Turkish Journal of Zoology

Volume 37 | Number 1 Article 10

1-1-2013

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Turkish Journal of Zoology
http://journals.tubitak.gov.tr/zoology/
Research Article
Turk J Zool
(2013) 37: 73-83

doi:10.3906/zoo-1204-10

Some biological characteristics of Atlantic bonito (*Sarda sarda* Bloch, 1793) from Gallipoli Peninsula and Dardanelles (northeastern Mediterranean, Turkey)

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Received: 10.04.2012 • **Accepted:** 11.07.2012 • **Published Online:** 24.12.2012 • **Printed:** 21.01.2013

Abstract: This study was carried out to determine some biological characteristics of Atlantic bonito (*Sarda sarda* Bloch, 1793) from the Gallipoli Peninsula and Dardanelles (northeastern Mediterranean, Turkey) between September 2006 and October 2009. The length–weight relationship was estimated as $W = 0.0020TL^{3.41}$ ($r^2 = 0.96$) for females, $W = 0.0029TL^{3.32}$ ($r^2 = 0.97$) for males, and $W = 0.0028TL^{3.32}$ ($r^2 = 0.97$) for all samples. The von Bertalanffy growth parameters were computed as $L_\infty = 68.5$ cm, $k = 0.78$ year^{-1}, $t_0 = -0.34$ years for females; $L_\infty = 72.2$ cm, $k = 0.69$ year^{-1}, $t_0 = -0.52$ years for males; and $L_\infty = 69.8$ cm, $k = 0.76$ year^{-1}, $t_0 = -0.44$ years for all samples. The length at first maturity was estimated to be 41.9 cm for females and 35.8 cm for males.

Key words: Atlantic bonito, *Sarda sarda*, age, growth, Gallipoli Peninsula, Dardanelles

1. Introduction

Information on age and growth of species is significant for a comprehensive understanding of their population dynamics. Age forms the basis for the calculations of growth, productivity estimates, and mortality rates (Campana, 2001). The growth rate of fish is an essential input parameter into stock assessment models of fish populations, with a significant impact on the outcome of the analysis (Karakulak et al., 2011).

Atlantic bonito, *Sarda sarda* (Bloch, 1793), is distributed along tropical and temperate coasts of the Atlantic Ocean, the Mediterranean, and the Black Sea (Collette and Chao, 1975; Yoshida, 1980). It is an epipelagic, neritic, schooling scombrid that can adapt to gradual changes in the environment (Collette and Nauen, 1983). In the eastern Mediterranean Sea, Atlantic bonito migrate toward the Black Sea for spawning (May to July), after which a reverse migration takes place (Nümann, 1954).

In the literature, age estimations and growth parameters of *S. sarda* have been determined using different methodologies: length–frequency analysis by Zusser (1954), Nümann (1955), Nikolsky (1957), Türgan (1958), Dardignac (1962), and Hansen (1989); otoliths by Kutaygil (1967) and Ateş et al. (2008); fin rays by Zaboukas and Megalofonou (2007), Valeiras et al. (2008), and Di Natale and Mangano (2009); length–frequency analysis and vertebrae by Rodriguez-Roda (1966, 1981); otoliths, vertebrae, and fin rays by Rey et al. (1986); and fin rays and vertebrae by Santamaria et al. (1998).

With regard to Turkish seas, the existing studies on this species were related to age and growth (Nümann, 1955; Nikolsky, 1957; Türgan, 1958; Kutaygil, 1967; Ateş et al., 2008) and fisheries (Oray and Karakulak, 1997; Zengin et al., 1998; Ateş and Kahraman, 2002; Zengin et al., 2005) of *S. sarda*. This species is one of the more important species from commercial fisheries in all Turkish seas and it is caught by handlines, encircling nets, and purse-seiners. The average total catch in 2010 of Atlantic bonito was 9401 t (TÜİK, 2011).

This paper updates information on population parameters such as length distribution, sex ratio, length–weight relationship, age, growth, and length at first maturity of Atlantic bonito in order to provide better parameters for stock assessments that should maintain the sustainability of stock in Turkish waters.

2. Materials and methods

Samples were obtained from the Gallipoli Peninsula and Dardanelles between September 2006 and October 2009 during the migration movements of Atlantic bonito, using handlines, encircling nets, and gill nets at depths ranging from 0 m to 40 m (Figure 1).

