mormyrus* is not overexploited. The estimated length class giving highest yield (Lopt) was  $17.15 \pm 1.71$  cm.

## Introduction

A monotypic species, the striped seabream *Lithognathus mormyrus* (Linnaeus 1758) belongs to the Sparidae family and is found in the Mediterranean Sea. It also occurs in the Eastern Atlantic from the Bay of Biscay to the Cape of Good Hope, and around the Canary Islands, Cape Verde and Madeira Archipelago. Moreover, it is present throughout the Western Indian Ocean, and in the Black, Azov and Red Seas (Bauchot & Hureau, 1986). The striped seabream is a demersal species that inhabits seagrass beds, and rocky and muddy bottoms down to 150 m, but is found mostly at depths of 10–20 m (Pajuelo *et al.*, 2002). Economic interest in this species and its adaptative success over its wide geographic distribution, have justified the study of various aspects of its biology. Qualitative and quantitative studies of the diet of the striped seabream were conducted (Suau, 1970; Badalamenti *et al.*, 1993; Bradai *et al.*, 1998; Harchouche *et al.*, 2005; Kallianiotis *et al.*, 2005; Šantić *et al.*, 2010; Ben Abdallah-Ben Hadj Hamida *et al.*, 2016; Khaldi & Chakroun-Marzouk, 2016). Weight–length relationships were estimated for the striped seabream from the Mediterranean coast of Spain (Suau, 1970), Gokova Bay (Ceyhan *et al.*, 2008), Adriatic Sea (Maci *et al.*, 2009) and Gulf of Gabes (Ghailen *et al.*, 2010). Reproduction and growth have been investigated in the western Mediterranean (Suau, 1970), northern and central Adriatic Sea (Kraljević *et al.*, 1996), central-eastern Atlantic (Lorenzo *et al.*, 2002; Pajuelo *et al.*, 2002), Iskenderun Bay (Türkmen & Akyurt, 2003), coastal waters of the Thracian Sea (Kallianiotis *et al.*, 2005), Beymelek Lagoon (Emre *et al.*, 2010), south-eastern coast of Tunisia (Ben Abdallah-Ben Hadj Hamida *et al.*, 2016) and in the central coast of Algeria (Boufersaoui *et al.*, 2018).

On the Tunisian coasts, *L. mormyrus*, like many other seabream species, is an important member of the continental shelf demersal fish community. The feeding habits, age, growth and reproduction of the striped seabream of the Gulf of Gabes (south-eastern coast of Tunisia) have been studied (Ben Abdallah-Ben Hadj Hamida *et al.*, 2016). Moreover, owing to the sexual pattern of the striped seabream which is characterized by protandric hermaphroditism (Türkmen & Akyurt, 2003; Kallianiotis *et al.*, 2005), a slow growth and a high instantaneous rate of natural mortality (Lorenzo *et al.*, 2002), the species is potentially vulnerable to overexploitation and therefore a follow-up of its stock status is required. However, biological parameters have not yet been determined for the striped seabream population of the Gulf of Tunis (north-eastern coast of Tunisia). Therefore, the aim of the present study was to provide basic information on growth parameters of the striped seabream in the Gulf of Tunis and on its exploitation status. The weight–length relationship was established. The methodology, reliability and validity of age estimates derived from the sagittal otolith were assessed. The von Bertalanffy growth parameters, optimum length at capture, mortalities and exploitation



rate were evaluated. These biological parameters are essential for the adoption of a sustainable stock management strategy of this species in the Gulf of Tunis.

## Materials and methods

### Fish sampling

Samples of *L. mormyrus* (N = 516) were obtained from the landings of the small-scale artisanal fleet of the Gulf of Tunis (central Mediterranean Sea, 37°N 10°30'E). Fish samples were randomly collected on a monthly basis, from February 2014 to July 2015, following capture by gillnet, trammel net and longline (Cherif *et al.*, 2019). Each individual was measured to the nearest mm for total length (TL) and weighed to the nearest gram for total weight (TW). After dissection, individuals were sexed as males (M), females (F) or hermaphrodites (H) by a visual observation of the gonads. Hermaphrodites were fishes presenting bisexual gonads clearly visible to the naked eye. Unsexed individuals (U) have thin and translucent gonads preventing any identification of the gender. In addition, sagittal otoliths were extracted, cleaned and stored dry in labelled envelopes for later treatment and examination.

