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Age and growth of the four-spotted megrim (*Lepidorhombus boscii* Risso, 1810) from Saros Bay (Northern Aegean Sea, Turkey)

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Abstract

In this study, the growth parameters of the four-spotted megrim, (*Lepidorhombus boscii* Risso, 1810), were studied in Saros Bay, which had been closed to bottom trawl fishing since 2000. The sex ratio of females to males was 1:0.42. Length-weight relationships were $W=0.0032L^{3.31}$ and $W=0.0069L^{3.04}$ for females and males, respectively. Growth parameters of the populations were L_∞=49.8 cm, k=0.09 year^{-1}, t_0=-2.15 year for females; L_∞=39.1 cm, k=0.11 year^{-1}, t_0=-2.59 year for males. The growth performance index (Φ') was found to be 2.35 and 2.23 for females and males, respectively.

Keywords: Four-spotted megrim, age, growth, Saros Bay, northern Aegean Sea.

Introduction

Age and growth of fish are fundamental to stock assessment. Information on age is significant because it sets the basis for the calculations of growth, mortality rates and productivity estimates (Campana, 2001), making it a necessity for fisheries management (Cailliet *et al*., 2001). Growth, however, is one of the most important life history processes influencing the dynamics of a fish population (Zhan, 1995).

The four-spotted megrim (*Lepidorhombus boscii* Risso,1810), a sinistrally orientated flatfish belonging to Scophthalmidae, is one of most important groundfish species, inhabiting the Mediterranean Sea and the eastern part of the Atlantic from the British Isles to Angola (Bauchot, 1987) and is common on soft sea bottoms at depths down to 700-800 m (Nielsen, 1986). In Turkey, this species occurs in the Mediterranean, Aegean and Marmara seas (Bilecenoglu *et al*., 2002). It is of commercial interest, particularly when longer than 20.0 cm in length (Vassilopoulou, 2000).

The age and growth of the four-spotted megrim in the Atlantic were studied by Fuertes (1978), Castilho *et al*. (1993), Santos (1994), Landa *et al*. (2002) and Teixeira *et al*. (2010), while Bello & Rizzi (1987), Mannini *et al*. (1990), Stergiou & Politou (1995) and Vassilopoulou & Ondrias (1999) reported data from the Mediterranean. In addition, Robson *et al*. (2000) presented the growth parameters off the west coast of Ireland.

Published literature on the biology of this species from the Turkish Seas, however, is extremely limited. Jica (1993) conducted its stock assessment in the Northern Aegean Sea. Bostanci & Polat (2008) studied the otolith structure, otolith dimensions-fish length relationships and age determination of *L. boscii*. Ismen *et al*. (2007) and Ozekinci *et al*. (2009) reported the length-weight relationships of the four-spotted megrim from Saros Bay.

The main aim of the present study was to estimate some basic biological parameters such as length distribution, sex ratio, age, growth, and length-weight relationships of the four-spotted megrim captured from Saros Bay and to compare these results with those of the previous studies.

Materials and Methods

All individuals were collected, monthly, between September 2006 and September 2008 using a commercial bottom trawl net of 44 mm codend stretched mesh size at depths ranging between from 0 m to 500 m in Saros Bay (Fig. 1), which had been closed to trawl fishing since 2000.

The samples were measured to the nearest 1 mm (total length), and weighed to the nearest 0.01 g (total weight). Differences in the sex ratio (female: male) were examined using a chi-square (X^2) test, while the Mann-Whitney U test was used to analyze the differences between the mean total length and total weight of the sexes**.** The length-weight relationship was calculated applying the equation $W = aL^b$, where W is the total weight, L is the total length and a and b are the parameters of the equa-