Specimens were measured to the nearest 1 mm (total length) and weighed to the nearest 1 g (total weight). The

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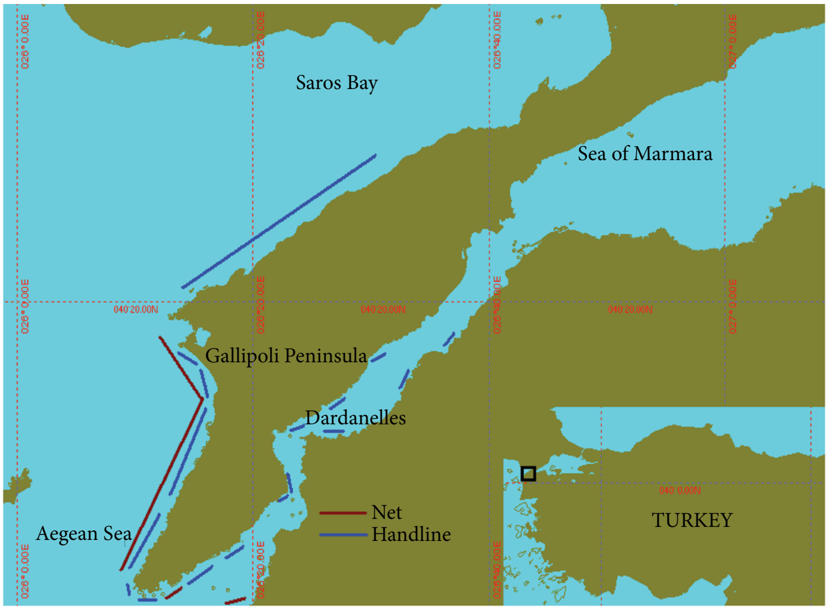

Figure 1. Study area.

chi-square (χ^2) test was used to detect deviations from the hypothetical equal distribution of males and females. Student's t-test was used to analyze differences between mean lengths and weights of both sexes. The length–weight relationship was calculated using 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 equation (Ricker, 1973). The growth type was identified by Student's t-test.

Age was determined by reading the sagittal otoliths. The entire otolith was cleaned in ethanol and then immersed in glycerin for examination using a binocular microscope against a black background with reflected light (Ateş et al., 2008). Opaque and transparent zones were counted; 1 opaque zone together with 1 transparent zone was assumed to be an age mark. The otoliths were read by 3 independent readers. As *S. sarda* has a spawning season in the Black Sea that peaks in May and June (Artüz, 1957), 1 June was chosen as the conventional birthday for all individuals for the estimation of the von Bertalanffy growth equation.

The von Bertalanffy growth equation was calculated according to $L_t = L_\infty [1 - e^{-k(t - t_0)}]$ for TL, where L_t is fish length (cm) at age t, L_∞ is the asymptotic fish length (cm), t is the fish age (years), t_0 (years) is the hypothetical time at which the fish length is zero, and k is the growth coefficient (year^{-1}) (Sparre and Venema, 1992).

The growth performance index (Φ') of Pauly and Munro (1984) was also estimated in order to compare growth parameters estimated by different authors, as it takes into account the correlation between L_∞ and k, t_o.

The length at first maturity was determined from asymptotic length by using the empirical relationship of Froese and Binohlan (2000):

$\log L_m = 0.9469 \times \log L_\infty - 0.1162$ (for female),

$\log L_m = 0.8915 \times \log L_\infty - 0.1032$ (for male).

3. Results

A total of 568 individuals were collected between September 2006 and October 2009 using handlines, encircling nets, and gill nets off the Gallipoli Peninsula and Dardanelles. The otoliths of 338 individuals were successfully extracted and they were read for age determination by 3 independent readers. Agreement was achieved for 238 otoliths. The remaining 100 otoliths were rejected due to disagreement between readers or because the otoliths were impossible to read. For this reason, those individuals were not further considered.

Of the 238 specimens, 100 were females, 82 were males, and 56 were of unknown sex. The mean total length and total weight of females were 34.8 ± 1.01 cm (28.0–72.0 cm) and 531.99 ± 72.66 g (132.1–4490.00 g); of males, 32.9 ± 0.89 cm (26.6–69.5 cm) and 406.48 ± 60.48 cm (158.78–3840.00 g); and of all samples, 32.7 ± 0.55 cm (23.8–72.0 cm) and 416.98 ± 37.88 g (102.00–4490.00 g) (Figure 2).

