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AGE, GROWTH, AND REPRODUCTION OF *DENTEX MAROCCANUS* (ACTINOPTERYGII: PERCIFORMES: SPARIDAE) IN THE SAROS BAY (NORTH AEGEAN SEA)

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Background. The Morocco dentex, *Dentex maroccanus* Valenciennes, 1830, is a sparid species, which has economical value and its population is expanding in a 20–500 m depth range throughout the Mediterranean. Worldwide, there is a lack of information about the biology (age, growth, reproductive season, first maturity length) of this species. This study provides the first data on population parameters of *D. maroccanus* in the Aegean Sea.

Materials and methods. *Dentex maroccanus* were caught in the Saros Bay (north Aegean Sea) between September 2006 and September 2008. The length–weight relations were determined according to the allometric equation: $W = aL^b$. The spawning season was determined by analyzing the maturity stages and gonadosomatic index, while first maturity length was defined as the size at which 50% of individuals were mature. Growth parameters were estimated using the von Bertalanffy growth equation.

Results. The female–male ratio was 4.8 : 1. The total length (weight) of females ranged from 11.4 cm to 25.2 cm (26.2 g to 289.3 g) and of males from 12.8 cm to 24.3 cm (19.8 g to 223.9 g). The growth parameters were calculated as $L_\infty = 25.31$ cm, $K = 0.49$ year^{-1}, $t_0 = -0.30$ year. The length at first maturity for females and males was 13.0 cm and 15.8 cm, respectively. Monthly values of the gonadosomatic index indicated that spawning occurred mainly between June and September.

Conclusion. Results reported in this work will contribute to the knowledge on the biology of *D. maroccanus* in the north Aegean Sea and also to a better understanding of its role in the marine ecosystem.

Keywords: Morocco dentex, otolith, growth, maturity, North Aegean Sea

INTRODUCTION

In the Mediterranean, sea breams (Sparidae) are represented by 22 species belonging to 10 genera (Arculeo et al. 2003), of which 14 species are also found in the north Aegean Sea (İşmen et al. unpublished**). The Morocco dentex, *Dentex maroccanus* Valenciennes, 1830, is an important demersal commercial sparid species inhabiting depths ranging from 20 to 500 m and can be found throughout the Mediterranean (absent in the Adriatic), especially in the areas featuring gravel or rubble bottoms. Morocco dentex ecologically prefers deep and higher-salinity waters. This species is distributed in the southern and eastern Mediterranean (Maravelias et al. 2007) and the Atlantic (Bay of Biscay to Gulf of Guinea) (Froese and Pauly 2014). The major studies on the Morocco dentex in the Mediterranean have been carried on its western basin and concerned the age, growth, feeding, reproduction, and distribution (Nguyen and Wojciechowski 1972, Mennes 1985, Lamrini and Bouymajjane 2002, Chemmam-Abdelkader et al. 2004, Maravelias et al. 2007). In the Aegean Sea (Saros Bay), a basin of the eastern-central Mediterranean, the sparids represent important components of the demersal fish stock and are generally caught by trawl, long line, and trammel nets. There is currently no information concerning the age, growth, and reproduction of this species or regarding the state of stocks in the Aegean Sea. Aspects concerning to the length–weight relation have been investigated, but these studies did not provide any population relations (Karakulak et al. 2006, Ceyhan et al. 2009).

As far as we know, this is the first report that provides a comprehensive picture of population parameters (length–weight relation, age, growth, reproduction, fecundity, first maturity length) of *Dentex maroccanus*, with the aim of generating sufficient information to improve future stock management and sustainable fishing.

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MATERIALS AND METHODS

Samples of *Dentex maroccanus* were collected monthly between September 2006 and September 2008 at depths ranging from 20 m to 300 m in the Saros Bay, Aegean Sea, using a commercial bottom trawl net (Cengiz et al. 2014). The final data set comprised 184 hauls and a total of 507 specimens.

