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GROWTH PATTERNS AND AGE STRUCTURE OF *MULLUS SURMULETUS* (MULLIDAE) FROM THE NORTHERN COAST OF TUNISIA (CENTRAL MEDITERRANEAN SEA)

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Institut National des Sciences et Technologies de la Mer, port de pêche, 2025 La Goulette, Tunisia

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ABSTRACT

Age and growth of striped red mullet, *Mullus surmuletus* Linnaeus, 1758 were estimated using sagittal otoliths from specimens collected off the northern coast of Tunisia between January 2005 and December 2007. In the studied sample, the males outnumbered the females ($\text{♀}/\text{♂} = 0.56$). The age composition ranged from one to five years, and most specimens belonged to the one-year age group. The length-weight relationship displayed positive allometry for both sexes. The fit of the von Bertalanffy growth curve was significantly different between sexes ($p < 0.05$): $TL_{\infty} = 267.8$ mm, $k = 0.242$ year⁻¹, $t_0 = -1.343$ years for males and $TL_{\infty} = 284.1$ mm, $k = 0.293$ year⁻¹, $t_0 = -0.872$ years for females.

Key words: *Mullus surmuletus*, sex ratio, growth parameters, length–weight relationship, Tunisia

MODELLI DI CRESCITA E STRUTTURA D'ETÀ DI *MULLUS SURMULETUS* (MULLIDAE) DELLA COSTA SETTENTRIONALE DELLA TUNISIA (MEDITERRANEO CENTRALE)

SINTESI

L'età e la crescita della triglia di scoglio, *Mullus surmuletus* Linnaeus, 1758 sono state stimate utilizzando gli otoliti sagittali di esemplari raccolti al largo della costa settentrionale della Tunisia tra gennaio 2005 e dicembre 2007. Nel campione studiato, i maschi hanno superato le femmine ($\text{♀}/\text{♂} = 0,56$). La composizione per età variava da uno a cinque anni, e la maggior parte degli esemplari apparteneva al gruppo di età di un anno. La relazione lunghezza-peso ha mostrato un'allometria positiva per entrambi i sessi. L'adattamento della curva di crescita di von Bertalanffy era significativamente diverso tra i sessi ($p < 0,05$): $TL_{\infty} = 267,8$ mm, $k = 0.242$ anno⁻¹, $t_0 = -1.343$ anni per i maschi, e $TL_{\infty} = 284,1$ mm, $k = 0,293$ anno⁻¹, $t_0 = -0.872$ anni per le femmine.

Parole chiave: *Mullus surmuletus*, rapporto fra sessi, parametri di crescita, rapporto lunghezza-peso, Tunisia

INTRODUCTION

The striped red mullet *Mullus surmuletus* Linnaeus, 1758 is one of the main target species of demersal fisheries in Tunisia constituting about 3% of total catch of demersal fishes (anonymous, 2018). This species is mainly exploited by trawl fishery in southern areas and small-scale fleets in northern areas (Chérif, 2013). Several aspects of *M. surmuletus* biology have been studied, including feeding and reproduction (Chérif *et al.*, 2007a, 2008a, 2013). Only a preliminary study on the age and growth patterns of the striped red mullet in northern Tunisian areas was conducted based on a scales analysis (Gharbi, 1980). Similarly, several studies reported that otoliths are the most widely used because they have proven to be a reliable and valid method for age determination in mullid species (Mahé *et al.*, 2016; ICES, 2017. Carbonara *et al.*, 2018).

The purpose of this paper is to determine age from otolith readings and estimate the growth parameters from length-age values. Additionally, length-weight relationships of *Mullus surmuletus* are calculated for specimens from the northern coast of Tunisia. The results of the study could complement previous studies and help improve strategies and policies for a sustainable production in the area.

MATERIAL AND METHODS

The otoliths of *M. surmuletus* were monthly collected from specimens caught off the northern Tunisian coast (Fig. 1) between January 2005 and December 2007. The specimens were captured by commercial trawlers using a Tunisian shrimp trawl with a stretched-mesh size of 52 mm in the wing and 40 mm in the cod end (Chérif *et al.*, 2007b). After landing, the specimens were sorted by sex, their total length (TL) was measured to the nearest millimetre and total weight (TW) recorded to the nearest gram.