No significant difference was found between mean total lengths and total weights of the sexes ($P > 0.05$; $P = 0.184$). The sex ratio was calculated as 1:0.82 (F:M). Although the sex ratio was in favor of females, it did not significantly deviate from the expected hypothetical distribution (χ^2 = 1.78, df = 1, P = 0.1821).

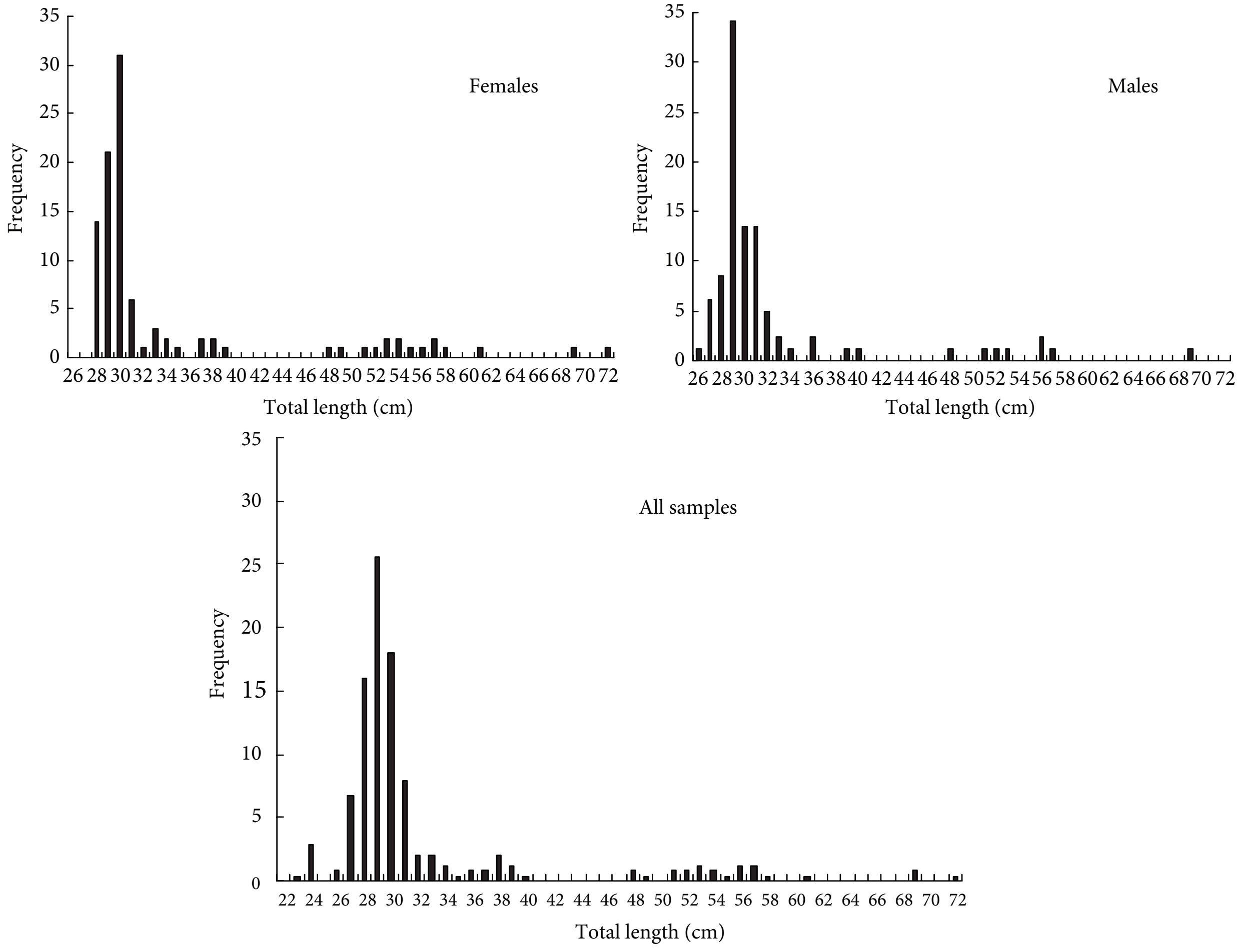

Figure 2. The length–frequency distributions for females, males, and all samples of *S. sarda* from Gallipoli Peninsula and Dardanelles.

