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Age and growth of *Spondyliosoma cantharus* (Sparidae) in the Gulf of Tunis

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Summary: Age and the growth of the black seabream *Spondyliosoma cantharus* (Linnaeus, 1758) from the Gulf of Tunis were investigated using scales and otoliths. The length-weight relationship showed that the growth rates were isometric for females whereas males and the whole sample present a positive allometry. The monthly evolution in marginal increment data of scales and otoliths revealed that only one annulus is formed per year in April. Fish length and radii of the scales or otoliths were closely correlated. The von Bertalanffy growth equation was fitted on mean back-calculated length-at-age data, resulting in the parameter values L_∞=35.4 cm, k=0.15 y^{-1} and t_0=–0.19 y for scales and L_∞=38.6 cm, k=0.10 y^{-1} and t_0=–0.14 y for otoliths. Parameters estimated from scale and otoliths were significantly similar. However, taking into consideration the lower standard deviations of means for estimates based on otolith readings and the higher variance explained by the regression line fitted to otoliths, the latter seem to be more appropriate for ageing *S. cantharus*. The maximum age of the black seabream of the Gulf of Tunis is 10 years. Large discrepancies in growth parameters between geographic areas are the result of different growth patterns.

Keywords: *Spondyliosoma cantharus*; growth ; scales; otoliths; length-weight relationship; Gulf of Tunis.

Edad y crecimiento de *Spondyliosoma cantharus* (Sparidae) en el Golfo de Túnez

Resumen: Se han investigado la edad y el crecimiento de la cántara *Spondyliosoma cantharus* (Linnaeus, 1758) del Golfo de Túnez a partir de la lectura de las escamas y los otolitos. La relación talla-peso revela que las tasas de crecimiento son isométricas en las hembras, mientras que los machos y en toda la muestra existe una alometría positiva. La evolución mensual de los incrementos marginales de las escamas y los otolitos muestra que se forma un solo anillo anual en abril. La correlación entre la longitud de los peces y el radio de las escamas o los otolitos es muy elevada. La ecuación de crecimiento de von Bertalanffy se ha ajustado a la media talla-edad retrocalculada resultando en los siguientes valores para los parámetros de las escamas (L_∞=35.4 cm, k=0.15 año^{-1}, t_0=–0.19 año) y los otolitos (L_∞=38.6 cm, k=0.10 año^{-1}, t_0=–0.14 año). Los parámetros estimados a partir de las escamas y los otolitos resultaron significativamente similares. Sin embargo, teniendo en cuenta que las desviaciones estándar de las medias en las estimas son más bajas, y que la varianza explicada es mayor en la regresión ajustada a los otolitos, la lectura de los otolitos parece ser la más apropiada para datar la edad de *S. cantharus*. La edad máxima de la cántara del Golfo de Túnez es de 10 años. Las grandes diferencias en los parámetros de crecimiento entre áreas geográficas se deben a diferentes pautas de crecimiento.

Palabras clave: *Spondyliosoma cantharus*; crecimiento; escamas; otolitos; relación talla-peso; Golfo de Túnez.

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INTRODUCTION

The genus *Spondyliosoma* Cantor, 1849 is represented by one species in the Mediterranean Sea: the black seabream, *Spondyliosoma cantharus* (Linnaeus, 1758). This species, belonging to the Sparidae family, occurs in the eastern Atlantic from Scandinavia to Namibia and around the Madeira, Cape Verde and Canary Islands (Heemstra 1995); it is also common in the Mediterranean Sea and rare in the Black Sea. The black seabream is a relatively common fish of inshore waters on rocky and sandy bottoms (Bauchot and Hureau 1986).