A total of 410 otoliths were used for ageing. Sagittal otoliths were removed, cleaned, and put in labelled envelopes with full information for further readings. All otoliths were placed in a concave black dish and examined using the reflected light of a binocular microscope at 10x magnification.

The length-weight relationship was described by the formula proposed by Ricker (1973): $W = aTL^b$, where (W) is the weight in grams, (TL) the total length in mm, (b) the growth exponent, and (a) is a constant. The hypothesis of isometric growth was tested using a t-test (Zar, 1999).

Growth was expressed in terms of the von Bertalanffy equation: $L_t = L_\infty (1 - e^{-K(t-t_0)})$, where (L_∞) is the asymptotic total length, (L_t) the total length at

age (t), (K) the growth curvature parameter, and (t_0) the theoretical age of fish at zero total length. For weight growth, the same function was used: $W_t = W_\infty (1 - e^{-k(t-t_0)})^b$, where (W_t) is the total weight, (W_∞) is the asymptotic weight, and (b) is the power constant of the length-weight relationship. The Fishparm software including the non-linear estimation method was used to estimate the growth parameters (Saila *et al.*, 1988).

RESULTS

Sample characteristics, sex ratio, and length-weight relationship (LWR)

Of the 818 examined specimens, 426 were females, 328 males, and 64 were unidentified. In the present sample females significantly outnumbered males (m/f= 0.56) 1:1 ($\chi^2=13.57$; df = 1; $P < 0.05$). The TL of the striped red mullet ranged from 66 mm to 262 mm and the weight from 4.56 g to 244.73 g. The TL of females ranged from 111

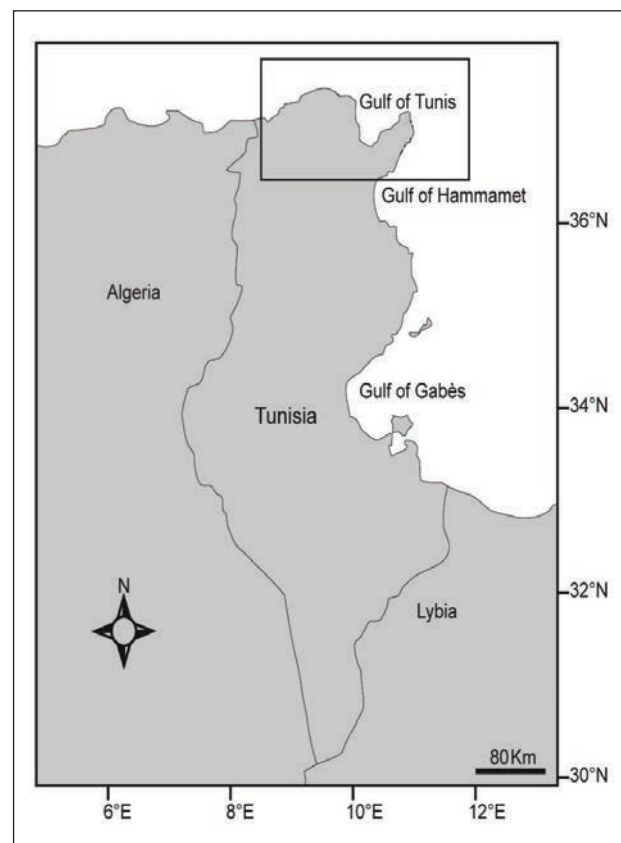
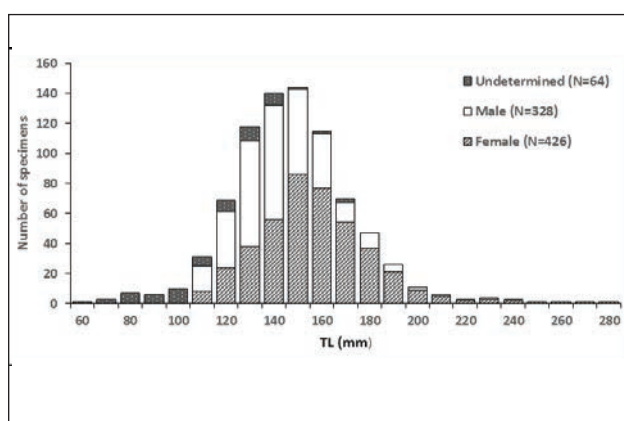