Total lengths (TL) of all fish were measured to the nearest 1 cm and nearest 1 g total weight (*W*). Size of the otoliths were measured by stereomicroscope with a camera sensitive to 0.01 mm. Gonad weight was determined to the nearest 0.01 g, while sex and maturity stages were determined macroscopically. Stages of maturation were classified using the scale of Holden and Raitt (1974): immature (1), pre-mature (2), mature (3), spawning (4), and spent (5). Readings and interpretations of otoliths were based on the sagitta, which is the largest otolith (Beckman and Wilson 1995).

The length–weight relations were determined according to the allometric equation (Sparre and Venema 1989):

$$W = aL^b$$

where W is the total body weight [g], L is the total length [cm], while a is the intercept and b is the slope of the regression.

The spawning season was determined by analyzing the temporal evolution in the relative frequency of maturity stages and gonadosomatic index (GSI) (Anderson and Gutreuter 1983):

$$\mathrm{GSI} = 100 W_G \cdot W_E^{-1}$$

where W_G is the weight of the gonads and W_E is the weight of eviscerated fish. Total fecundity was determined as the total number of oocytes in the ovaries (Valladolid and Przybylski 2008). Size at maturity was defined as the size at which 50% of individuals were mature. Specimens were grouped in 1-cm size classes and the proportion of mature and immature individuals recorded (Fontana 1969, Cherif et al. 2007). The percentages of maturity by length class and sex were fitted to a logistic function using the Newton algorithm from Microsoft Excel® solver routine:

$$F_{(L)} = (1 + e^{-(\beta 0 + \beta 1 L)})^{-1}$$

where $F_{(L)}$ is the proportion of mature fish at length L, β_0 is the intercept and β_1 is the regression coefficient (Piñeiro and Saínza 2003).

Sagittal otoliths from each fish were removed, cleaned, and stored in labelled Eppendorf tubes. Age was estimated by interpreting growth rings on 194 otoliths. All otoliths were immersed in glycerol in a Petri dish, then opaque and hyaline zones were counted by a stereozoom microscope illuminated from above with a magnification up to 10 × using reflected light and a dark background. Age was determined by counting the annual ring marks on the surface of the otoliths. Growth parameters were estimated with the von Bertalanffy growth equation (Beverton and Holt 1957):

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

where L_∞ is the asymptotic length, L_t is the length at age t, K is the growth coefficient, and t_0 is the theoretical age when fish would have been at zero length. Growth parameters were estimated according to the nonlinear method using the FISAT (FAO-ICLARM Stock Assessment Tools) program package (Sparre and Venema 1989). The growth performance index (Pauly and Munro 1984) was estimated to compare growth rate by formula

$$Ø' = \log(k) + 2 \times \log(L_\infty)$$

A Kolmogorov–Smirnov two-sample test was used to determine if two datasets differed significantly and all statistical analyses were performed using SPSS 16.0.

RESULTS

A total of 507 *Dentex maroccanus* specimens were collected for this study, 185 (82%) were females and 38 males (18%) (Table 1). Approximately 30 specimens were caught each month. However, the minimum and maximum number of specimens was caught in July 2007 (n = 1) and October 2007 (n = 121), respectively. The sex of the remaining 280 fish could not be identified macroscopically due to their very thin and unclear gonads. Female–male ratio was 4.8 : 1. The majority of individual specimens were obtained from 50 to 100 m depth. A total of 52.37 kg specimens were collected and the mean CPUE was calculated at 0.5 kg · h^{-1} in Saros Bay.

Descriptive statistics for the length and weight measurements of *Dentex maroccanus* are presented in Table 1. The length and weight frequency distributions ranged from 8.9 to 25.2 cm in length and from 11.2 to 289.2 g in weight. The length frequency distribution in the *D. maroccanus* population showed that the most frequent size classes in females were 19–20 cm (about 35%) whereas for males 21 cm was most frequent (about 27%) (Fig. 1). Size frequency distribution between males and females was significantly different (Kolmogorov–Smirnov two sample test, $P < 0.05$).