The length–weight relationship was estimated as $W = 0.0020TL^{3.41}$ ($r^2 = 0.96$) for females, $W = 0.0029TL^{3.32}$ ($r^2 = 0.97$) for males, and $W = 0.0028TL^{3.32}$ ($r^2 = 0.97$) for all samples (Figure 3). While the *b*-values and t-test results indicated positive allometric growth for females, males, and all samples, the *b*-values showed no significant difference for females, males, and all samples ($P > 0.05$).

Age distribution ranged from 0 to 3 years. Year class 0 (86.8%) was dominant, followed by year classes I (6.6%), II (4.4%), and III (2.2%) (Table 1).

The von Bertalanffy growth parameters were computed as $L_\infty = 68.5$ cm, $k = 0.78$ year^{-1}, $t_0 = -0.34$ years for females; $L_\infty = 72.2$ cm, $k = 0.69$ year^{-1}, $t_0 = -0.52$ years for males; and $L_\infty = 69.8$ cm, $k = 0.76$ year^{-1}, $t_0 = -0.44$ years for all samples. The growth performance index (Φ') was found to be 3.56, 3.56, and 3.57 for females, males, and all samples, respectively. The length at first maturity was estimated to be 41.9 cm for females and 35.8 cm for males.

4. Discussion

The probable reasons for variations in size range between different areas could be attributed to using different sampling instruments, collecting samples from different areas and depths (Soykan et al., 2010), and the selectivity of fishing gear (İlkyaz et al., 2010). The length–weight relationships are related to the combination of one or more factors such as area, gonad maturity, habitat, degree of stomach fullness, season, length range, sex, health, and preservation techniques (Baganel and Tesch, 1978; Froese, 2006). The size selectivity of the sampling gear may also affect the length–weight relationships (İşmen et al., 2007). Some previous studies on length–weight relationship and length range for *S. sarda* in different areas are represented in Table 2.

The comparable maximum ages in previous studies include age 9 (76.2 cm by Zusser [1954]) and age 7 (71.7 cm by Hansen [1989] and 72.7 cm by Zaboukas and Megalofonou [2007]). In the western Atlantic, Bigelow