Fig. 1: Map of the Tunisian coast with a rectangle indicating the sampling area of *Mullus surmuletus*.

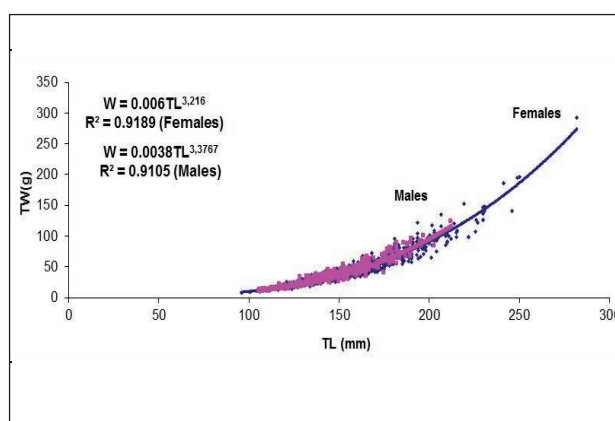
Sl. 1: Zemljevid tunizijske obale s pravokotnikom, ki označuje območje vzorčenja progastega bradača.

Tab. 1: Sample characteristics of *Mullus surmuletus* from the northern coast of Tunisia.**Tab. 1: Značilnosti vzorcev progastih bradačev s severne obale Tunizije.**

Sex	Length (mm)			Weight (g)		
	Min	Max	Mean	Min	Max	Mean
Male	105	212	145.2	9.85	123.73	34.74
Female	111	262	160.6	9.41	244.73	49.01
Unsexed	66	175	120.1	4.56	57.97	20.58

**Fig. 2: Length-frequency distribution by sex of *Mullus surmuletus*.**

Sl. 2: Dolžinsko-frekvenčna porazdelitev glede na spol progastih bradačev.

**Fig. 3: Length-weight relationship of *Mullus surmuletus* (females and males).**

Sl. 3: Razmerje med dolžino in težo progastih bradačev (samice in samci).

mm to 262 mm and the TL of males from 105 mm to 212 mm. The TW of females ranged from 9.41 g to 244.73 g and the TW of males from 9.85 g to 123.73 g (Tab. 1). The dominant length group was 130–160 mm, which represented 63.2% of all examined specimens (Fig. 2). Females prevailed in size classes larger than 150 mm, whereas males significantly outnumbered females in smaller size classes ($\chi^2 = 9.81$; $df = 1$; $P < 0.05$).

The length-weight relationship of *Mullus surmuletus*, as presented in Table 2 and Figure 3, indicated a positive allometry for males, females, and all specimens. The (b) coefficient was significantly different from 3 (t-test, $P < 0.05$). In addition, the (R^2) values for relationships among males, females, and all fish indicated a strong correlation between length and weight.

Age and growth

The age sample consisted of sagittal otoliths from 218 females, 104 males, and 88 fish of unidentified sex. Age estimates ranged from 1 to 5 years for males, females, and all specimens. Most of the fish, i.e., 90% of the total sample, were between 1 and 3 years old (Fig. 4). Specimens older than 4 years old were poorly represented in the sample.