There were significant differences in length–weight relations between males and females (df = 222, t_s = 2.245,

Table 1

Descriptive statistics for length and weight of *Dentex maroccanus* from the Saros Bay

Sex	n	Total length		Total weight	
		Mean ± SE [cm]	Range [cm]	Mean ± SE [g]	Range [g]
Female	185	18.4 ± 0.17	11.4–25.2	96.7 ± 2.58	26.2–289.3
Male	38	19.7 ± 0.42	12.8–24.3	120.0 ± 7.71	19.8–223.9
Total	507	17.7 ± 0.13	8.9–25.2	89.7 ± 1.77	11.2–289.3

n = number of specimens, SE = standard error.

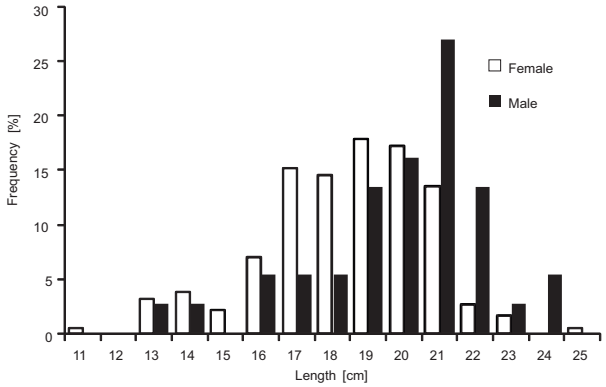

Fig. 1. Length frequency distribution by sex of *Dentex maroccanus* from the Saros Bay

$t_s > t_t$). Where df is degrees of freedom, t_s is t value of statistic and t_t is value of t table. Values for b were 3.067 ($r^2 = 0.962$) for females and 2.899 ($r^2 = 0.951$) for males, which indicated negative growth for females and positive allometric growth for males (t-test, $P < 0.05$) (Table 2). The relation for combined sexes was $W = 0.0144 \cdot L^{3.012}$ ($r^2 = 0.96$)

Age was determined by 124 specimens ranging between 1 to 3 years, whereas the estimated maximum age was 3 years. Age group 2 (44 %) was dominant followed by age group 3 (30 %) and age group 1 (26%) (Table 3). The von Bertalanffy population growth parameters for *D. maroccanus* were estimated as $L_\infty = 25.31$ cm, $K = 0.49$ year^{-1}, and $t_0 = -0.30$ year (Fig. 2).

An increase in GSI was observed for the *Dentex maroccanus* population from April–May to July (Fig. 3). The percentage of each gonad development stage is illustrated in Fig. 4. Mature females of *D. maroccanus* were found mostly in the summer months (June–August). Conversely, immature and pre-mature individuals were most abundant in the winter months (December–May). Monthly variation of GSI and maturity stages showed that the spawning period occurs between June and September.

The fecundity of *Dentex maroccanus* increased with the growth of females. The relation between fecundity and length was described by the exponential equation

$$F = 0.981 \cdot L^{3.991}$$

whereas ripe females in spawning condition were generally few in number (Fig. 5). Lengths of first maturity were 15.8 and 13 cm TL for males and females, respectively, and lengths at 100% maturity (L_{100}) were 21 cm TL for females and 19 cm TL males, respectively (Fig. 6).

DISCUSSION

Dentex maroccanus is an economically important a species as the other Sparidae family members and Turkey's sea bream production is about 2700 tons in the fishery statistics (Anonymous 2013). Studies of the population dynamics required knowledge about the growth, reproduction, and age of the population. However, relatively little is known about *D. maroccanus* length–weight relation and growth parameters in Turkey. Reproduction period and first maturity length are important topics, but only few studies have been conducted on the reproduction of *D. maroccanus* (see Lamrini and Bouymajjane 2002).

