ACTA ZOOLOGICA BULGARICA

Acta zool. bulg., 72 (1), 2020: 149-154

Published online 31 March 2020

http://www.acta-zoologica-bulgarica.eu/002191

Aquatic Ecology
Research Article

Age and Growth of Morocco Dentex *Dentex maroccanus* Valenciennes, 1830 (Actinopterygii: Sparidae) in Izmir Bay, Central Aegean Sea, Turkey

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Abstract: Growth characteristics and age structure of 439 specimens of *Dentex maroccanus* captured by fishermen in December 2012 – March 2014 from Izmir Bay, Aegean Sea, Turkey, were studied. Of the 346 fish specimens whose sex was determined, 206 were female and 140 were male. The length-weight relationships of females, males and the entire population were described by the equations $W=0.0194*L^{2.924}$, $W=0.0269*L^{2.789}$ and $W=0.0228*L^{2.856}$, respectively. The highest condition factor of the population was 1.59 and was recorded in spring. According to the age identification using otoliths, the population was in the age range of I–V. With 39%, the II age group had the highest ratio. The infinite length value for the entire population was calculated to be $L_\infty=27.43*(1–e^{-0.21\ (t-(-0.68))})$. The growth performance index was 2.20.

Key words: otolith, Mediterranean Sea, fisheries, length-weight relationship.

Introduction

Represented by 37 genera and 148 species in Earth's seas (Fishbase 2015), the family Sparidae includes 21 species of ten genera in the Turkish waters, including four species of the genus *Dentex*: *Dentex dentex*, *D. gibbosus*, *D. macrophthalmus* and *D. maraccanus* (Bilecenoğlu et al. 2014). Of the total fish production of 263.725 tons from the Turkish seas, 5.000 tons (or c. 2%) comprise the species of the family Sparidae (Tüik 2016). Morocco dentex *D. maroccanus* Valenciennes, 1830 is an important commercial species of Sparidae, inhabiting depths from 20 to 500 m and can be found throughout the Mediterranean Sea (except the Adriatic Sea). Ecologically, it prefers deep waters with higher salinity and is distributed in the southern and eastern Mediterranean Sea (Maravelias et al. 2007) and the Atlantic Ocean (from Bay of Biscay to Gulf of Guinea) (Froese & Pauly 2014). Comprehensive studies on the Morocco dentex in the Mediterranean Sea were carried out in the western parts of the sea and were focused on its age, growth, feeding, reproduction and distribution (Nguyen & Wojciechowski 1972, Mennes 1985, Lamrini & Bouymajjane 2002, Chemmam-Abdelkader et al. 2004, Maravelias et al. 2007, Aura et al. 2013, Mohdeb & Kara 2014).

Species of Sparidae in the Aegean Sea (İzmir Bay), a basin of the east-central Mediterranean Sea, are important components of the demersal fish stock and are generally caught using trawl, long line and trammel nets. In Turkey, the first studies on the length-weight relationship of *D. maroccanus* were by carried out by Karakulak et al. (2006), Işmen et al. (2007) and Ceyhan et al. (2009). The growth and reproduction characteristics of this species were studied in the Saros Bay, northern Aegean Sea (Gül et al. 2014) while its dietary composition was studied in the İzmir Bay, central Aegean Sea (Bayhan et al. 2017). There is currently no information concerning the age, growth and length-weight relationships of the species from the Izmir Bay.

The present study is focused on the length-weight relationship and certain biological characteristics such as age and growth of the species. It aims to obtain important data that can contribute to the stock management and sustainable fishery of this economically important species.

Materials and Methods

Samples of *Dentex maroccanus* were collected between December 2012 and March 2014 by commercial fishermen who generally use trawl nets (full cod-end mesh size 44 mm; hull length 17-22 m, 240-400 HP) in Izmir Bay, Aegean Sea. The total length of 439 specimens was measured in the laboratory using a fish measuring board with 0.1-cm divisions. The body weight of the fish was measured using Scaltec precision scales with 0.01 g sensitivity. Statistical differences between the length and weight values of females and males were determined with t-tests. Before the t-test procedure, the Kolmogorov-Smirnov test was utilised to check for normality and the Levene test was used to test for homogeneity of the variance. The categorical changes, the female and male counts were analysed using the Chi-square test. All calculations were performed using the SPSS software and the level of significance was set to 0.05.