The von Bertalanffy relationships between age and length, derived from the assumed annual periodicity of the growth increments, were described by the growth parameters (Tab. 3; Fig 4):

$TL_{\infty} = 267.8$ mm, $k = 0.242$ year⁻¹, $t_0 = -1.343$ years for males;

Tab. 2: Length-weight relationship parameters of *Mullus surmuletus*.**Tab. 2: Dolžinsko-masni parametri progastih bradačev.**

Equations	Sex	a	b	R ²	t-test	Allometry
$W = aTL^b$	♀	0.0061	3.216	0.9189	7.51	+
	♂	0.0038	3.3767	0.9105	9.13	+
	combined sexes	0.0036	3.3279	0.8922	11.09	+

Tab. 3: Age and growth parameters of *Mullus surmuletus* in the northern coast of Tunisia.**Tab. 3: Starostni in rastni parametri progastih bradačev na severni obali Tunizije.**

	Males (N = 104)	Females (N = 218)	All individuals (N = 410)
Age (years)	TL (mm) (Average + SD)	TL (mm) (Average + SD)	TL (mm) (Average + SD)
I	115.2±1.4	120.3±0.9	117.8±0.7
II	159.4±0.3	161.4±1.1	156.7±0.6
III	182.8±0.7	192.9±1.3	182.1±0.9
IV	199.3±0.2	216.8±1.5	206.1±1.9
V	210.6±0.9	233±0.8	221.8±1.4
Growth parameters (L_{∞}, W_{∞}, K and t_0)			
L_{∞} (mm)	267.8	284.1	274.6
K	0.242	0.293	0.271
t_0	-1.343	-0.872	-1.071
W_{∞} (gr)	251.8	283.5	269.96

$TL_{\infty}=284.1$ mm, $k=0.293$ year⁻¹, $t_0 = -0.872$ years for females;

$TL_{\infty}=274.6$ mm, $k=0.271$ year⁻¹, $t_0 = -1.071$ years for all individuals.

Females tend to grow slightly faster in length than males. The growth patterns by sex were similar up to the age of 1 year (group I), after that age, the females grew faster and attained a greater maximum length

than males (Fig. 6). Significant differences were found between the growth of males and females (t-test, $P < 0.05$).

DISCUSSION

The present sample, with the females significantly outnumbering males, is in total accordance

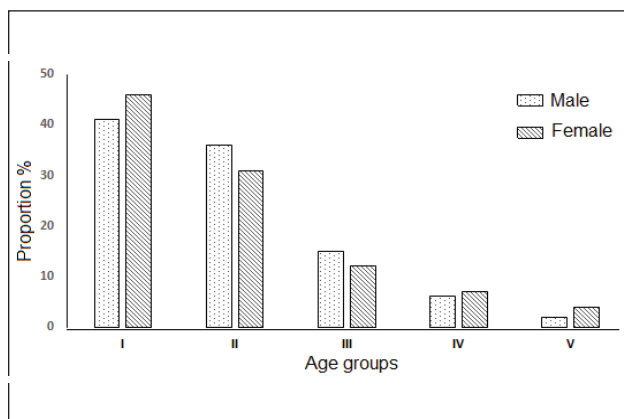


Fig. 4: Age group proportions for females and males of *Mullus surmuletus*.

Sl. 4: Razmerja starostnih skupin za samice in samce progastih bradačev.

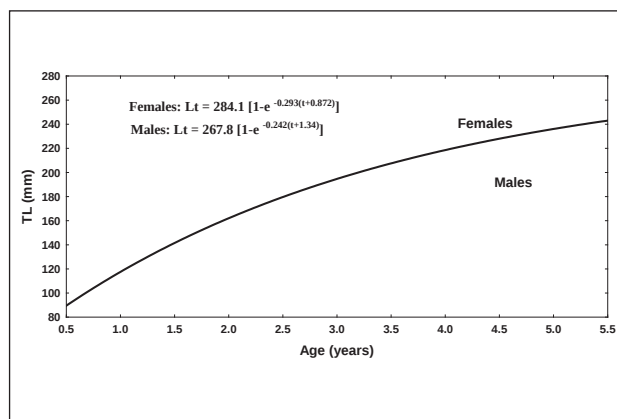


Fig. 5: The von Bertalanffy growth curve for females and males of *Mullus surmuletus*.