### Weight-length relationships

The fish somatic growth was described by the power function  $TW = a.TL^b$ , where TW is the total weight (g) and TL the total length (cm). According to the recommendations of Froese *et al.* (2011) the log-transformed data were plotted and obvious outliers were removed before fitting the linear regression. The regression coefficients  $a$  and  $b$  were then calculated for the whole sample using a least square linear regression on log-transformed data. The determination of the growth type was realized using the  $t$ -test to investigate whether the slope  $b$  was significantly different from the theoretical value of 3, whereas analyses of covariance (ANCOVA) were employed to detect any significant differences in the linear relationships between sexes (Zar, 1999).

### Otolith preparation and ageing precision

According to the international ageing protocol used for most Mediterranean species (Vitale *et al.*, 2019), sagittal otoliths were used in order to determine age of each specimen analysed. For this species, transverse sections (mean width 0.8 mm) of the otoliths were used for age determination. All otolith sections were photographed using a Zeiss microscope under transmitted light, assisted by an image analysis system using the TNPC software for digital processing of calcified structures. Three thin sections were prepared for each otolith to optimize the observation of a succession of alternate translucent and opaque bands (Figure 1). It was assumed that annual growth rings (the 'annulus') consisted of one opaque and one translucent band.

Counts of the annual growth increments were made by two readers, without reference to fish length or sex to avoid subjectivity on age estimations. To minimize observation errors, only coincident readings were accepted. For that purpose, the index of average percentage error (IAPE) was performed to evaluate the precision of the age determinations between the two readers using the formula described by Beamish & Fournier (1981):

$$APE_j(\%) = 100 \times \frac{1}{R} \sum_{i=1}^R \frac{|X_{ij} - X_j|}{X_j}$$

where  $R$  is the number of readings,  $X_{ij}$  is the  $i$ th age determination of the  $j$ th fish and  $X_j$  is the mean age calculated for the  $j$ th fish, with greater precision achieved as the IAPE is minimized.

### Validation and estimation of age

To validate the seasonality and to determine the periodicity of the translucent zones, marginal increment ratio analysis (MIR, 0.01 mm) was used. This relies on the assumption that if a zone is laid down once a year, there should be a clear annual pattern of periodic growth on the edge of the otolith during the year. Thus the monthly estimates of the MIR were carried out on the entire otolith sample and followed throughout the year. Marginal increment ratio was calculated using the formula:

$$MIR = R_o - R_n/R_n - R_{n-1}$$

For that purpose, the radius of the otolith ( $R_o$ ) was measured and also the distance from the nucleus to the last growth increment ( $R_n$ ) and to the penultimate growth increment ( $R_{n-1}$ ). The Kruskal–Wallis test was used to test the homogeneity of MIR among months followed by a Student–Newman–Keuls test (SNK).

### Growth biological parameters

Since *L. mormyrus* displays protandric hermaphroditism, sexes were pooled together for the estimation of the growth parameters as they could be considered as the same individuals but at different reproductive stages (Kallianiotis *et al.*, 2005).

Growth was described by the von Bertalanffy model (1938) according to the formula:

$$TL_i = TL_\infty(1 - e^{-k(t-t_0)})$$

Where  $TL_i$  is the total length at age  $i$ ,  $TL_\infty$  is asymptotic total length,  $k$  is the growth coefficient ( $\text{year}^{-1}$ ),  $t$  is the age (year from birth), and  $t_0$  is the theoretical age at zero length (years). The determination of the growth parameters ( $TL_\infty$ ,  $k$  and  $t_0$ ) and all the statistical analyses were conducted using Fishpam, a computer program based on a non-linear model with an algorithm for least-square estimation (Saila *et al.*, 1988). The estimated parameters of the von Bertalanffy growth allowed the estimation of the length at maximum yield per recruit ( $L_{opt}$ ), and the growth performance index ( $\Phi'$ ). For that purpose, the following empirical relationships of Froese & Binohlan (2000) ( $L_{opt} = L_\infty \times [3/(3 + M/k)]$ ) and Munro & Pauly (1983) ( $\Phi' = \log k + 2 \log TL_\infty$ ) were used, with  $L_\infty$  the asymptotic length,  $k$  the growth coefficient ( $\text{year}^{-1}$ ) and  $M$  the natural mortality ( $\text{year}^{-1}$ ).