Otoliths were used for age determination. Prior to the age determination, the otoliths preserved in U-plates were kept for 5 min in 0.4% NaOH solution and, after rinsing with pure water, were dried with drying cloth. It was a challenge to use the relatively thicker otoliths for the identification of the annual rings, which were, therefore, sanded with no. 400 and no. 1000 sandpapers. Then, the otoliths in black-based petri dishes were separately and independently analysed by two researchers under a Nikon SMZ 445 stereo-zoom microscope with overhead lighting. The otoliths, for which the researchers did not reach a consensus after the microscope analysis, were re-analysed for age determination to achieve the most accurate data. In the infinite length calculation, the $L_t = L_\infty [1 – e–K(t-t_o)]$ model developed by von Bertalanffy was employed (Avşar 2005), where L_t was the mean length of the fish at age (t) (cm); L_∞ was the infinite length of the fish (cm); K was the Brody growth coefficient (year-1); t was the age of the fish (year); t_0 was the theoretical age of the fish prior to hatching (year); e was the logarithmic base. The equation $W = a*L^b$ was used to reveal the relationship between the weight and length within the population (Ricker 1979), where W was the weight of the fish (g); L was the total length of the fish (cm); *a* was the point at which the curve determining the length-weight relationship intercepted the Y-axis; *b* was the slope of the curve determining the length-weight relationship (the growth type of the fish). The value of K was calculated following Froese (2006), i.e. $K = W/L^3*100$. The growth performance index (Pauly & Munro 1984) was used to compare the growth rates. It was estimated using the formula $Ø'=\log(k)+2\times\log(L_\infty)$.

Results

Of the 439 Morocco dentex specimens examined in this study, 67% were female and 33% were male. There was a significant difference in numbers of males and females (t=12.737; p=0.000). The minimum and maximum total length of females, males and the entire population were 8.1-22.1 cm, 8.7-22.0 cm and 7.0-22.1 cm, respectively (Fig. 1). There

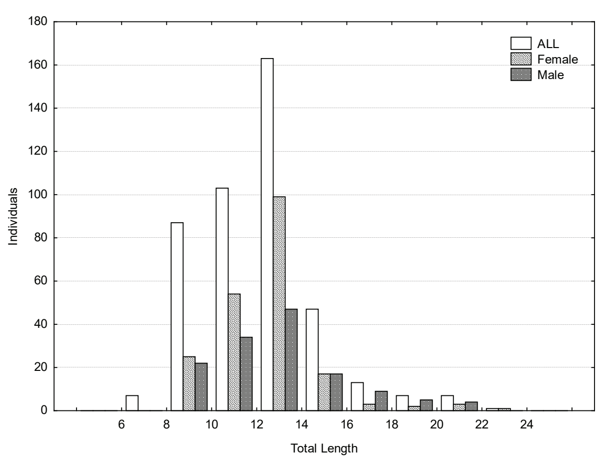

Fig. 1. Total length distribution in male, female and all individuals.

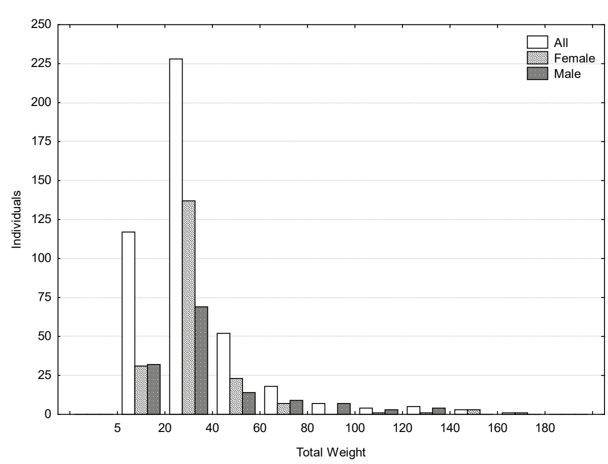

Fig. 2. Total weight distribution in male, female and all individuals.