Sl. 5: Von Bertalanffyjeva krivulja rasti za samice in samce progastih bradačev.

with previous reports (Hashem, 1973; Gharbi & Ktari, 1981b; Pajuelo *et al.*, 1997; Amin *et al.*, 2016). Such pattern could be due to differences in the spatial distribution of males and females in the water column, as suggested by Lozano-Cabo (1983) and Caminias *et al.* (1990). It also appears that females are captured more frequently than males during fishing efforts because of the body shape dimorphism: females are heavier and fatter than males (N'Da *et al.*, 1993; Jabeur, 1999; Chérif *et al.*, 2007b).

The length-weight relationship of *M. surmuletus* in the northern area of Tunisia displays a positive allometric growth, showing that the species finds favourable conditions to develop and reproduce in the wild. The analyses of the LWR provided by several authors show, however, some differences in *b* values (Tab. 4). This variability in *b* values could be explained by many factors, such as food availability, environmental conditions, sampling methods, and the stage of maturity (Shepherd & Grimes 1983; Pauly, 1984; Chérif *et al.*, 2008b).

Males and females of *M. surmuletus* grew similarly in weight during the first year of life, after that age, the females grew faster and attained a greater maximum weight than males. This differential growth between sexes is attributed to differences in reproductive physiology and feeding behaviour (Ricker, 1975; Morey *et al.*, 2003; Chérif *et al.*, 2021). Mahé *et al.*, 2013 reported that the growth was important during the first year and slowed down thereafter. This reduction in the growth rate coincided with the age at first maturity, reflecting that the energy used for reproduction is no longer available for somatic growth (Pauly, 2010; Grabowska *et al.* 2011).

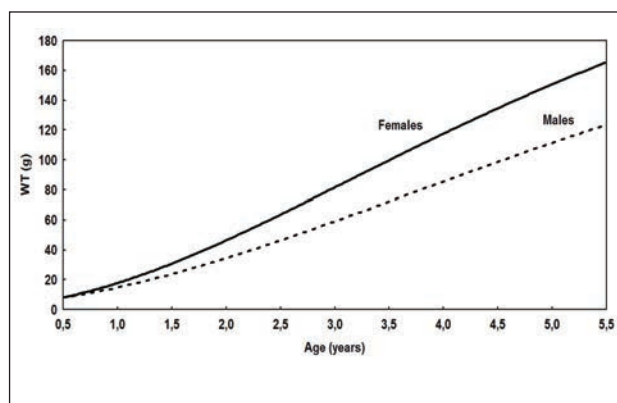


Fig. 6: Growth patterns for females and males of *Mullus surmuletus*.

Sl. 6: Rastni parametri za samice in samce progastih bradačev.

The use of whole sagittal otoliths for age determination concerning mullid species was considered to be the most suitable method and displaying the best results because the alternative pattern of translucent and opaque zones was easily distinguishable (Pajuelo *et al.*, 1997; Mahé *et al.*, 2012, 2013). Thus it was determined that the individuals sampled from the northern area of Tunisia belonged to age groups I–V. The specimens were mostly between 1 and 3 years old.

The growth rate of *M. surmuletus* recorded in this study is very similar to that reported for the same species in other areas (Tab. 4), except in the Catalonia region, where Andaloro (1981, 1982) and Sanchez *et al.* (1983) found that red

Tab. 4: Growth parameters (L_{∞} , t_0 and k) and the length-weight relationship (a and b) for *Mullus surmuletus* from different localities.**Tab. 4: Rastni parametri (L_{∞} , t_0 in k) in razmerje med dolžino in težo (a in b) za progaste bradače iz različnih lokalitet.**