### Mortalities and exploitation rates

Instantaneous total mortality ( $Z$ ,  $\text{year}^{-1}$ ) was estimated from the slope of the linear regression through the descending right limb of the established linearized catch curve (Pauly, 1983). Natural mortality ( $M$ ,  $\text{year}^{-1}$ ) was calculated using the empirical relationship of Pauly (1980):

$$\ln M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log k + 0.4634 \log T,$$

where  $T$  is the mean water temperature. Indeed, after the use of the Alagaraja (1984) equation ( $T_e = 4.605/M \text{ year}^{-1}$ ), which calculates longevity ( $T_e$ ) from natural mortality ( $M$ ), it has been found that the obtained value of  $M$  with the method of Pauly (1980) gives an adequate estimation of the striped seabream longevity. The instantaneous rate of fishing mortality ( $F$ ,  $\text{year}^{-1}$ ) was obtained from the difference between  $Z$  and  $M$ . The exploitation rate ( $E$ ) was determined according to Gulland (1971):

$$E = F/Z.$$

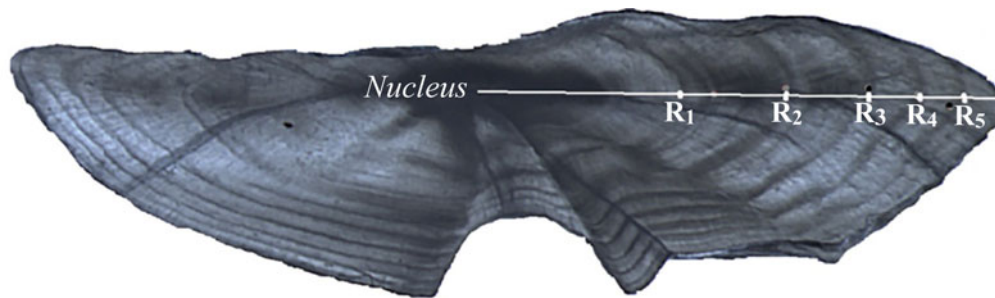


Fig. 1. Transverse section of sagittal otolith of a 5-year-old *L. mormyrus* in the Gulf of Tunis (TL = 20 cm, female), showing the annual rings (R1, R2, R3, R4, R5).

## Results

### Sample structure, sex ratio and weight-length relationship

Of the 516 fish examined, 231 were males, 224 females and 3 hermaphrodite individuals. The sex of the remaining 58 fish could not be determined and they were recorded as unsexed. The global sex ratio (M:F) did not differ significantly from 1:1 ( $\chi^2$  test < 3.84;  $N = 455$ ,  $P > 0.05$ ).

Males ranged in size from 10.3–27.5 cm and females from 10.7–25.4 cm respectively (Figure 2). The mean total length (TL) of males (TL =  $17.28 \pm 0.17$  cm) was significantly different (Mann–Whitney U test;  $N = 455$ ;  $P = 0.003$ ) from that of females (TL =  $18.25 \pm 0.17$  cm). Hermaphrodites were found at sizes between 15.1 and 17.4 cm ( $16.3 \pm 0.66$  cm) and unsexed fish between 6 and 18 cm ( $13.05 \pm 0.52$  cm). The total weight (TW) of fish was 53.4–293.5 g (mean TW =  $66.4 \pm 2.4$  g) for males and 18.3–285.1 g (mean TW =  $79.7 \pm 2.8$  g) for females. The mean total weight was not significantly different between sexes (Mann–Whitney U test,  $N = 455$ ,  $P = 0.0059$ ). Total weight of hermaphrodites and unsexed individuals varied respectively from 57.1 to 69.7 g ( $63.63 \pm 3.66$  g) and 2.2 to 72 g ( $32.95 \pm 3.20$  g).

The estimated weight-length relationship for the combined sexes was  $TW = 0.00654 TL^{3.213}$  ( $N = 516$ ;  $r^2 = 0.977$ ;  $SE(b) = 0.063$ ) and was highly significant ( $P < 0.001$ ); its slope ( $b$  value) differed significantly from the theoretical value of 3 ( $t$ -test;  $P < 0.05$ ) indicating a positive allometric growth of *L. mormyrus* in the Gulf of Tunis.

### Age validation

Of the 516 specimens examined, 488 were retained for age determination and the remaining ones were discarded as they showed disagreement in the reading of otoliths. The low value of the IAPE (1.61%) demonstrated consistency and high precision in distinguishing and counting growth marks.

The lowest average values of the otolith marginal increment ratio were observed from February to April (Kruskal–Wallis test,  $P = 0.04$ ; SNK,  $P = 0.001$ ) while an increasing trend of MIR values was discerned throughout the rest of the year (Figure 3). Thus, the recorded fluctuations of MIR, performed on the entire sample, validated the deposition of two different growth zones composing a yearly annulus.