Table 1. Minimum and maximum length values of the studied population of *Dentex maroccanus*; comparison with other studies

Source	Locality	TL_{min}-TL_{maks}	Female TL_{min}-TL_{maks}	Male TL_{min}-TL_{maks}
Chemmam-Abdelkader et al. (2004)	Tunisian coasts	12.2-27.1	-	-
Karakulak et al. (2005)	Gökçeada Bay (North Aegean Sea)	18.9-34.0	-	-
İşmen et al. (2007)	Saros Bay (North Aegean Sea)	14.2-26.5	-	-
Ceyhan et al. (2009)	Gökova Bay (South Aegean Sea)	14.8-21.8	-	-
Aura et al. (2013)	Kenya	12.6-40.3	-	-
Mohdeb & Kara (2014)	Algeria	10.5-26.8	10.5-26.8	11.1-26.1
Gül et al. (2014)	Saros Bay (North Aegean Sea)	11.4-25.2	11.4-25.2	12.8-24.3
Present study	İzmir Bay (Central Aegean Sea)	7.00-22.13	8.10-22.13	8.70-22.00

Table 2. The length-weight relationship in the studied population of *Dentex maroccanus* compared to other studies. Abbreviations: a: intercept, b: slope of the regression, r^2: coefficient of determination

Source	Location	a	b	r^2
Loc & Wojciechowksi (1972)	North-West African Coast	0.016	3.06	-
Mennes (1985)	Western Sahara Regions	0.020	3.00	-
Lamrini & Bouymajjane (2002)	Morocco	0.084	3.30	-
Chemmam-Abdelkader et al. (2004)	Tunisian Coasts	0.140	3.02	0.99
Karakulak et al. (2006)	Gökçeada- Northern Aegean	0.080	3.18	0.99
İşmen et al. (2007)	Saros Bay	0.028	2.72	0.92
Ceyhan et al. (2009)	Gökova Bay	0.119	2.29	0.90
Aura et al. (2013)	Kenya	2.04	2.91	-
Mohdeb & Kara (2014)	Eastern Coast of Algeria	0.140	3.02	0.99
Gül et al. (2014)	Saros Bay - North Aegean	0.144	3.01	0.96
Present study (∑)	İzmir Bay – Central Aegean	0.023	2.86	0.98
Present study (♀)		0.019	2.93	0.98
Present study (♂)		0.023	2.79	0.99

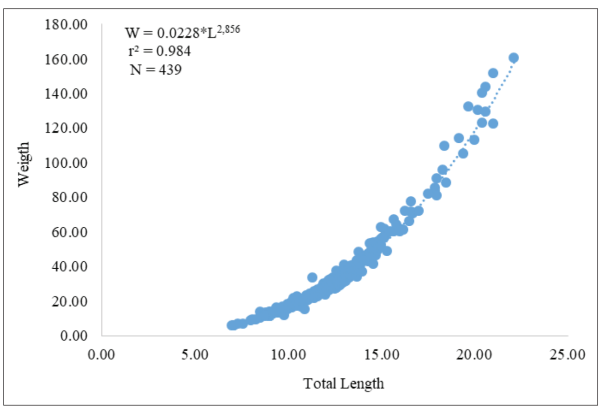

Fig. 3. Total length-weight relationship in all individuals.

was no statistical difference between the length of female and male individuals (t=0.08; p=0.994). The frequency of the total length distribution showed that the 12-14 cm length range was predominant in the females, males and the entire population, with ratios of 36%, 51% and 39%, respectively. The minimum and maximum weight values of females, males and the entire population were 9.0-160.6 g, 11.3-130.3 g and 9.0-160.6 g, respectively (Fig. 2). There was no statistical difference between the weight of the female and male individuals (t=0.438; p=0.662). The frequency of the weight distribution showed that the 20-40 g weight range was the predominant range in the female, male and the entire population, with ratios of 67%, 49% and 52%, respectively.