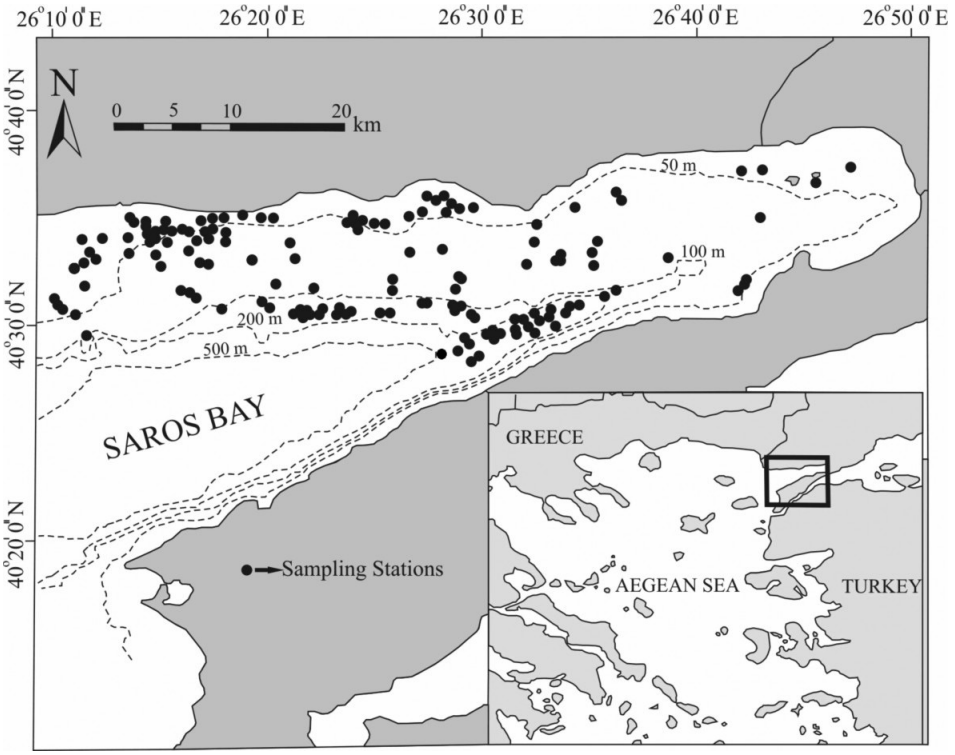

Fig. 1: Saros Bay and sampling stations.

tion (Ricker, 1973). The growth type was identified using student's *t*-test.

The otoliths from the blind side were used for age determination, as the nucleus was more central here than the otoliths in the ocular side (Fig. 2) and it was easier to interpret the zones (Bostanci & Polat, 2008).

Following removal, the blind side otoliths were first soaked in 5% HCL and 3% NaOH solutions, respectively, and washed in distilled water and subsequently dried. Age determination was performed using a stereoscopic zoom microscope under reflected light against a black background, filled with the water. Opaque and transparent zones were counted; one opaque zone plus one transparent zone was assumed to be one age mark.

The von Bertalanffy growth equation was calculated according to $L_t = L_\infty [1\text{-}e^{-k(t - to)}]$ for total length TL, where L_t is fish total length (cm) at age t, L_∞ is the asymptotic fish length (cm), t is the fish age(year), t_0 (year) is the hypothetical time at which the fish length is zero, k is the growth coefficient (year^{-1}) (Sparre & Venema, 1992). We used the growth performance index (Φ') of Pauly & Munro (1984), which takes into account the correlation between L_∞ and k, to compare the growth parameters estimated by different authors.

Results

In this study, a total of 2224 individuals were sampled during the study period. Of the 788 specimens examined by picking the sub-samples randomly, 553 were females and 235 were males. The sex ratio was calculated as 1:0.42 (F:M). The fish size ranged from 10.9 to 40.8 cm (TL) and weighed between 9.9 and 679.2 g. The mean total length and total weight of the females were 25.6±0.32 (11.4-40.8) cm and 202.68±7.35 (10.74-679.18) g, respectively, while that of the males were 17.6±0.26 (10.9-30.3) cm and 50.00±2.67 (9.88-271.18) g, respectively. The Mann-Whitney U and chi-square tests showed that the mean total lengths and total weights between the sexes and the sex ratio were significantly different ($P<0.05$). The length-frequency distribution for females and males of the four-spotted megrim (*Lepidorhombus boscii* Risso, 1810) from Saros Bay is displayed in Figure 3.

Length-weight relationships calculated for females and males were: $W=0.0032L^{3.31}$ ($r^2=0.99$, 95% CL of b=3.28-3.33) and $W=0.0069L^{3.04}$ ($r^2=0.97$, 95% CL of b=2.97-3.11), respectively (Fig. 4). The b-values showed significant differences for females and males ($P<0.05$). While b-values and t-test results indicated a positive allometric growth for females, an isometric growth was noted for males.