Despite the wide distribution of *S. cantharus*, the majority of biological studies, in particular on reproductive aspects, have been reported from the eastern Atlantic (Perodou and Nedelec 1980, Soletchnik 1983, Balguerías Guerra et al. 1993, Pajuelo and Lorenzo 1999, Gonçalves and Erzini 1998). In the Mediterranean Sea, some aspects of black seabream growth (Dulčić and Kraljević 1996), recruitment (Guidetti and Bussotti 1997), fecundity (Dulčić et al. 1998) and reproduction (Mouine et al. 2011) have been described.

Due to low commercial interest of the black seabream on the Tunisian coast, the catch statistics of this species were unfortunately not available. Therefore, no specific management plan has been developed in spite of the vulnerability of this species owing to its sexual pattern characterized by protogynous hermaphroditism (Mouine et al. 2011).

Estimation of accurate fish age is considered an essential step for age-based assessment of fish population and successful resource management. Because of the lack of basic biological information for the black seabream in Mediterranean, the objective of this study is to provide information on the age and growth of this species in the Gulf of Tunis. First, parameters of length-weight relationship were estimated for males, females and all fish. Second, the reliability of age estimates of *S. cantharus* was tested by evaluating the precision of two hard structures, scales and otoliths and by validating the yearly frequency and timing of ring formation on both hard pieces. Finally, age and growth parameters were estimated from the analysis of marks recorded in the two hard structures and compared with those from other areas.

The results of this study can be used as biological input parameters for further evaluation of the black seabream stock in the Gulf of Tunis and lead to improved management

MATERIALS AND METHODS

Sampling

Samples were collected from the commercial trammel and gill net catches of the artisanal fleet in the Gulf of Tunisia from January 2005 to June 2006. A total of 369 black seabream were collected fortnightly at the landing port and stored in iceboxes. In the laboratory, for each fish, the total length (TL) was measured to the nearest millimetre and the total weight (TW) to the nearest gram. Macroscopic examination of gonads was used to determine the sex of individuals as males, females, immatures and hermaphrodites. Sagittal otoliths were extracted from each specimen, cleaned and stored dry in paper envelopes. Scales were sampled from the left side of the body beneath the pectoral fin, cleaned and mounted between glass slides.

Scale and otolith preparation and reading techniques

Whole otoliths were immersed in a glycerine-ethanol (1:1) solution, to improve the visualization of annual increments, and examined under a compound microscope with reflected light against a dark background. Increments on the whole otoliths comprised two zones: an opaque zone; and a narrower translucent zone, which appears dark with reflected lighting and a black background (Mann-Lang and Buxton 1996). Typically, opaque and translucent increments are seen alternating outward from the nucleus. The succession of one opaque band and one translucent band was considered one annual increment. The count path of annuli was from the core towards the tip of the rostrum where they were most visible. Distance from otolith core to rostrum (Ro) and radius of each annulus were measured with an ocular micrometer. Likewise, distances from the scale focus to each annulus and to the margin (Rs) were recorded at the left edge.

Length-weight relationship

The relationship between total weight (g) and TL (cm) was described by the power function $TW=aTL^b$. The regression parameters a, b and the coefficient of determination (r^2) were estimated for both for the whole population and for each sex by least square linear regressions after log transformation of both variables. According to Ricker (1973), the slope of the regression was corrected to follow a geometric mean regression. Student's t-test was used to appreciate the hypothesis of isometric relationship (H_0: slope=3; H_1: slope≠3), whereas analyses of covariance (ANCOVA) were employed to detect any significant differences in the linear relationships between sexes (Zar 1999).

Age accuracy and validation

Each otolith was examined twice by a single reader, with an interval of 3-4 months between readings, and only coincident interpretations were accepted. All counts were performed in random order of fish size and without reference of fish length, sex or the previous reading. The consistency in otoliths readings was quantified by calculating the index of average percentage error (IAPE) (Beamish and Fournier 1981).

To validate seasonality of deposition of the opaque and translucent zone, the marginal increment analysis was carried out on the entire otolith and scale samples (Jearld 1983). The marginal increment (MI, 0.01 mm) was measured as the distance from the inner margin of the outermost ring and the periphery of each otolith or scale. The Kruskal-Wallis test was used to test the homogeneity of MI among months followed by a Student-Newman-Keuls nonparametric test after null hypothesis rejection (Zar 1999).