The length-weight relationships that were separately calculated for the females, males and the entire population are presented in Fig. 3 and Table 2. For age determination, the otoliths of 184 specimens were analysed. The results showed that the population had an age range of I-V (Fig. 5). The majority of the population was in the II and III age groups (Table 3). The growth parameters of the population were L_∞: 27.43 cm, K: 0.21 year-1 and t_0: -0.68.

Discussion

Sex ratio and size structure provide basic information in assessing reproductive potential and establishing stock size in fish populations (Vazzoler

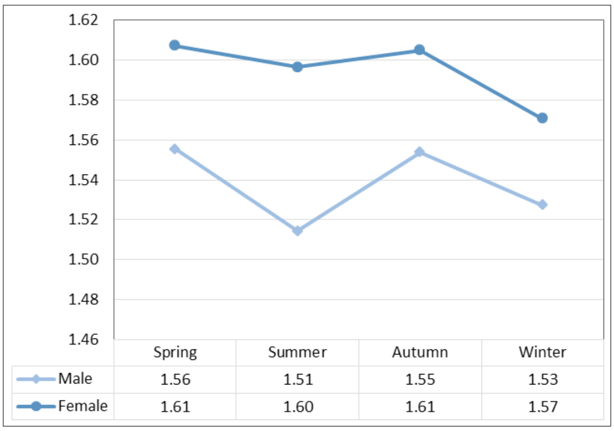

Fig. 4. Condition factor values in male and female individuals with respect to seasons.

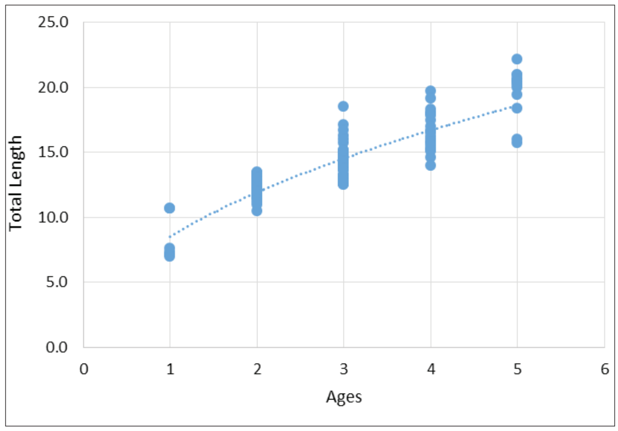

Fig. 5. Length distribution by age groups.

Table 3. Total length values for each age group. Abbreviations: N: number of individuals, SE: standard error

Age	N	Min-Max. (TL)	Mean (TL) ± SE	%
I	8	7.0-10.7	8.1±0.54	4
II	71	10.5-13.5	12.3±0.07	39
III	70	12.5-18.5	14.2±0.14	38
IV	22	14.0-19.7	16.7±0.31	12
V	13	15.7-22.1	19.1±0.51	7

1996). In fish, the ratio of the sexes is important as the reproductive success in many fish species has been shown to be influenced by, among other factors, the broodstock, sex ratio, stocking density, age, size, nutrition and feeding regime (Khalfalla et al. 2008). Variation in the adult sex ratio may emerge because of the differences in the sexes in age at maturity, reproductive longevity, sex change behaviour (in hermaphrodites) and differential mortality (Kappus 2012). As a widely accepted rule of thumb, the sex ratio in a healthy population should be 1:1 (Nickolsky 1963). Of the 439 specimens of Morocco dentex, 67% were females and 33% were males. In another study carried out in the northern Aegean Sea, 82% of the population were females and 18% were males (Gül et al. 2014). In other two studies carried out in Morocco and Algeria, the ratios of the females and males were 69% and 30% (Lamrini & Bouymajjane 2002) and 50% and 47%, respectively (Mohdeb & Kara 2014). The reason for the departure from 1:1 sex ratio is not clear but could have been influenced by differentiation in fish growth of the sexes as well as by food availability (Vincentini & Araujo 2003).