The otoliths of 471 individuals were successfully extracted. These otoliths were used to investigate the age and growth by three independent readers. Age was determined from 422 otoliths. The remaining 49 otoliths were rejected due to the disagreement between readers or because they were, generally, considered unreadable. Age distribution ranged from 1 to 13 years. The mean TLs corresponding to each age class are given for females and males in Table 1.

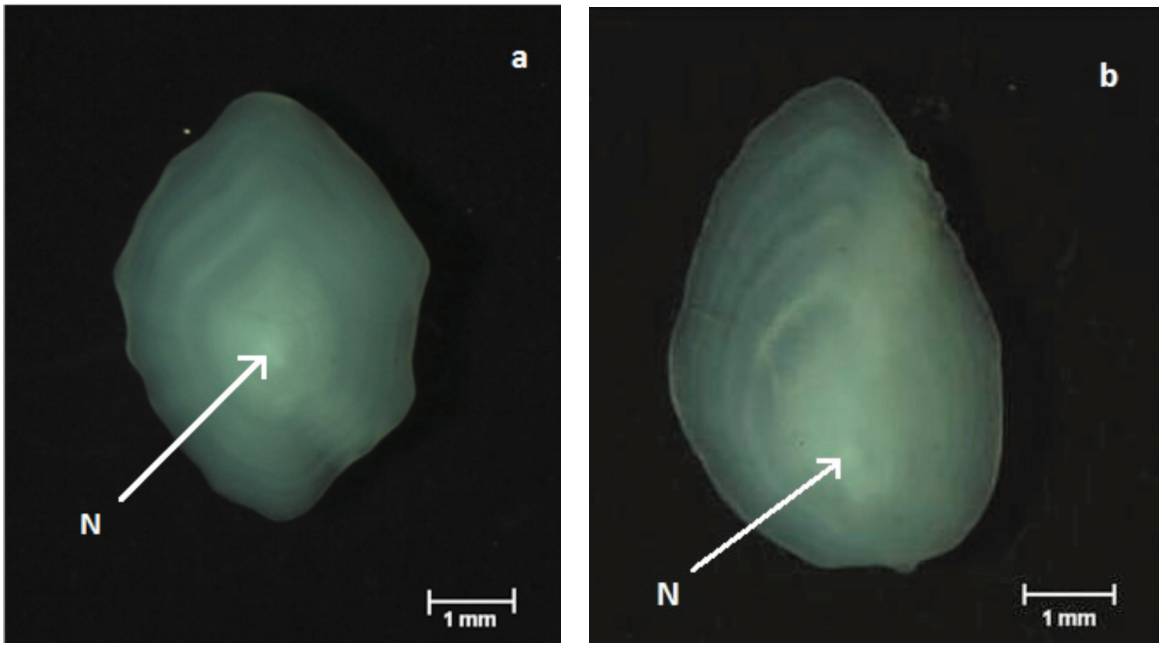

Fig. 2: Blind side (a) otolith; ocular side (b) otolith and nucleus (N).

Significant differences were found between the mean lengths of each age class for females and males, except for age class I (Table 1). The von Bertalanffy growth equations were computed as L_{∞}=49.8 cm, k=0.09 year^{-1}, t_0=-2.15 year for females; L_{∞}=39.1 cm, k=0.11 year^{-1}, t_0=-2.59 year for males. The growth performance index (Φ') was found to be 2.35 and 2.23 for females and males, respectively.

Discussion

The reasons for the differences in length range have been attributed to various factors such as the type and the selectivity of the gear (Ilkyaz *et al*., 2010), sampling strategy, sampling period, variations in temperature and differences between the trophic potential of the various areas (Ozaydin *et al*., 2000). The possible reasons of differences in the length-weight relationships could be attributed to area, gonadal maturity, habitat, degree of stomach fullness, season, length range, sex, health and preservation techniques (Baganel & Tesch, 1978) and the size selectivity of the sampling gear (Ismen *et al*., 2007). As Saros Bay had been closed to bottom trawl fishing since 2000 and no industrial activity was prevalent in the area (Sari & Cagatay, 2001), the bay can be considered