In detail, the change in relative frequency of each edge zone was plotted across months all year round; the cycle frequency of formation of the opaque and translucent zones should equal one year in true annuli (Campana 2001). According to the study on the reproductive characteristics of *S. cantharus* in the Gulf of Tunis (Mouine et al. 2011), the peak of the reproductive season is between March and April, so 1 May was considered the birth date of fish.

Table 1. – Parameters of the length-weight relationships for females, males and all fish (males, females, immatures and hermaphrodites) of *Spondyliosoma cantharus* in the Gulf of Tunis. All three relationships were significant (ANOVA, $p<0.001$). The isometry was tested by Student t-test (H_0: t=3); a, intercept; b, slope; s.e. (b), standard error of b; n, sample size; r^2, coefficient of determination.

	a	b	s.e (b)	n	r^2	t-test	p
Males	0.012	3.099	0.111	15	0.975	8.306	0.000
Females	0.012	3.098	0.025	330	0.990	1.608	0.109
All fish	0.012	3.100	0.021	369	0.991	3.887	0.000

Back-calculated size of each fish at the time of formation of each annulus was determined by substituting the measurement of each annulus in the body proportional equation (Francis 1990). The relationship between the radius of the scale or the otolith at capture and the TL was estimated by regressions of log (TL) on log (rs) or log (ro). The length of an individual when the i_{th} band is laid down (Li, mm) was calculated according to the formula: $(ri/r)^{v}$ Lc, where ri is the radius of the i_{th} band, r is the radius of otolith or scale at capture, Lc is the length at capture and v is the constant derived from the power function that describes the relationship between the radius of the calcified structures and TL of fish (Francis, 1990). To summarize the age composition of *S. cantharus*, age-length keys were constructed.

Growth model

The von Bertalanffy growth model, by far the most commonly used to estimate growth in fishes, was fitted to the back-calculated mean length at age for the whole population by means of Marquardt's algorithm for non-linear least squares parameter estimation (Prager et al. 1989):

$$Lt=L_{\infty}\,(1-e^{-k\,(t-t_0)}),$$

where Lt is the length at age t, L_{∞} is the asymptotic length, k is the growth coefficient, and t_0 is the theoretical age at zero length.

Statistical comparisons of growth equations between structures (otoliths and scales) were conducted using Hotteling tests (Zar 1999).

The growth performance index Φ', expressed as the logarithmic relationship between the von Bertalanffy growth coefficient and asymptotic length, was used to compare growth of *S. cantharus* between regions.

RESULTS

Length-weight relationship

Among the 369 fish individuals examined, 15 were males, 330 were females, 6 were hermaphrodites, and the remaining 18 individuals were immatures with small gonads. The length and weight of the black seabream ranged from 13.4 to 36.6 cm and total weight from 39 to 806 g TW, respectively. TL of males ranged from 16.0 to 36.6 cm and TW from 72 to 806 g. Female TL ranged from 13.4 to 31.6 cm and TW from 39 to 564 g.

The parameters of the linear regression of the weight and length logarithm are provided for each sex and all individuals in Table 1. Results showed that the growth rates were isometric for females, whereas males and the whole sample showed a positive allometry (t-test, $p<0.05$). The ANCOVA test indicated that length-weight relationships were not significantly different in slopes or intercept between the two sexes (ANCOVA, n=345; $p>0.05$).