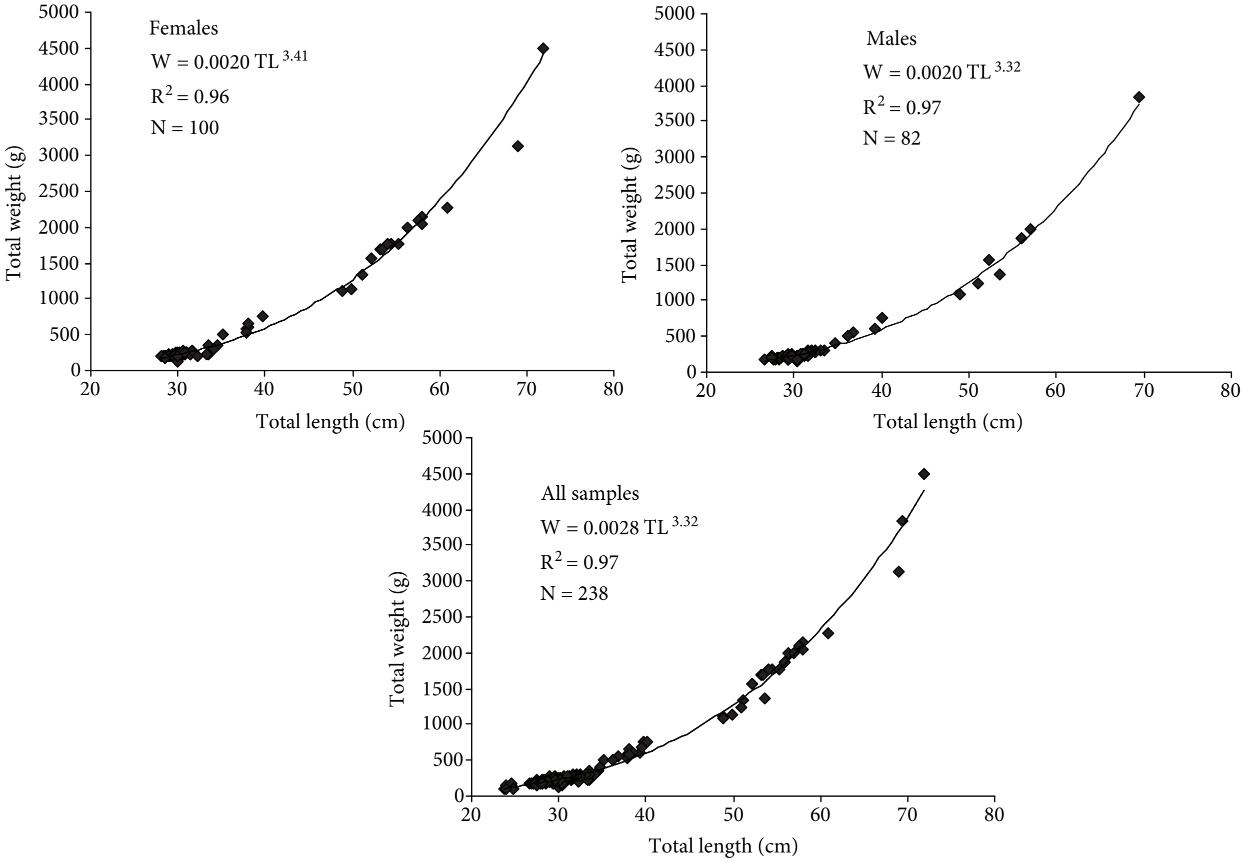

Figure 3. The length–weight relationships for females, males, and all samples of *S. sarda* from Gallipoli Peninsula and Dardanelles.

and Schroeder (1953) stated that *S. sarda* grow to about 91.4 cm. Gibson (2005) stated that maximum ages can vary widely between populations within species, especially those that have wide distributions. In this case, the growth of fish could be affected by environmental conditions and fishing efforts (Weatherley and Gill, 1987). The mean lengths at age for *S. sarda* given by various authors are shown in Table 3.

In general, the differences in length at age and growth parameters between different areas could probably be attributed to differences in length at first maturity (Champagnat, 1983); gear selectivity (Ricker, 1969; Potts et al., 1998); different environmental conditions, such as temperature, salinity, and food (Jabeur et al., 2000; Santic et al., 2002; Mahe et al., 2005; Basilone et al., 2006); a combination of sample characteristics (sample sizes and range of sizes); geographical differences; ageing methodology used (Monterio et al., 2006); and inaccuracy of age interpretation (Matić-Skoko et al., 2007). Gordoa and Balbina (1997) expressed that species that remain in the same habitats throughout their lives could maintain the same growth model. However, Avsar (1995) stated that differences in growth parameters calculated from data gathered at different times from the same area could be attributed to annual variations in average length with age.

The von Bertalanffy growth parameters derived in this study are generally different from those of previous studies. The discrepancies with previous studies can be explained partly by the maximum recorded length of Atlantic bonito sampled in each study. Larger maximum lengths increase the estimation of L_{inf}, which results in a lower estimation of k due to the inverse relationships between L_{inf} and k (Gallucci and Quinn, 1979). The growth coefficient found by Zusser (1954) was the lowest value in the literature so far.

The probable reasons for similarity between results from this study and those of Ateş et al. (2008) concerning growth parameters may be the use of the same ageing methodology, age interpretation, and length range corresponding to each age in samples examined. The t-test showed no significant differences between the growth performance indexes in the other areas ($P > 0.05$). The overview of growth parameters and growth performance indexes obtained from previous studies for *S. sarda* are given in Table 4.

Table 1. Age–length key for females, males, and all samples of *S. sarda* from Gallipoli Peninsula and Dardanelles.