### Growth parameters

To summarize the age composition of *L. mormyrus*, an age-length key was constructed (Table 1). The age of the sample varied from 0 to 7 years and was characterized by a high percentage of specimens (81%) between 1 and 3 years and a modal age of 2 years. The mean observed length-at-age data were fitted to the von Bertalanffy growth function. The size increments between

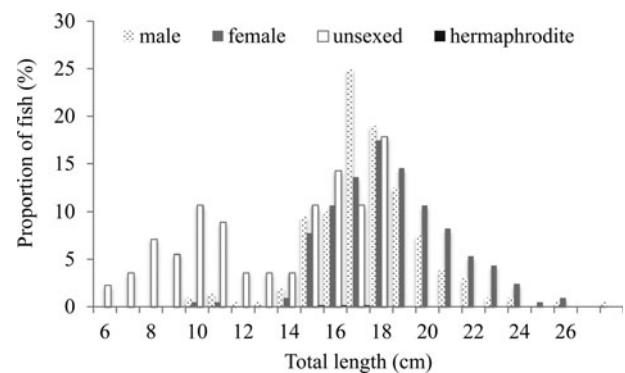


Fig. 2. Length frequency distribution of males, females, hermaphrodites and unsexed individuals of *L. mormyrus* in the Gulf of Tunis.

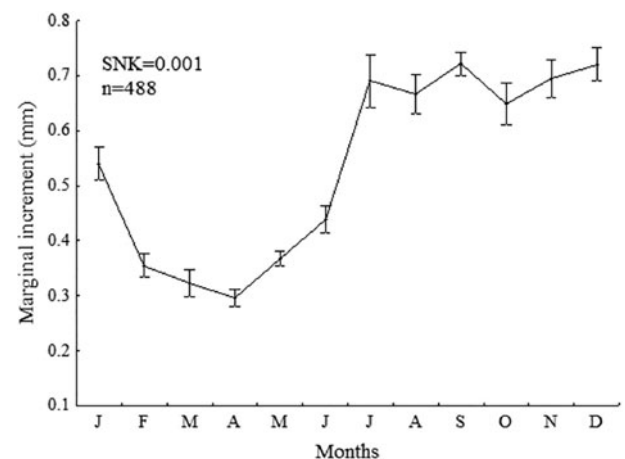


Fig. 3. Monthly evolution of average marginal increment of *L. mormyrus* in the Gulf of Tunis.

successive age groups showed a rapid growth until the third year, which slowed down considerably beyond this age.

The estimated parameters of the von Bertalanffy growth were  $L_{\infty} = 30.180 \pm 0.660$  cm,  $k = 0.303 \pm 0.024$  year<sup>-1</sup> and  $t_0 = -1.420 \pm 0.110$  years (Figure 4). The length at maximum yield per recruit (Lopt) was  $17.150 \pm 1.715$  cm. The calculated growth performance index of *L. mormyrus* was  $\Phi' = 2.440$ .

### Mortality and exploitation rate estimates

The instantaneous rate of total mortality, corresponding to the slope of the descending limb of the catch curve was  $Z = 0.784$  year<sup>-1</sup> (Figure 5). The calculated instantaneous rate of natural

**Table 1.** Age length key of *L. mormyrus* in the Gulf of Tunis

Size (cm)	Age group							
	0	I	II	III	IV	V	VI	VII
3								
4								
5								
6	1							
7								
8								
9	1							
10	3	3						
11	1	6						
12		10						
13		8						
14		21						
15		28						
16		20	2					
17		13	18					
18		5	31					
19			62					
20			43	9				
21			20	24				
22			3	52	5			
23				15	17	1		
24				4	29	4		
25					2	11	3	
26					1	2	6	3
27								1
N	6	114	179	104	54	18	9	4
%	1.23	23.36	36.7	21.3	11.1	3.689	1.844	0.82
Mean size (cm)	10.55	15.68	19.47	22.27	24.33	25.86	26.43	26.97
SD	0.005	0.067	0.034	0.1	0.07	0.054	0.034	0.23