Age accuracy and precision

Otoliths and scales of *S. cantharus* showed clear growth rings. The annuli from the scales were easily and clearly identifiable (Fig. 1) since among the total scales examined, 367 (99.5%) were useful for age es-

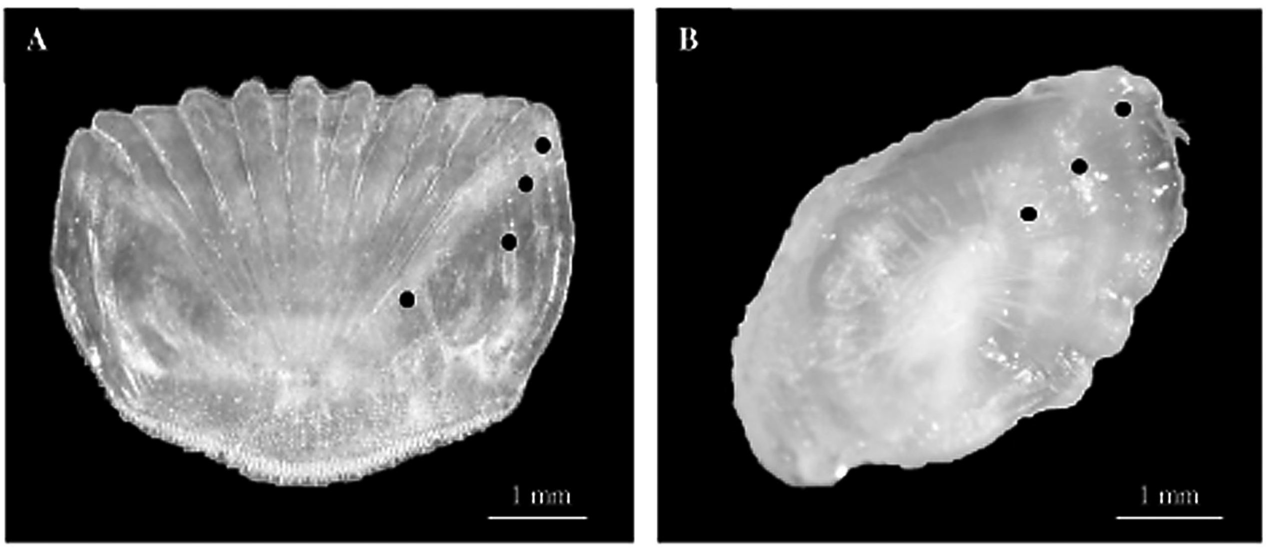

Fig. 1. – Examples of scale (A) and sagittal otolith (B) of *Spondyliosoma cantharus* from the Gulf of Tunis. A, individual of 4 years of age (TL=17.1 cm); B, individual of 3 years of age (TL=16.3 cm).

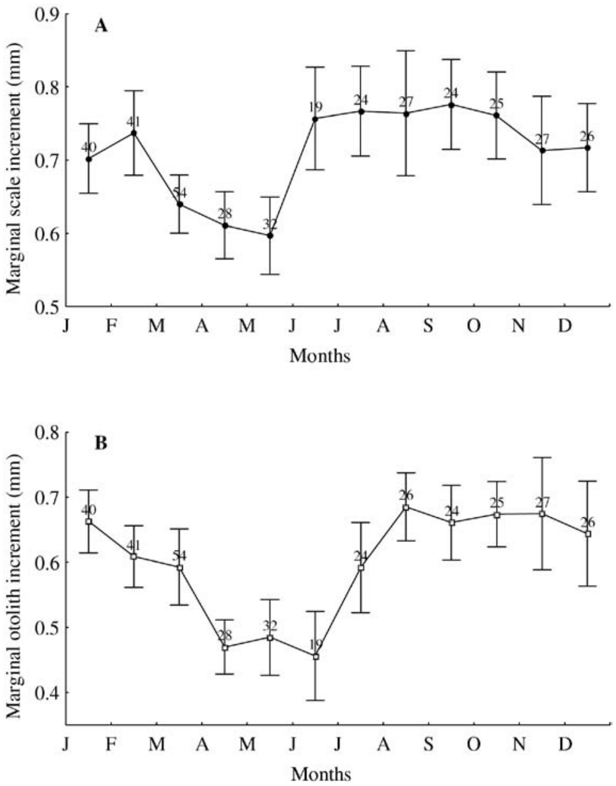

Fig. 2. – Mean monthly marginal increments of scales (A) and otoliths (B) of *Spondyliosoma cantharus* from the Gulf of Tunis. The errors bars represent ± standard error with monthly sample size above.