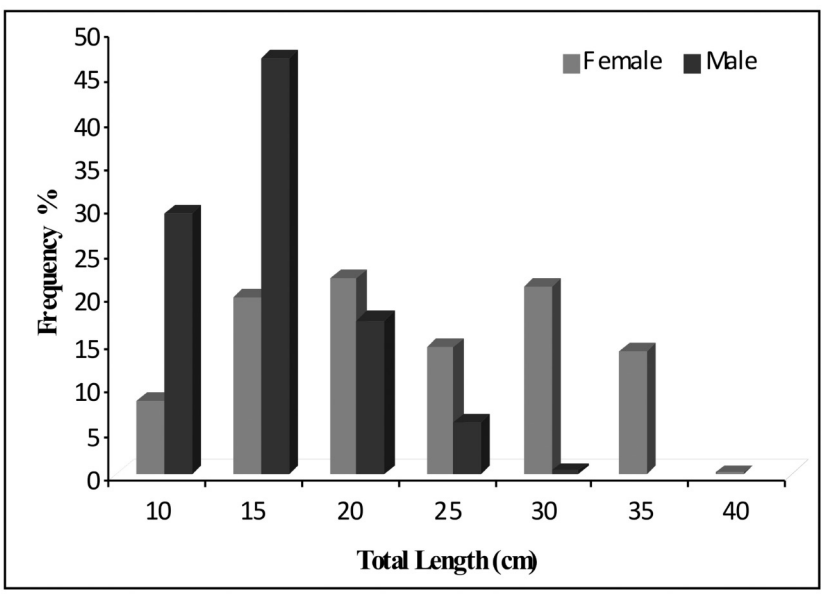

Fig. 3: The length-frequency distribution for females and males of the four-spotted megrim (*Lepidorhombus boscii* Risso, 1810) from Saros Bay.

Table 1. Age-length key for females and males of *Lepidorhombus* boscii from Saros Bay.

Length class (cm)	Age													Females	Males
	1	2	3	4	5	6	7	8	9	10	11	12	13		
10.0-11.0	1														1
11.1-12.0	4													1	3
12.1-13.0	12													4	8
13.1-14.0	5	10												1	14
14.1-15.0		7												0	7
15.1-16.0		14												9	5
16.1-17.0		2	14											2	14
17.1-18.0		1	7											1	7
18.1-19.0			10	10										6	14
19.1-20.0			12	15	7									16	18
20.1-21.0			3	7	7									3	14
21.1-22.0				17	10									16	11
22.1-23.0				41	7	1								48	1
23.1-24.0				27	13	2	3							40	5
24.1-25.0				4	5	8								10	7
25.1-26.0					2	3	2							5	2
26.1-27.0						12	3	1						13	3
27.1-28.0						7	5	3						12	3
28.1-29.0						2	9							11	
29.1-30.0							3	3	1					5	2
30.1-31.0							2	4	4					9	1
31.1-32.0							2	7	5	1				15	
32.1-33.0							1	4	4	1				10	
33.1-34.0								2		2				4	
34.1-35.0								2	2	6	1			11	
35.1-36.0									4	2	2			8	
36.1-37.0										3	5	3	1	12	
37.1-38.0											2	4	1	7	
38.1-39.0													2	2	
39.1-40.0													1	1	
Females															
N	6	12	21	91	28	25	23	21	18	15	10	7	5	282	
Mean	12.6	15.8	19.4	22.6	23.6	26.8	28.9	31.7	32.7	34.6	36.4	37.2	38.2	25.9	
Min	11.8	14.8	18.4	19.5	22.0	24.8	26.5	29.1	30.2	32.0	34.8	36.1	36.9	11.8	
Max	13.5	17.1	21.0	24.3	25.7	28.9	32.8	34.8	35.6	36.5	37.8	38.0	39.8	39.8	
S.E	0.25	0.17	0.14	0.11	0.16	0.18	0.32	0.30	0.43	0.36	0.27	0.23	0.49	0.36	
%	2.1	4.3	7.4	32.3	9.9	8.9	8.2	7.4	6.4	5.3	3.5	2.5	1.8	100.0	
Males															
N	16	22	25	30	23	10	7	5	2						140
Mean	12.5	14.3	17.1	19.5	20.8	24.0	25.0	27.8	29.9						18.7
Min	10.9	13.1	16.2	18.4	19.6	22.3	23.5	26.4	29.5						10.9
Max	13.4	15.7	18.5	21.3	22.0	25.0	26.7	29.7	30.3						30.3
S.E	0.19	0.18	0.15	0.16	0.18	0.25	0.48	0.55	0.40						0.36
%	11.4	15.7	17.9	21.4	16.4	7.1	5.0	3.6	1.4						100.0

N=Sample size; Min=Minimum; Max=Maximum; S.E=Standard Error

as a pristine environment. Therefore, it is quite possible that the characteristics of the area are more important factors affecting the length-weight relationship of the four-spotted megrim in this study. Some of the available studies on the length-weight relationships and length ranges for *Lepidorhombus boscii* by various authors are given in Table 2.