Compared to other populations, the total length of our specimens was small, similarly to those of other populations in the Mediterranean Sea. In contrast, the highest total length (40.3 cm) was recorded in the cold and nutrient-rich Kenya coast (Table 1). The Mediterranean Sea has generally been regarded as an oligotrophic sea (Margalef 1985, Estrada 1996, Stergiou et al. 1997b). Increase in its temperatures and salinity challenges aquatic life. The Mediterranean Sea has a negative water budget: the loss of water through evaporation is greater than the inputs from rain and river runoff, but the contribution of Atlantic water through the Strait of Gibraltar balances these losses (Lleonart & Maynou 2003). Moreover, evaporation of the eastern Mediterranean surface waters and the resultant settling of nutrients to the bottom, release of the nutrient-poor Atlantic Ocean waters through the surface of the Strait of Gibraltar and transport of nutrients from the Mediterranean Sea to the ocean through the bottom result in the further impoverishment of the Mediterranean Sea in nutrients. As a result of these conditions, the species distributed along the Mediterranean coasts have lower length values.

Values of "*b*" close to 3 indicate that fish grow isometrically, values other than 3 indicate allometric growth, which occurs when fish change slope during growth and the cubic law is no longer valid (Ayo-Olalusi 2014). The calculated "*b*" values revealed that the female and male populations and the entire population exhibited negative allometry. The comparison of the results to the results obtained by other studies showed that the length-weight values determined in the present study were similar to those obtained by some other studies, albeit diverging from others (Table 2). The highest condition factor for females and males was observed in spring (Fig. 4). Overall, the allometric model is the most appropriate for describing morphometrics in fish and applies to the vast majority of relationships of various morphological characteristics with body length (Karachle & Stergiou 2012). However, many factors, such as gonad maturity, sex, age, diet, stomach fullness, health, sampling methods, sample sizes and preservation techniques as well as season, habitat and environmental conditions affect fish condition and parameters of length-weight relationships in fish (Adaka et al. 2015).

We found that the population had an age range of I-V. The majority of the population was in the II and III age-groups. The lower number of specimens in the I age-group was attributed to small fish being discarded by fishermen as well as to the selectivity of the net used during fishing. Furthermore, the low length ranges with respect to the age-groups indicated that the species was subjected to fishing pressure. With 39.00 cm, the highest infinite length for the species was determined along the Moroccan coasts (Mennes 1985, see Table 4). Data on age provide precious information on the life history of a fish species. However, reliability of the age determination largely depends on the size of the studied individuals and interpretation of the growth zones on the otoliths (Bayhan et al. 2008). The maximum lifespan of *Dentex* can exceed 20 years and it is, therefore, among the relatively long-lived species (Morales-Nin & Moranta 1997). As expected, the highest infinite length values were calculated for fish along the African coasts, which also had the highest length values and, correspondingly, the 10-age group determined for the species also was from the same region. The sample size and the fishing tool used are also known to cause changes in the length groups. Furthermore, the favourable physicochemical properties of the nutrient-rich water along the African coasts led to the greater length values as well as more age-groups as compared to those of the populations distributed in other seas. The growth performance index values estimated in the present study were similar to those in other studies (Table 4).

Economically important fish species have always been target species for fishermen and, therefore, unless permanent management strategies are developed for their protection, their stocks will unavoidably become endangered. Similar to the other species of the genus *Dentex*, Morocco dentex is a demersal fish species with economic importance in seas in which it is distributed (Marengo et al. 2014). The species is currently categorised in the LC (least concern) category by the European Red List of Marine Fishes (Nieto et al. 2015), which indicates that determining the current state of the population and monitoring the change over time are crucial. In conclusion, our findings on the Morocco dentex distributed along the coasts of the central Aegean Sea will contribute both to the determination of the current state of the species and to the future fishery studies aiming to develop management strategies for the species.

Acknowledgments: The present study was carried out with the financial support of the Ege University Scientific Research Project BAP No. 2013-SUF-017, Izmir, Turkey.

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Received: 28.01.2018
Accepted: 21.11.2019