Length class (cm)	Age groups				Total	Females	Males
	0	I	II	III			
26.1–28.0	8	-	-	-	8	1	7
28.1–30.0	80	-	-	-	80	45	35
30.1–32.0	49	-	-	-	49	26	23
32.1–34.0	8	-	-	-	8	4	4
34.1–36.0	4	-	-	-	4	3	1
36.1–38.0	6	-	-	-	6	4	2
38.1–40.0	2	-	-	-	2	1	1
40.1–42.0	1	-	-	-	1	-	1
42.1–44.0	-	-	-	-	-	-	-
44.1–46.0	-	-	-	-	-	-	-
46.1–48.0	-	-	-	-	-	-	-
48.1–50.0	-	3	-	-	3	2	1
50.1–52.0	-	2	-	-	2	1	1
52.1–54.0	-	5	1	-	6	4	2
54.1–56.0	-	2	2	-	4	2	2
56.1–58.0	-	-	5	-	5	4	1
58.1–60.0	-	-	-	-	-	-	-
60.1–62.0	-	-	-	1	1	1	-
62.1–64.0	-	-	-	-	-	-	-
64.1–66.0	-	-	-	-	-	-	-
66.1–68.0	-	-	-	-	-	-	-
68.1–70.0	-	-	-	2	2	1	1
70.1–72.0	-	-	-	1	1	1	-
Total							
N	158	12	8	4	182	-	-
Mean	30.5	52.2	56.3	67.9	33.9	-	-
Min.	26.6	48.9	53.2	61.0	26.6	-	-
Max.	40.1	56.0	58.0	72.0	72.0	-	-
S.E.	0.19	0.68	0.61	2.68	0.69	-	-
%	86.8	6.6	4.4	2.2	100.0	-	-
Females							
N	84	7	6	3	-	100	-
Mean	30.7	52.1	56.3	67.3	-	34.8	-
Min.	28.0	48.9	53.2	61.0	-	28.0	-
Max.	39.8	55.3	58.0	72.0	-	72.0	-
S.E.	0.26	0.87	0.82	3.28	-	1.01	-
%	84.0	7.0	6.0	3.0	-	100.0	-
Males							
N	74	5	2	1	-	-	82
Mean	30.4	52.3	56.5	69.5	-	-	32.9
Min.	26.6	48.9	56.0	69.5	-	-	26.6
Max.	40.1	56.0	57.0	69.5	-	-	69.5
S.E.	0.28	1.20	0.50	0.00	-	-	0.89
%	90.3	6.1	2.4	1.2	-	-	100.0

N = sample size; Min. = minimum; Max. = maximum; S.E. = standard error.

Table 2. Some previous studies on length–weight relationship (LWR) and length range for *S. sarda* in different areas.

Author(s)	Area	Sex	N	Length range (cm)	LWR
Rodriquez-Roda (1966)	Gibraltar (Spain)	Σ	165	40.0–55.0	$W = 0.0148FL^{2.97}$
Kara (1979)	Mediterranean (Turkey)	Σ	1608	14.0–90.0	$W = 0.0236FL^{2.87}$
Diouf (1980)	Eastern Tropical Atlantic (Senegal)	Σ	372	19.0–64.0	$W = 0.0094FL^{3.10}$
Dardignac (1962)	Atlantic (Morocco)	-	-	-	$W = 0.0079FL^{3.14}$
Rey et al. (1984)	Gibraltar (Spain)	Σ	878	19.0–72.0	$W = 0.0072FL^{3.16}$
		♀	229	33.0–70.5	$W = 0.0084FL^{3.12}$
		♂	242	33.0–65.2	$W = 0.0065FL^{3.18}$
Hansen (1987)	Argentina	Σ	-	33.0–77.0	$W = 0.0035FL^{2.95}$
Giacchetta et al. (1995)	Gulf of Taranto (Italy)	Σ	845	-	$W = 0.0252FL^{2.83}$
Morato et al. (2001)	Azores (Portugal)	Σ	31	22.0–83.0	$W = 0.0176FL^{2.87}$
Oray et al. (2004)	Eastern Mediterranean (Turkey)	Σ	1168	23.0–66.0	$W = 0.0039FL^{3.32}$
Franičević et al. (2005)	Adriatic Sea	Σ	665	33.0–67.0	$W = 0.0085FL^{3.12}$
		♀	353	33.0–64.5	$W = 0.0056FL^{3.23}$
		♂	285	35.0–67.0	$W = 0.0038FL^{3.34}$
Macías et al. (2005)	Western Mediterranean (Spain)	Σ	183	41.0–48.0	$W = 0.0046FL^{2.67}$
Di Natale et al. (2006)	Tyrrhenian Sea (Italy)	Σ	240	35.0–82.0	$W = 0.0003FL^{2.83}$
	Strait of Sicily (Italy)	Σ	109	35.0–67.0	$W = 0.0004FL^{2.18}$
Ateş et al. (2008)	Black Sea and Marmara Sea (Turkey)	Σ	694	23.5–71.0	$W = 0.0054TL^{3.21}$
This study	Gallipoli Peninsula and Dardanelles	Σ	238	23.8–72.0	$W = 0.0028TL^{3.32}$

FL: fork length; TL: total length.