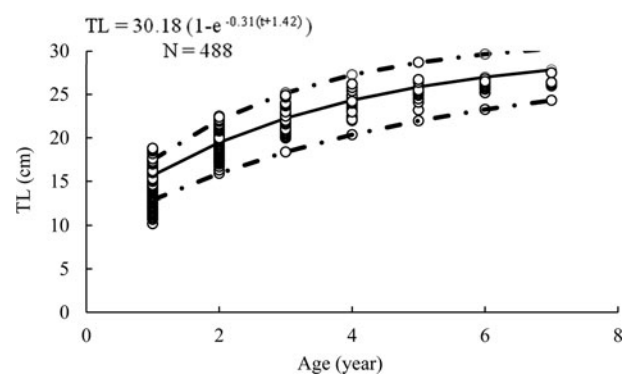
N, number of fish; SD, standard deviation; %, frequency of fish by age group.

mortality was  $M = 0.698 \text{ year}^{-1}$ . Taking into account the estimated values of  $Z$  and  $M$ , instantaneous rate of fishing mortality was  $F = 0.067 \text{ year}^{-1}$ . Knowing  $M$  and  $F$ , the computed exploitation ratio was  $E = 0.11$ .

## Discussion

### Sample characteristics and sex ratio

In the Gulf of Tunis, male and female striped seabream displayed a large overlap in their length distributions and did not present the bimodal distribution often expected in sequential hermaphroditic populations. However, the mean size of females was significantly greater than that of males as a result of the dominance of males in the lower length classes and of females in greater ones. This pattern of gender distribution by size is one of the characteristics of a protandrous hermaphroditism and has been already described in other studies dealing with the sexuality of the striped seabream (Lorenzo et al., 2002;



**Fig. 4.** Von Bertalanffy growth curve of *L. mormyrus* in the Gulf of Tunis.

Türkmen & Akyurt, 2003; Kallianiotis et al., 2005; Vitale et al., 2011; Ben Abdallah-Ben Hadj Hamida et al., 2016). Moreover, the presence of individuals with visible bisexual



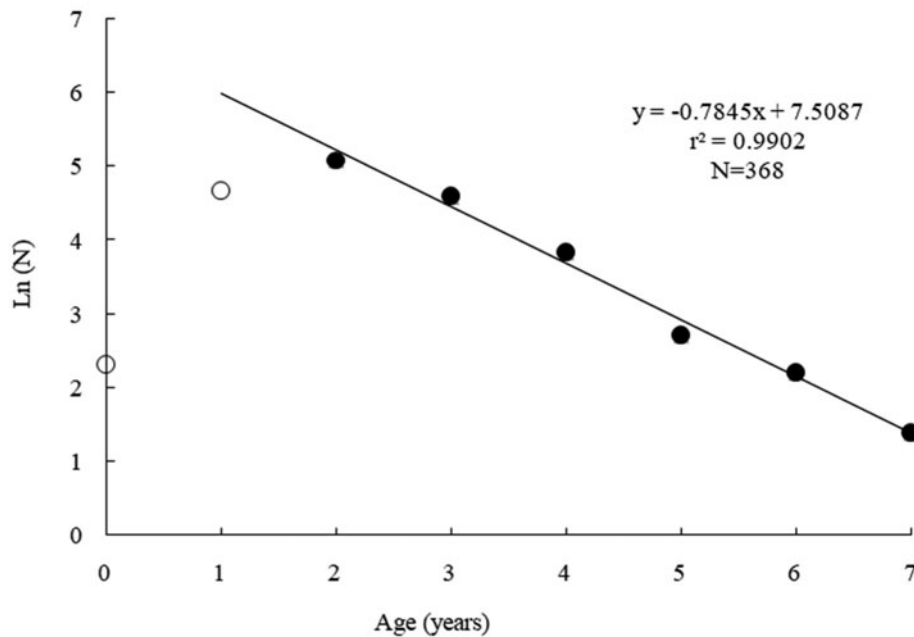


Fig. 5. Length-converted catch curve of *L. mormyrus* in the Gulf of Tunis.

gonads, even in very low proportion (0.58%), supports the occurrence of hermaphroditism in the population.

The mean total length (TL =  $17.5 \pm 0.4$  cm) of the sample of the Gulf of Tunis was very similar to the average size (TL =  $17.32 \pm 2.08$  cm) observed for the captured individuals from Tunisian lagoons (Hammami *et al.*, 2013). However, the mean sizes recorded for the populations from two sites from the Portuguese coasts (TL =  $23.79 \pm 8.71$  cm; TL =  $27.73 \pm 3.08$  cm; Gonçalves *et al.*, 1997) and from the Turkish coast of the Aegean Sea (TL =  $23.7 \pm 0.35$  cm; Ceyhan *et al.*, 2008) were greater. Several factors may be responsible for the differences in the mean sizes among intra-specific populations: the differential growth of fish in their environment, the size selectivity properties of the fishing gears used in the fisheries and the fishing pressure (Gonçalves *et al.*, 1997; Trenkel & Rochet, 2003).