In the Aegean Sea, the biology of this species is unknown and there is a gap in our knowledge on its growth and reproduction. This study therefore represents

Table 2

Length–weight relation parameters for male and female *Dentex maroccanus* from the Saros Bay

Sex	*n*	*a*	*b*	r^2	*P*
Male	38	0.020 ± 0.101	3.067 ± 0.131	0.962	<0.05
Female	185	0.012 ± 0.061	2.899 ± 0.048	0.951	<0.05
Total	507	0.014 ± 0.032	3.012 ± 0.026	0.960	<0.05

n = number of specimens, *a* = intercept, *b* = slope of the regression, r^2 = coefficient of determination, *P* = significance level.

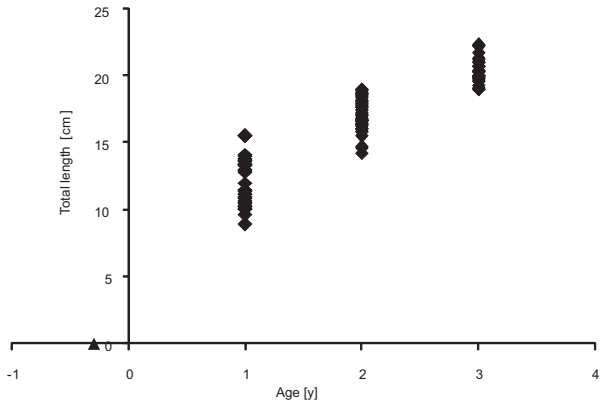

Fig. 2. Von Bertalanffy growth model for *Dentex maroccanus* by total length at age data in the Saros Bay

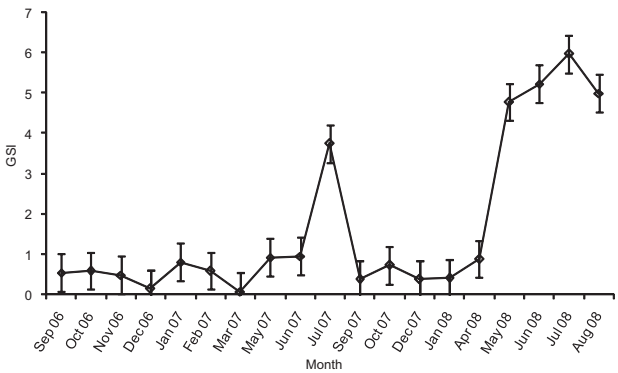

Fig. 3. Monthly variation of gonadosomatic index (GSI) values of female *Dentex maroccanus* from the Saros Bay

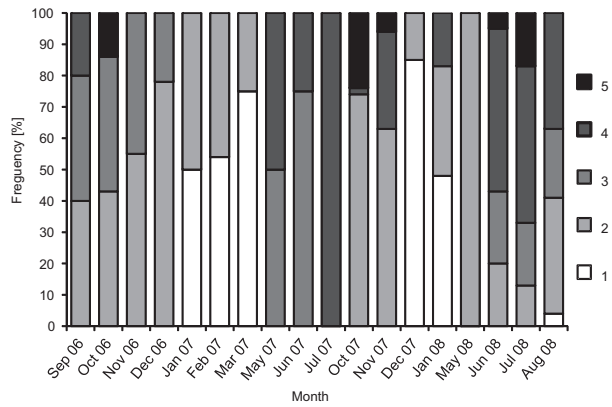

Fig. 4. Monthly variation of maturity stages for females of *Dentex maroccanus* from the Saros Bay (1 = immature, 2 = maturing, 3 = mature, 4 = spawning, 5 = spent)