The present study showed that the female four-spotted megrims were dominant over the males. The dominance of females has also been reported by other authors

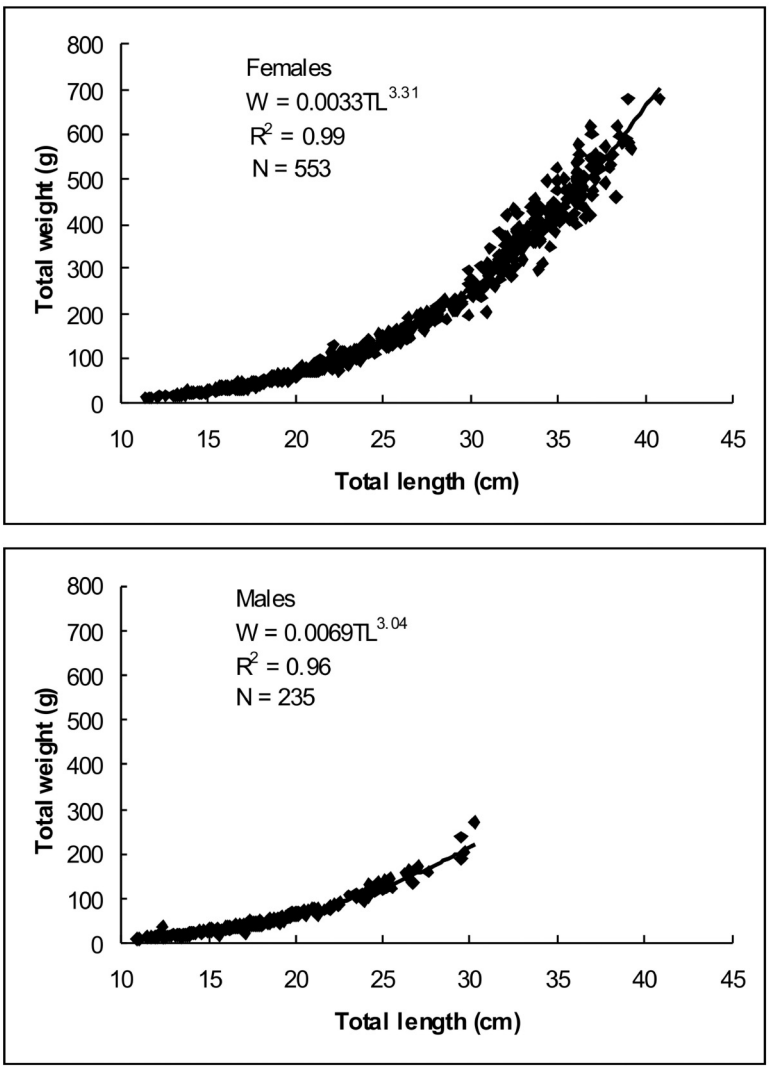

Fig. 4: The length-weight relationships for females and males of the four-spotted megrim (*Lepidorhombus boscii* Risso, 1810) from Saros Bay.

except for Bello & Rizzi (1987), Castilho *et al*. (1993) and Santos (1994) (Table 2). It has been suggested that the sex ratio may vary from species to species, even from population to population of the same species, and may change from year to year within the same population (Nikolsky, 1963). This could be attributed to the differences in feeding, maturation, migration, mortality and growth rates between the two sexes (Avsar, 2005; Innal, 2010). The dominance of females over males in the present study is most likely due to the different growth rates between the two sexes.

In this study, the age class of the four-spotted megrims ranged between 1 and 13 ages. Castilho *et al*. (1993), Vassilopoulou & Ondrias (1999), Robson *et al*. (2000), Bostanci & Polat (2008) and Teixeira *et al*. (2010) reported the longevity limits as 0-12, 0-8, 4-11, 3-8 and 2-9 ages, respectively. Nash & Geffen (2005) stated that the reasons of differences in longevity could be attributed to latitudinal differences as well as to the effects of temperature, intensities of competition for food, food availability, life history strategies and fishing efforts. The maximum age of the four-spotted megrim was reported as 15 (Fuertes, 1978). Maximum age can vary widely between populations within species, especially among those that exhibit wide distributions (Gibson, 2005). The mean lengths at different ages for females and males of *Lepidorhombus boscii* given by various authors are listed in Table 3.