#### Length-weight relationship

The study of the weight-length relationship in different maritime sectors showed that the observed  $b$  values were between 2.69 (Kraljević *et al.*, 1996) and 3.14 (Matić-Skoko *et al.*, 2007) (Table 2). In the Mediterranean Sea, most studies showed an isometric somatic growth of the striped seabream, except in those conducted in Kastela Bay on the Northern Adriatic coast (Kraljević *et al.*, 1996), the Croatian coast (Matić-Skoko *et al.*, 2007) and the Gulf of Tunis (present study) where growth was allometric. Also, different growth types were registered in Mediterranean lagoons and in the Atlantic. Many factors such as seasonality, temperature, photoperiod, food availability and range sizes of the sample may be responsible for the varying somatic growth rates observed between localities.

#### Age and growth

Precise estimation of fish age and validation of the timing of ring formation are essential steps for age-based evaluation of fish populations and management (Morales-Nin & Panfili, 2002). In the Gulf of Tunis, the monthly fluctuations of the otoliths' marginal increment confirmed an annual periodicity of growth with the deposition of a translucent zone of slow growth in the winter and of an opaque zone of rapid growth in the summer. In the Gulf of Gabes, Ben Abdallah-Ben Hadj Hamida *et al.* (2016)

mentioned a winter hyaline increment deposition while in the Thracian Sea, Kallianiotis *et al.* (2005) suggested that the hyaline zone is completed between January and May.

The readings of the growth rings performed by two researchers were efficient as 94.6% of the otoliths were easily interpreted; the otolith is therefore an appropriate tool for age and growth estimation of *L. mormyrus*.

In the Gulf of Tunis, the oldest striped seabream observed was 7 years old. Previous studies in different marine localities recorded longevities from 7 to 14 years with ages ranging from 7–11 years in the Mediterranean Sea and 8–14 years in the Atlantic Sea (Table 3). Other studies have only reported younger fish, such as in the lagoon of Beymelek (Turkey), where the oldest individuals reached 4 years old (Emre *et al.*, 2010). The variable age ranges may be attributed to geographic and environmental differences, as well as differences in sampling. According to Carbonara *et al.* (2019) geographic location was the most important factor significantly correlated to age variability in *Mullus barbatus* in the Mediterranean, with the longitudinal (west–east) sample geographic component influencing more than the latitudinal (north–south) one.

In the Gulf of Tunis, the theoretical maximum length ( $TL_{\infty}$ ) was found to be similar to values estimated in other areas of the Mediterranean Sea by Türkmen & Akyurt (2003), Kallianiotis *et al.* (2005), Ben Abdallah-Ben Hadj Hamida *et al.* (2016) and Emre *et al.* (2010), with an exception for the striped seabream in the Adriatic Sea where a higher value was reported (Table 3). However, in the Atlantic, theoretical maximum lengths estimated by Pajuelo *et al.* (2002), Lorenzo *et al.* (2002) and Monteiro *et al.* (2010) were greater than reported from the Mediterranean Sea.

Otherwise, the growth coefficient  $k$  varied from 0.11–0.30  $\text{year}^{-1}$  over the distribution area of the studied species (Table 3). The specimens from the Gulf of Tunis (north-eastern coasts of Tunisia) presented the fastest growth pattern ( $k = 0.3 \text{ year}^{-1}$ ); similar to the results of Emre *et al.* (2010) and Kraljević *et al.* (1996) for Beymelek Lagoon and the northern Adriatic Sea, respectively. This is probably related to the structure of the studied populations as their length–frequency distribution is composed of a higher percentage of young individuals. Ben Abdallah-Ben Hadj Hamida *et al.* (2016) found, on the south-eastern coast of Tunisia of the Gulf of Gabes, a slower growth pattern ( $k = 0.11$ ) than on the north-eastern coast of