timation. Black seabream otolith consisted of clearly discernible opaque and translucent zones (Fig. 1). Of the total otolith removed, 366 (99.2%) were retained for age determination and the remaining ones were discarded as they showed disagreement in readings. The low IAPE of scales (1.2%) and otoliths (1.4%) demonstrated the consistency and the high precision in ageing for each structure.

Validation of otolith and scale increment

The minimum mean scale increment was observed from March to May, suggesting that the annulus formation period occurred in spring (Fig. 2A). The marginal otolith increment showed considerable monthly variation (Fig. 2B) but with a consistent pattern of higher values from August to November and lower values from April to June, the months corresponding to the annulus formation period (Kruskall-Wallis test, p=0.006). The monthly trends in MI data of scales and otoliths were consistent and revealed that only one annulus is formed per year in April.

Age and growth

The relationships between TL and otolith radius (Ro) or scale radius (Rs) was calculated for females, males and the sexes combined. Fish length and radii of the calcified structure were closely correlated (p=0.00; Fig. 3). The analysis of covariance showed that for the length-radius (otolith or scale) relationship there was no significant difference between sexes (ANCOVA, p>0.05). Thus, for the estimation of back-calculated lengths at each age we used the relationships with sexes combined.

Back-calculated length-at-age data were fitted to von Bertalanffy growth function, and the parameters of mean (±s.e) L_∞, k and t_0 were estimated to be 35.4 (±5.3) cm, 0.155 (±0.04) and –0.193 (±0.27) year, respectively, for scalimetry and 38.6 (±3.2) cm, 0.100 (±0.02) and –0.142 (±0.12) year, respectively, for otolithometry. Parameters estimated from scale and otoliths were significantly similar (Hotteling T^2 test, T^2=14.28; p>0.05). However, taking into consideration the lower standard deviations of means for estimates based on otolith readings and the higher variance explained by the regression line fitted to otoliths (r^2=0.984 and 0.954 for otoliths and scales, respectively), the latter seem to be more appropriate for ageing black seabream.

DISCUSSION

Length-weight relationship

The analysis of covariance showed no significant difference between males and females in the length-weight relationship for the same range of lengths, although males tended to be slightly heavier than females for the same length. This may be explained by protogyny, because females predominated in smaller size classes and males in larger classes. In fact, the