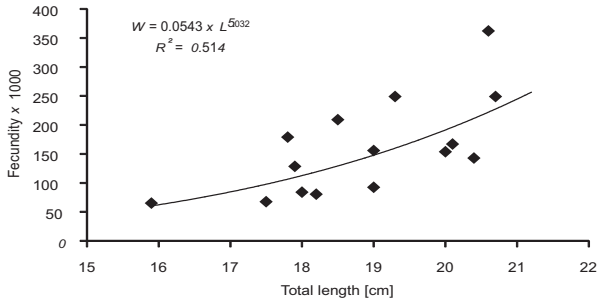

Fig. 5. Relation between fecundity and total length of *Dentex maroccanus* from the Saros Bay

Table 3

Age–total length key for all individuals of *Dentex maroccanus* collected from the Saros Bay

TL [cm]	Age [years]			*n*
	1	2	3	
9	1			1
10	8			8
11	9			9
12	3			3
13	7			7
14	6	1		7
15		2		2
16	3	11		14
17		16		16
18		13		13
19		11	5	16
20			15	15
21			9	9
22			4	4
n	37	54	33	124
%	29.8	43.8	26.67	100
MTL	12.14	16.5	20.5	
SE	0.29	0.10	0.15	

TL = total length, *n* = number of specimens, MTL = mean total length, SE = standard errorr.

the first report on growth, reproduction, and length at first maturity of *Dentex maroccanus* in the Aegean Sea.

The results showed that the total length (TL) at which *D. maroccanus* first reached maturity was 15.8 cm for females and 13 cm for males. In this study, the reproduction period was defined based on the monthly changes in GSI. The GSI values started to increase after the winter months, and then decreased in summer (Fig. 4). This continued until the beginning of spawning. It decreased rapidly with the start of reproduction. Lamrini and Bouymajjane (2002) indicated that first sexual maturity occurred at 15.6 cm and this size corresponds to the age of 2 years and a reproduction period from March to September. Additionally, Bauchot and Hureau (1986) noted a spawning period in spring and maturity being reached at 10 cm in the Mediterranean.

Fecundity is used to understand the reproduction potential of the spawning stock. However, it must be noted that there has been no specific study on the fecundity of *D. maroccanus*. In the presently reported study the fecundity ranged from 65 000 to 362 000 eggs in Saros Bay. The environmental factors, such as temperature may affect fish behaviour and metabolism, and populations show differences in size at maturity and spawning time, (Murua et al. 2003), which may caused of variation among the GSI values of *D. maroccanus* in summer 2007 and summer 2008.

Maximum age was determined for *Dentex maroccanus* to be 3 years, although other studies reported a maximum of 10 years (Nguyen and Wojciechowski 1972). The reason for this difference might be that the size range of this study is lower than that of other studies. Parameters of the von Bertalanffy growth equation used by different authors are given in Table 4. Φ-test indicated that there were no significant differences between von Bertalanffy growth parameters of other studies ($t_s < t_t$).

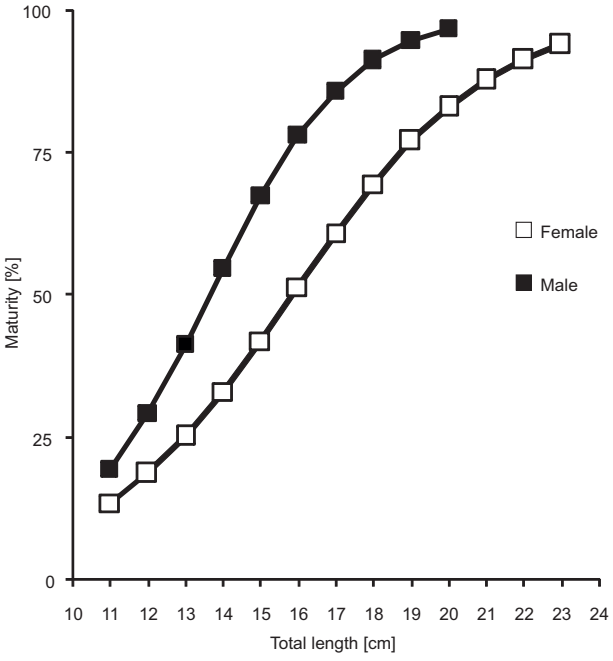

Fig. 6. Length at first maturity for females and males of *Dentex maroccanus* from the Saros Bay