**Table 2.** Biogeographic comparison of the parameters of the sex-combined weight-length relationships of *L. mormyrus*

Sector	Area	Author	N	size range (cm)	<i>a</i>	<i>b</i>	SE <sub><i>b</i></sub>	<i>r</i> <sup>2</sup>	Growth type
Atlantic Sea	South coast of Portugal	Gonçalves <i>et al.</i> (1997)	143	21.4–40.6	24.10 <sup>-4</sup>	2.901	0.050	0.960	–
	South-west coast of Portugal	Gonçalves <i>et al.</i> (1997)	33	18–36.5	39.10 <sup>-4</sup>	2.810	0.079	0.980	–
	Canary Islands	Lorenzo <i>et al.</i> (2002)	731	11.3–37.2	27.10 <sup>-4</sup>	2.907	0.028	0.968	A–
Mediterranean Sea	Castellón coast	Suau (1970)	421	–	–	–	–	–	I
	Iskenderun Bay	Türkmen & Akyurt (2003)	3335	9.1–27.7	11.3.10 <sup>-3</sup>	3.042	0.019	0.982	I
	North-east Mediterranean	Kallianiotis <i>et al.</i> (2005)	1688	4.2–34.1	8.5.10 <sup>-3</sup>	3.108	0.009	0.985	–
	Gokova Bay (Turkey)	Ceyhan <i>et al.</i> (2008)	141	14.5–32.6	12.2.10 <sup>-3</sup>	3.034	0.047	0.967	I
	Gulf of Gabes (Tunisia)	Ghailen <i>et al.</i> (2010)	161	15.5–24	7.1.10 <sup>-3</sup>	2.931	0.091	0.960	I
	French Catalan coast	Crec'hriou <i>et al.</i> (2012)	300	14.5– 40	3.7.10 <sup>-3</sup>	2.810	–	0.933	–
	Central coast of Algeria	Boufersaoui <i>et al.</i> (2018)	449	11.5–34.5	12.10 <sup>-3</sup>	3.029	0.006	0.979	I
	Gulf of Tunis (Tunisia)	Present study	516	10.9–27.5	6.5.10 <sup>-3</sup>	3.213	0.063	0.977	A+
	Croatian Adriatic coast	Matić-Skoko <i>et al.</i> (2007)	2133	8–10.3	–	3.141	–	0.996	A+
Mediterranean Lagoon	Lagoon of Adriatic Sea	Maci <i>et al.</i> (2009)	–	–	15.4.10 <sup>-3</sup>	3.140	–	0.996	A+
	Beymelek Lagoon (Antalya, Turkey)	Emre <i>et al.</i> (2010)	339	14.3–27.4	13.2.10 <sup>-3</sup>	3.036	0.049	0.971	I
	Northern Adriatic Sea (Kastela Bay)	Kraljević <i>et al.</i> (1996)	133	15– 40.5	40.1. 10 <sup>-3</sup>	2.69	0.067	0.989	A–
	Northern Adriatic Sea (Mirna Bay)	Kraljević <i>et al.</i> (1996)	197	15–35	10.4. 10 <sup>-3</sup>	3.05	0.070	0.993	I

N, sample; *a*, intercept; *b*, slope; SE<sub>*b*</sub>, standard error of *b*; *r*<sup>2</sup>, coefficient of determination; I, isometric growth; A–, negative allometric growth; A+, positive allometric growth.

Tunisia of the Gulf of Tunis ( $k = 0.3 \text{ year}^{-1}$ ). Hydrological parameters and productivity are different in these two regions (Azouz, 1971; Ben Othman, 1973) and the fishing pressure is known to be higher in the Gulf of Gabes. Geographic variations in the estimated growth parameters of fishes may be attributed to several factors, such as gear selectivity, methodologies of study (reader experience), fishing exploitation and geographic location of samples (Carbonara *et al.*, 2019); however, they generally represent epigenetic responses to environmental conditions (Ibrahim *et al.*, 2008).

The growth performance index ( $\Phi'$ ) values varied from 2.04–2.54 (Table 3). The growth potential of the striped seabream of the Gulf of Tunis is quite comparable to those estimated in the different areas of the Atlantic and in some locations of the Mediterranean Sea.

#### Mortality and exploitation rate estimates

The estimation of mortalities indicates that the striped seabream of the Gulf of Tunis (northern coast of Tunisia) have a rational exploitation; this is probably due to the fact that the species is essentially caught by selective fishing gears.