The differences in lengths at first maturity between different localities could be attributed to food availability and temperature (Nikolsky, 1963; Hempel, 1965), over-fishing pressure and selectivity (Trippel, 1995; Helser and Almeida, 1997; Jennings et al., 2001), genetic factors (Wootton, 1998), and the use of different methods (Trippel and Harvey, 1991; Froese and Binohlan, 2000). Previous studies on length at first maturity of *S. sarda* from different areas are summarized in Table 5.

The fishery management of Atlantic bonito in Turkey depends on the fishing season. Purse seines are used intensively for Atlantic bonito fishing from September to November, but due to the bonito's reproduction period, Atlantic bonito fishing by various fishing gear is prohibited completely between 1 April and 31 August. The use of trolling for Atlantic bonito is permitted between 15 and 31 August. Furthermore, there are no legal regulations on catching quotas and fishing effort control for *S. sarda* in the Turkish Fishery Regulations. For this reason, Zengin and Dinçer (2006) recommended that the total amount of annual catch should not be over 10,000 t and that the catch per unit effort (CPUE) values should not exceed daily rates of 166 kg/vessel and 1240 kg/vessel for small and large fishing vessels for Turkish waters, respectively. There are no International Commission for the Conservation of Atlantic Tunas regulations directly concerning the Atlantic bonito stock..

As shown in Table 1, while 86.8% of Atlantic bonito caught are 26.0–42.0 cm, the remaining 13.2% have a size interval range of 48.0–72.0 cm. In this respect, Oray et al. (2004) found that 90.7% were within the size interval of 25.0–39.0 cm and suggested that this was probably due to fishing pressure. Ateş et al. (2008) stated that 86.2% (23.5–40.5 cm) of the Atlantic bonito caught were smaller than 41.0 cm; only 13.8% (52.5–71.0 cm) were larger than 51.0 cm and it is quite possible that the reason for the smaller number of large individuals (those over 50.0 cm are identified as Torik by fishermen) was recent increased fishing efforts. They put forward the suggestion that this is most likely owing to the rising number of purse seines.

Table 3. Mean lengths at age for *S. sarda* given by various authors.

Author(s)	Area	Method	0	1	2	3	4	5	6	7	8	9
Zusser (1954)	Black Sea (Russia)	Length–frequency	-	31.5	41.5	48.8	56.2	61.2	66.5	69.5	73.5	76.2
Nümann (1955)	Black Sea (Turkey)	Length–frequency	-	38.0–41.0	53.0–57.0	60.0–64.0	-	-	-	-	-	-
Postel (1955)	Eastern Atlantic	-	-	45.0	45.0–60.0	60.0	-	-	-	-	-	-
Nikolsky (1957)	Black Sea (Turkey)	Length–frequency	-	35.3	55.1	64.2	72.5	-	-	-	-	-
Türgan (1958)	Black Sea (Turkey)	Length–frequency	-	30.0–40.0	50.0–55.0	55.0–60.0	60.0-65.0	-	-	-	-	-
Nikolov (1960)	Black Sea (Bulgaria)	-	-	38.8	52.6	60.0	67.0	74.0-75.0	-	-	-	-
Rodriquez-Roda (1966)	Gibraltar (Spain)	Length–frequency	-	43.4	51.5	62.0	-	-	-	-	-	-
Kutaygil (1967)	Sea of Marmara (Turkey)	Otoliths	-	45.1	58.3	64.9	-	-	-	-	-	-
Rodriquez-Roda (1981)	Gibraltar (Spain)	Vertebrae	42.5	50.5	60.5	64.0	-	-	-	-	-	-
Rey et al. (1984)	Gibraltar (Spain)	-	46.0	51.7	57.0	63.1	64.0	-	-	-	-	-
Rey et al. (1986)	Gibraltar (Spain)	Fin rays, otoliths, vertebrae	37.0	51.7	57.0	63.1	71.0	-	-	-	-	-
Hansen (1989)	Argentina	Length–frequency	42.1	49.7	54.0	57.8	61.6	65.2	68.8	71.7	-	-
Santamaria et al. (1998)	South Adriatic (Italy)	Fin rays, vertebrae	34.8	50.9	57.5	64.8	70.4	-			-	-
Zaboukas and Megalofonou (2007)	Eastern Mediterranean (Greece)	Fin rays	28.6	40.1	49.2	56.3	62.0	66.4	69.9	72.7	-	-
Ateş et al. (2008)	Sea of Marmara and Black Sea (Turkey)	Otoliths	23.5–40.5	52.5–62.5	54.0–67.5	68.0–70.5	-	-	-	-	-	-
Valeiras et al. (2008)	Western Mediterranean (Spain)	Fin rays	-	43.7	53.1	57.7	-	-	-	-	-	-
Di Natale and Mangano (2009)	Tyrrhenian Sea and Strait of Sicily (Italy)	Fin rays	39.6	50.1	58.8	67.0	-	-	-	-	-	-
This study	Gallipoli Peninsula and Dardanelles	Otoliths	30.5	52.2	56.3	67.9	-	-	-	-	-	-