Table 4

Parameters of von Bertalanffy growth equation (K, L_∞, t_0) for *Dentex maroccanus* provided by different authors

Author	Region	Age [year]	L_∞ [cm]	K [year]	t_0 [year^{-1}]	Sex	Ø'-
Nguyen and Wojciechowski 1972	Cape verde	1–10	32.5	0.18	–0.62	—	2.28
Nguyen and Wojciechowski 1972	Cape Blanc	1–10	34.3	0.18	–0.49	—	2.33
Mennes 1985	Morocco	—	39.0	0.32	—	—	2.54
Chemmam-Abdelkader et al. 2004	Morocco	1–7	33.9	0.18	–1.59	M	2.33
Chemmam-Abdelkader et al. 2004	Morocco	1–7	35.9	0.16	–1.85	F	2.3
Lamrini and Bouymajjane 2002	Morocco	1–7	30.2	0.16	–1.97	M	—
Lamrini and Bouymajjane 2002	Morocco	1–7	31.5	0.18	–1.63	F	—
This study	Saros Bay	1–3	25.3	0.49	–0.30	∑	2.16

L_∞ = theoretical asymptotic length, K = growth rate coefficient, t_0 = theoretical age when fish length is zero, Ø' = growth performance index.

Table 5

Estimates of total length – total weight relations for *Dentex maroccanus* provided by different authors

Author	Region	Sex	Length range [cm]	n	a	b	r^2
Nguyen and Wojciechowski 1972	African coasts	F + M	—	—	0.016	3.06	—
Mennes 1985	Morocco	F + M	—	—	0.021	3	—
Lamrini and Bouymajjane 2002	Morocco	F	—	134	0.012	3.15	—
Lamrini and Bouymajjane 2002	Morocco	F + M	—	297	0.084	3.3	—
Chemmam-Abdelkader et al. 2004	Morocco	F + M	12.2–27.1	349	0.14	3.02	0.991
Karakulak et al. 2006	N Aegean Sea	F + M	18.9–34.0	9	0.008	3.18	0.996
Ismen et al. 2007	Saros Bay	F + M	14.2–26.5	146	0.028	2.724	0.925
Ceyhan et al. 2009	Gökova Bay	F + M	14.8–21.8	8	0.119	2.29	0.904
Presently reported study	Saros Bay	F	11.4–25.2	185	0.02	2.899	0.84
Presently reported study	Saros Bay	M	12.8–24.3	38	0.01	3.067	0.98
Presently reported study	Saros Bay	F + M	8.9–25.2	507	0.144	3.012	0.96

n = number of specimens, a = intercept, b = slope of the regression, r^2 = coefficient of determination, F = female, M = male.

Previous studies providing length–weight relations for *Dentex maroccanus* are given in Table 5 for comparative purposes. There were some studies about length–weight relation of *D. maroccanus* but only two such studies were conducted in the Aegean Sea. Differences in the number of individual specimens may also affect the relations. However, the differences between b values are due to one or more factors: the season and effects of origin, sex, and food availability (Pauly and Munro 1984, Cherif et al. 2007).

The results of the presently reported study will contribute to knowledge concerning age composition, growth and reproduction of *Dentex maroccanus* in the Saros Bay and also to a better understanding of its role in the marine ecosystem. This information will help fisheries scientists in future studies of *D. maroccanus* populations, as well as providing some basic fundamental knowledge about the species and helping to enforce regulations on commercial fisheries with regard to minimum landing size restrictions.

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