Also, 18 years ago in the same location, Ezzeddine-Najai *et al.* (2001) reported that the species was not overexploited. Kallianiotis *et al.* (2005) indicated that the trammel net fishery of the Thracian Sea may be sustainable as the fishing mortality rate was low, but that it is necessary to consider the impact of the other

fishing gears to determine the real status of exploitation of the species. Monteiro *et al.* (2010) recommended the use of longlines for sustainable fishing of the striped seabream from the south coast of Portugal, as these fishing gears tend to catch large individuals. However, Ben Abdallah-Ben Hadj Hamida *et al.* (2016) reported that the striped seabream is overexploited in the Gulf of Gabes (south-eastern coast of Tunisia) and that this status explains its low growth and the absence of very large individuals in this area. Otherwise, the stock of the striped seabream from Iskenderun Bay was found to be heavily exploited (Türkmen & Akyurt, 2003).

The estimation of percentage of fish caught at optimum length and the percentage of mega-spawners are useful indicators, allowing effective assessment of status and trends in fisheries (Froese, 2004). The target will be to catch all fish within  $Lopt \pm 10\%$  to obtain the maximum possible yield in the Gulf of Tunis; 59.27% of the individuals were caught within these size limits. According to Froese (2004), mega-spawners are much more fecund females and constitute reservoirs and distributors of desirable genes that naturally safeguard against recruitment failure by their longevity and by the extension of their reproductive phase. Mega-spawners are represented by all fish whose size is larger than optimum length plus 10%. Moreover, as no upper size limit exists in the Gulf of Tunis, the catch reflects the age and size structure of the stock and the percentage of mega-spawners in the catch is an indicator of the state of the stock. In the sample of the Gulf of Tunis, mega-spawners comprise 28.95% of the stock which represents an almost healthy age structure for the striped seabream.

**Table 3.** Biogeographic comparison of the von Bertalanffy growth parameters of *L. mormyrus*

Sector	Authors	Area	N	M	Sex	TL (cm)	TL <sub>∞</sub> (cm)	k (years <sup>-1</sup> )	t <sub>0</sub> (years)	Φ'	A
Atlantic Sea	Abecasis <i>et al.</i> (2008)	Portugal	530	O	CS	6–42	37.10	0.210	−1.24	2.46	13
	Pajuelo <i>et al.</i> (2002)	Canary Islands	427	O	F + M	11.3–35	42.70	0.190	−1.46	2.53	8
	Lorenzo <i>et al.</i> (2002)	Canary Islands	429	O	F + M	11.3–37.2	42.90	0.188	−1.37	2.54	10
	Monteiro <i>et al.</i> (2010)	Southern Portugal	548	S	F + M	6.7–42.7	35.30	0.264	−0.80	2.52	13
Mediterranean Sea	Kraljević <i>et al.</i> (1996)	Northern Adriatic		S	CS	19.4–37.6	40.05	0.196	−0.94	2.49	12
	Türkmen and Akyurt (2003)	Iskenderun Bay (Turkey)	3335	O	F + M	9.1–27.7	30.22	0.157	−2.12	2.15	7
	Kallianiotis <i>et al.</i> (2005)	Thracian Sea (Greece)	1688	O	CS	5.1–34.1	30.94	0.210	−0.99	2.30	11
	Osman (2005)	Alexandria		S	F + M	–	37.08	0.127	−1.49	2.24	7
			292	S	CS	3–40	43.70	0.100	−2.80	2.28	14
	Vitale <i>et al.</i> (2011)	Strait of Sicily (Licata)		O	CS	12–32.6	38.44	0.200	−1.48	2.47	8
		Strait of Sicily (Selinunte)		O	CS	13–32.9	38.39	0.224	−1.01	2.52	10
	Boufersaoui <i>et al.</i> (2018)	Central coast of Algeria	449	O	CS	11.5–34.5	34.85	0.280	1.12	2.5	7
	Ben Abdallah-Ben Hadj Hamida <i>et al.</i> (2016)	Gulf of Gabes (Tunisia)		O	M	9.7–24.1	30.99	0.114	−2.39	2.04	8
					F		31.37	0.112	−2.20	2.04	8
Present study	Gulf of Tunis (Tunisia)	449	O	CS	6–27.5	30.18	0.310	−2.31	2.19	7	
Mediterranean Lagoon	Emre <i>et al.</i> (2010)	Beymelek Lagoon	399	S	CS	14.3–27.4	31.50	0.319	−2.20	2.50	4

N, number of fish; M, Method; O, Otolithometry; S, Scalimetry; F, female; M, male; CS, combined sexes (males, females, hermaphrodites, unsexed); M + F = males + females; TL, total length; TL<sub>∞</sub>, asymptotic length; k, growth coefficient; t<sub>0</sub>, theoretical age at zero length; Φ', growth performance index; A, maximum age.

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