Table 4. The overview of growth parameters and growth performance indexes obtained from previous studies for *S. sarda* from different areas.

Author(s)	Area	Length Type	L_∞	k	t_o	Φ'
Zusser (1954)	Black Sea (Russia)	FL	103.0	0.13	−1.80	3.14
Nümann (1955)	Black Sea (Turkey)	FL	67.8	0.79	-	3.56
Nikolsky (1957)	Black Sea (Turkey)	FL	81.5	0.52	-	3.54
Türgan (1958)	Black Sea (Turkey)	FL	64.0	0.86	-	3.55
Nikolov (1960)	Black Sea (Bulgaria)	FL	95.6	0.24	−1.24	3.34
Dardignac (1962)	Atlantic (Morocco)	FL	64.0	0.69	−1.42	3.45
Rey et al. (1986)	Gibraltar Strait (Spain)	FL	80.8	0.35	−1.70	3.36
Hansen (1989)	Argentina	FL	74.6	0.22	−2.74	3.09
Cayre et al. (1993)	NE Atlantic	FL	80.8	0.35	−1.70	3.36
Santamaria et al. (1998)	Ionian Sea (Italy)	FL	80.6	0.36	−1.37	3.37
Zaboukas and Megalofonou (2007)	Eastern Mediterranean (Greece)	FL	82.9	0.24	−0.77	3.22
Ateş et al. (2008)	Black Sea and Marmara Sea (Turkey)	TL	68.0	0.82	−0.39	3.58
Valeiras et al. (2008)	Western Mediterranean (Spain)	FL	62.5	0.72	−1.21	3.45
This study	Gallipoli Peninsula and Dardanelles	TL	69.8	0.76	−0.44	3.57

FL: fork length; TL: total length.

Table 5. Previous studies on length at first maturity of *S. sarda* from different areas.

References	Length at first maturity	Area	Method
Postel (1954)*	37.0 cm (♀) 39.2 cm (♂)	Atlantic	-
Dardignac (1962)*	45.0 cm (♀) 40.0 cm (♂)	Atlantic (Morocco)	-
Rey et al. (1984)	39.0 cm (♀) 38.0 cm (♂)	Gibraltar (Spain)	Macroscopic observations of gonads
Ateş et al. (2008)	36.9 cm (Σ)	Black Sea and Marmara Sea (Turkey)	Empirical relationship
This study	41.9 cm (♀) 35.8 cm (♂)	Gallipoli Peninsula and Dardanelles	Empirical relationship

Σ: all samples; ♀: females; ♂: males; *from Rey et al. (1984).

Although the minimum landing size (MLS) for *S. sarda* is 25.0 cm in the Turkish Fishery Regulations, the minimum size regulation is not based on scientific evidence to protect the first spawners, unfortunately. To maintain the sustainability in population, it is of great importance to give each fish the chance to reproduce at least once in its lifetime (Türkmen and Akyurt, 2003). In light of these findings, if the MLS remains as it is now and legal regulations are not implemented (higher MLS, size selectivity, catching quote, fishing effort control, etc.), the sustainability of stock will be at risk as time goes by. Therefore, the fishing efforts and gear of purse seines must be optimized; alternative fishing methods such as handlines, encircling nets, and gill nets should be encouraged; and the selectivity of this equipment must be adjusted. In addition, marking studies could be carried out to better understand the migration patterns of Atlantic bonito. If these precautions could be put into practice successfully for fishery management, the *S. sarda* population will continue to be sustainable.

Acknowledgments
The present study was carried out with the financial support of TÜBİTAK (Project No: 106O097). The author thanks Uğur Özekinci, Alkan Öztekin, Cahit Ceviz, Adnan Ayaz, Uğur Altınağaç, and Fikret Çakır, who assisted in both field and laboratory work.

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