In general, the differences in length at different ages and growth parameters between different areas could probably be attributed to a combination of sample characteristics (sample sizes and range sizes), geographical differences, ageing methodology used (Monterio *et al*., 2006), incorrect age interpretation (Matić-Skoko *et al*., 2007), size, quantity and quality of food and water temperature (Santic *et al*., 2002) and differences in length at first maturity (Champagnat, 1983) Besides, gear selectivity can also affect the estimates of growth parameters (Ricker, 1969; Potts *et al*., 1998). A species which remains in the same habitat throughout its life could main-

Table 2. Some of the available studies on the length-weight relationships and length ranges for *Lepidorhombus boscii.*

References	Locality	Sex	N	L_{min}	L_{max}	a	b
Fuertes (1978)	Galicia (Spain)	♀	1118	–	–	$3.70*10^{-6}$	3.12
		♂	877	–	–	$5.47*10^{-6}$	3.05
Bello & Rizzi (1987)	Southern Adriatic (Italy)	♀	109	–	–	0.0032	3.26
		♂	128	–	–	0.0034	3.24
Mannini *et al*. (1990)	Northern Tyrrhenian Sea (Italy)	♀	–	–	–	0.004	3.26
		♂	–	–	–	0.009	3.02
Castilho *et al*. (1993)	Portuguese coast	♀	250	–	–	0.002	3.25
		♂	315	–	–	0.0041	3.11
Santos (1994)	Portuguese coast	♀	428	–	–	0.0025	3.36
		♂	448	–	–	0.0045	3.16
Stergiou & Politou (1995)	Northern Euboikos Gulf (Grecee)	Σ	219	5.7	37.1	0.0017	3.29
Merella *et al*. (1997)	Balearic Islands (Western Mediterranean)	Σ	84	7.0	19.5	0.0045	3.14
Vassilopoulou & Ondrias (1999)	Eastern Mediterranean waters (Greece)	♀	1422	–	–	$1.89*10^{-6}$	3.26
		♂	1009	–	–	$1.66*10^{-6}$	3.29
		Σ	2431	–	–	$1.89*10^{-6}$	3.27
Robson *et al*. (2000)	West coast of Ireland	Σ	150	–	–	0.0062	3.37
Borges *et al*. (2003)	Algarve (Southern Portugal)	Σ	7	10.3	23.9	0.0035	3.13
Morey *et al*. (2003)	Western Mediterranean	Σ	364	1.4	37.8	0.0643	2.27
Mendes *et al.* (2004)	Portuguese west coast	Σ	82	16.2	34.6	0.0041	3.20
Ismen *et al*. (2007)	Saros Bay (Turkey)	Σ	521	10.2	39.5	0.0032	3.29
Ozekinci *et al*. (2009)	Saros Bay (Turkey)	Σ	2224	10.9	40.8	0.0039	3.25
This study	Saros Bay (Turkey)	♀	553	11.4	40.8	0.0032	3.31
		♂	235	10.9	30.3	0.0069	3.04

N=Sample size; Min=Minimum; Max=Maximum; *a* and *b* are the parameters of the relationships; Σ=All samples; ♀=Females; ♂=Males

tain the same growth model (Gordoa & Balbina, 1997). However, Avsar (1995) suggested differences in the growth rates of fish sampled at different periods from the same locality and concluded that such differences might be due to annual variations in the mean length of fish corresponding to each age.

The growth coefficient (k=0.09 $year^{-1}$) found in this study was of the lowest value in the literature, thus far. This is probably due to the maximum or minimum fish size as it has been shown that the values of k, t_0 and L_∞ are a function of the fish size sampled (King, 1995). An inverse relationship between L_∞ and k has been established in fish population studies. (Gallucci & Quinn, 1979). The *t*-test showed no significant differences between the growth performance indexes in the other areas (P>0.05). A comparison of the growth parameters and growth performance indexes obtained from previous studies for *Lepidorhombus boscii* are given in Table 4.