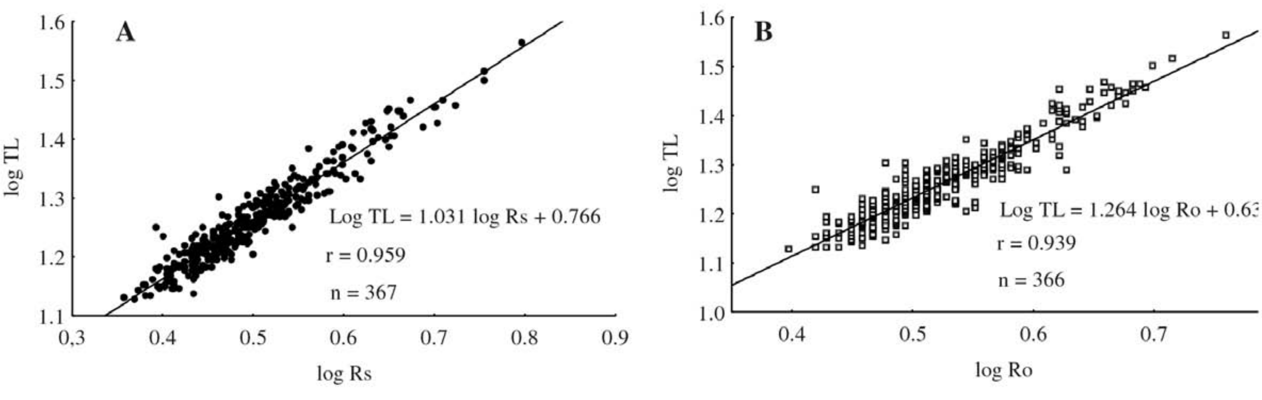

Fig. 3. – Relationships between scale (A) or otolith (B) radius and total length (TL) in cm for *Spondyliosoma cantharus* of the Gulf of Tunis.

Table 2. – Biogeographic comparison of parameters of length-weight relationships of *Spondyliosoma cantharus*. *, authors utilizing TL in mm; n, sample size; a, intercept; b, slope; s.e. (b), standard error of b; r^2, coefficient of determination.

Authors	Regions	TL (cm)			Parameters of length-weight relationships			
		n	min	max	a	b	s.e (b)	r^2
Gonçalves et al. (1996)*	Portugal	886	19.0	37.0	9.93×10^{-6}	3.066	0.038	0.88
Bradai (2000)*	Gulf of Gabes	109	8.3	27.0	1.17×10^{-5}	3.061	-	0.984
Moutopoulos and Stergiou (2002)	Greece	53	12.6	39.6	0.01772	2.951	0.079	0.97
Karakulak et al. (2006)	Turkey	46	8.2	28.7	0.019	2.87	0.151	0.891
Morey et al. (2003)	Western Mediterranean	86	6.4	31.5	0.016	2.995	0.074	0.994
Present study	Gulf of Tunis	369	13.4	36.6	0.012	3.099	0.021	0.991

Table 3. – Biogeographic comparison of von Bertalanffy growth function parameters and growth performance index (Φ') of *Spondyliosoma cantharus*. L_∞, asymptotic length; k, growth coefficient; t_0, theoretical age at zero length; n, sample size; age max, maximum age.

Authors	Regions	Methods	L_∞ (cm)	k (/an)	t_0 (an)	n	TL (cm)	Φ'	Age max
Dulčić and Kraljević (1996)	Adriatic	Scales	47.70	0.178	0.270	745	6.2 - 46.5	2.61	14
Bradai et al. (1998)	Gulf of Gabes	Scales	35.73	0.144	–1.425	109	8.3 - 27.0	2.26	6
Pajuelo and Lorenzo (1999)	Canary Islands	Otoliths	43.35	0.240	–0.110	1272	8.0 - 40.0	2.65	
Abecasis et al. (2008)	Portugal	Scales	34.48	0.210	–1.220	378	5.0 - 35.0	2.39	11
		Otoliths	30.32	0.260	–1.200	905	4.0 - 40.0	2.38	13
Present study	Gulf of Tunis	Scales	35.35	0.155	–0.193	367	13.4 - 36.6	2.29	10
		Otoliths	38.61	0.100	–1.142	366	13.4 - 36.6	2.17	10

black seabream has been catalogued as a diandric species (Mouine et al. 2011).

Biogeographic analysis of *S. cantharus* length-weight relationship showed dissimilarities among areas (Table 2). The growth mode was similar in the Gulf of Tunis and in the Gulf of Gabes, but was higher than in the other regions. The black seabream of the Turkish coast showed the weakest relative growth. These divergences can be assigned to the combination of one or several factors, such as differences of sample size and the interval of species size captured (Moutopoulos and Stergiou 2002). Petrakis and Stergiou (1995) suggest that the utilization of the length-weight relationship must be limited to the interval of size used to evaluate linear regression parameters. Otherwise, these variations are especially the reflection of environmental conditions for each locality, such as temperature, salinity of the sea water, availability of food and modifications of maturity stages.