Area	L_{∞} (mm)	t_0	K	a	b	Reference
Marmara Sea	328.3 TL	-2.13	0.23	0.0089	3.12	Moldur (1999)
Aegean Sea	278.2 TL	-2.16	0.2	0.0084	3.12	Mukadder & Ismen (2013)
Egyptian coast	317.4 TL	-0.30	0.47	0.0104	3.0617	Mehanna (2009)
Izmir Bay	278.5 TL	-1.58	0.19	0.0083	3.127	İlhan <i>et al.</i> (2009)
Edremit Bay	250.9 TL	-2.48	0.14	0.0044	3.35	Üstün (2010)
Mediterranean Sea	276 TL	0.39	0.27	-	2.925	Andalora (1981)
Catalan Sea	309.4 TL	3.85	0.11	-	-	Morales-Nin (1986)
Majorca	297.6 TL	-2.06	0.24	0.016	2.91	Morales-Nin (1991)
Majorca	312.8 TL	-2.35	0.21	0.009	3.12	Reñones <i>et al.</i> (1995)
Gulf of Gabés	212 TL (♀)	-0.65	0.43	710-6	3.12	Jabeur <i>et al.</i> (2000)
	226 TL (♂)	-1.07	0.27			
Gulf of Biscay	427 TL (♀)	0.641	0.28	-	-	N'Da <i>et al.</i> (2006)
	359 TL (♂)	0.74	0.30			
Gulf of Tunis	218.2 SL (♀)	-0.112	0.51	0.1403	3.351	Gharbi & Ktari (1981a)
	198.7 SL (♂)	-0.025	0.49	0.1443	3.28	
Catalonia	355.2 TL	-3.65	0.11	0.0073	3.1	Sanchez <i>et al.</i> (1983)
Canaries	357.1 TL	-1.84	0.22	0.0074	3.1826	Pajuelo <i>et al.</i> (1997)
English Channel	511.7 TL (♀)	-2.9	0.2	3,2810-6	3.24	Mahé <i>et al.</i> (2013)
	360.4 TL (♂)	-3.23	0.22			
Moroccan coast	392 TL	-3.21	0.3	0.0071	3.17	Bakali <i>et al.</i> (2016)
Northern Tunisian coasts	267.8 TL (♂)	-1.343	0.242	0.0061	3.216	Present study
	284.1 TL (♀)	-0.872	0.293	0.0038	3.376	
	274.6 TL (♂+♀)	-1.071	0.271	0.0036	3.327	

mullet can reach the age of 7. In that region, Andaloro and Giarritta (1985) and Reñones *et al.* (1995) recorded fish up to 6 years old, while Bougis (1952), Hashem (1973), and Morales Nin (1991) recorded them up to 3, 5, and 4 years old, respectively. According to Pajuelo *et al.* (1997), these age differences are attributable to

differences in the lengths of the largest fish sampled in the various studies and the selectivity of fishing gears. Finally, the results obtained from the current study provide much information that may be useful for stock assessment and optimal management in the study area and other regions of the Mediterranean Sea.

RASTNI PARAMETRI IN STAROSTNA STRUKTURA PROGASTIH BRADAČEV *MULLUS SURMULETUS* (MULLIDAE) IZ SEVERNE TUNIZIJSKE OBALE (OSREDNJE SREDOZEMSKO MORJE)

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POVZETEK

Avtorji so ocenjevali starost in rast progastih bradačev, *Mullus surmuletus* Linnaeus, 1758, ujetih blizu severne tunizijske obale med januarjem 2005 in decembrom 2007 na podlagi sagitalnih otolitov. Samcev je bilo več kot samic ($\frac{\text{♀}}{\text{♂}} = 0,56$). Starostna struktura je bila od 1 do 5 let, pri čemer je glavnina primerkov pripadala starostni skupini v prvem letu. Dolžinsko-masni odnos je pokazal pozitivno alometrijo za oba spola. Prileganje von Bertalanffyjeve rastne krivulje se je med spoloma bistveno razlikovalo ($p < 0,05$): telesna dolžina $\infty = 267,8$ mm, $k = 0,242 \text{ leto}^{-1}$, $t_0 = -1,343$ leta za samce in telesna dolžina $TL_{\infty} = 284,1$ mm, $k = 0,293 \text{ leto}^{-1}$, $t_0 = -0,872$ leta za samice.

Ključne besede: *Mullus surmuletus*, razmerje med spoloma, rastni parametri, dolžinsko-masni odnos, Tunizija

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