In the four-spotted megrim, body size is sexually dimorphic, with females being larger than the males (Vassilopoulou & Ondrias, 1999). The differences in the growth rate between the male and female four-spotted megrim were also observed by Fuertes (1978), Bello & Rizzi (1987), Castilho *et al*. (1993), Santos (1994), Landa *et al*. (2002) and Teixeira *et al*. (2010). Similarly, our findings indicated that female four-spotted megrims were larger than the males. The greater and faster growth in females over the males is a feature which is common in many pleuronectiforms (Lozan, 1992; Pauly, 1994a; Landa & Pinerio, 2000). This phenomenon may be related to the differences in metabolism between females and males, such as the oxygen consumption rate (Pauly, 1994a; 1994b), level of surplus energy between reproduction and somatic growth (Rijnsdorp & Ibelings, 1989) and food ingestion (Lozan, 1992).

In conclusion, this study updated the information on the length-weight relationship, sex ratio, length distribution, age and growth of the four-spotted megrim from Saros Bay. The possible reasons for the differences in the life-history parameters between these results and those of

Table 3. The mean lengths at different ages for females and males of Lepidorhombus boscii given by various authors.

References	Locality	Sex	Age Group														
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fuertes (1978)	Galicia (Spain)	♀	–	14.9	20.4	23.4	26.0	27.5	28.0	30.6	31.5	32.6	33.0	34.0	35.0	38.2	39.3	40.5
		♂	–	14.6	18.4	20.7	23.0	25.7	26.6	27.5	29.5	30.5	31.5	–	–	–	–	–
Castilho *et al*. (1993)	Portuguese coast	♀	–	13.2	17.2	20.2	23.3	27.0	28.7	30.2	32.5	35.1	37.1	37.2	37.6	–	–	–
		♂	11.0	13.3	16.4	18.7	22.0	24.4	25.2	27.1	31.8	–	–	32.5	–	–	–	–
Vassilopoulou & Ondrias (1999)	Eastern Mediterranean waters (Greece)	Σ	8.2	11.8	14.9	17.2	19.3	21.2	22.9	24.6	25.7	–	–	–	–	–	–	–
This study	Saros Bay (Turkey)	♀	–	12.6	15.8	19.4	22.6	23.6	26.8	28.9	31.7	32.7	34.6	36.4	37.2	38.2	–	–
		♂	–	12.5	14.3	17.1	19.5	20.9	24.1	25.5	27.8	29.9	–	–	–	–	–	–

Σ=All samples; ♀=Females; ♂=Males

Table 4. A comparison of the growth parameters and growth performance indexes obtained from previous studies for *Lepidorhombus boscii.*

References	Locality	Sex	L_∞	k	t_0	Φ
Fuertes (1978)	Galicia (Spain)	♀	42.9	0.15	-1.36	2.44
		♂	34.7	0.19	-1.37	2.36
Bello & Rizzi (1987)	Southern Adriatic (Italy)	♀	28.5	0.26	–	2.32
		♂	27.6	0.21	–	2.20
Mannini *et al*. (1990)	Northern Tyrrhenian Sea (Italy)	Σ	38.0	0.20	–	2.46
Castilho *et al*. (1993)	Portuguese coast	♀	44.0	0.14	-1.52	2.43
		♂	37.5	0.14	-1.93	2.29
Santos (1994)	Portuguese coast	♀	39.8	0.16	-1.84	2.40
		♂	34.8	0.20	-1.44	2.38
Stergiou & Politou (1995)	North Euboikos Gulf (Grecee)	Σ	43.3	0.26	–	2.69
Vassilopoulou & Ondrias (1999)	Eastern Mediterranean waters (Greece)	♀	30.5	0.18	-1.10	2.22
		♂	25.5	0.22	-1.09	2.16
		Σ	31.2	0.17	-1.12	2.22
Robson *et al*. (2000)	West coast of Ireland	Σ	34.4	0.27	-1.99	2.50
Landa *et al*. (2002)	Northeast Atlantic	♀	45.6	0.17	0.07	2.55
		♂	39.9	0.17	-0.37	2.43
Teixeira *et al*. (2010)	Portuguese coast	♀	38.1	0.14	-2.85	2.31
		♂	32.4	0.20	-2.49	2.32
This study	Saros Bay (Turkey)	♀	49.8	0.09	-2.15	2.35
		♂	39.1	0.11	-2.59	2.23

Σ=All samples; ♀=Females; ♂=Males

the previous studies may be related to the differences in the environmental conditions and/or sampling strategy. The findings from this study can be used for stock assessment studies in the future.

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