Age and growth

Accurate estimation of fish age is considered an essential step for age-based assessment of fish population and successful resource management (Morales-Nin and Panfili 2002). Comparison of age estimates from various ageing structures has been undertaken in a number of fishes with a view to identifying the most suitable structure for a fish population (Abecasis et al. 2008).

In the current study, age and growth investigations of *S. cantharus* were conducted by using two hard parts (scales and otoliths). MI confirmed the annual pattern of deposition of an opaque and a translucent increment. It also proved that annuli were deposited (in scales and otoliths) during April, which corresponds to the spawning season (Mouine et al. 2011). This result is very close to the one in the Atlantic (Pajuelo and Lorenzo 1999, Abecasis et al. 2008) and the other subspecies *S. emarginatum* in South Africa (Fairhurst et al. 2007). Using combinations of verification (scales and otoliths) and validation (MI) is most likely to produce convincing results.

The high correlation found between TL and otoliths or scales radius indicates that both hard structures are useful for estimating age and for reconstructing past growth history of fishes by back-calculation (Campana 1990, Francis 1990). The lower standard deviations of the growth parameters for estimates based on otolith readings than on scales and the higher variance explained by the regression line fitted to otoliths indicate that the latter seem to be more appropriate for ageing black seabream. However, Abecasis et al. (2008) stated that scales are better structures for ageing the black seabream, although the scales were not easy to count, mainly because of poorly defined and sometimes double growth increments. Fairhurst et al. (2007) argued for the subspecies *S. emarginatum* that in spite of the lower precision of the whole otolith technique, the sectioned otolith method was preferred because it was free of bias.

According to the scalimetric method, the theoretical maximum length, L_∞, of *S. cantharus* is invariable on the Tunisian coasts. It is very close to that of the Portuguese coasts (Abecasis et al. 2008), but lower than that of the Adriatic (Dulčić and Kraljević 1996) (Table 3). For the otolithometry, the asymptotic length of the black seabream of the Gulf of Tunis is lower than that of the Canary Islands (Pajuelo and Lorenzo 1999), but higher than that of southern Portugal (Abecasis et al. 2008). These variations in asymptotic size are essentially the result of differences in sampling sizes and size composition of populations. In fact, growth model estimates are greatly affected by the lack of very young or old individuals. The lack of small specimens may affect our estimations of the maximum observed size and L_∞.

The growth rate k is higher in the Atlantic than in the Mediterranean. The lowest growth is recorded on the Tunisian coasts.

The maximum age observed in the present findings was 10 years for a fish of 36.6 cm TL. *S. cantharus* of the Gulf of Tunis has a smaller longevity than in the Adriatic and the Atlantic but a longer life span than in the Gulf of Gabes (Table 3).

The geographical comparison of the growth performance index Φ' of the black seabream indicates that it shows a minimal variation since it combines several parameters of the equation of von Bertalanffy (Munro and Pauly 1983) and these values are therefore characteristic of the species (Chilari et al. 2006).

Compared with other sparids, black seabream are slow-growing and short-lived, but fast to mature. These characteristics would imply that the stock can withstand more intense fishing than many other sparids, which reach marketable size long before maturity (Fairhurst et al. 2007).

The results from the current study provide practical, biologically related parameters for stock assessment and management proposals of the Mediterranean black seabream, which is a vulnerable species owing to its sexual pattern characterized by protogynous hermaphroditism (Mouine et al. 2011). Sex change is a characteristic that could place fished populations at extra risk of collapse (Fairhurst et al. 2007). A study conducted on a longline fishery using small hooks for black seabream in the Algarve, Portugal showed that of four sparids, *S. cantharus* was the most vulnerable when smaller hook sizes were used (Erzini et al. 1998). Until recently, the small size of black seabream and the steentjies *S. emarginatum* has meant that the species has largely escaped commercial interest (Fairhurst et al. 2007), but this respite may not last with increasing demand for fish and fishing opportunities, allied to the dwindling supply of reef fish.

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