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Contribution to the knowledge of Atlantic bonito (*Sarda sarda* Bloch, 1793) from Bulgarian Black Sea coast

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Abstract
Some aspects concerning the growth and population dynamics of *Sarda sarda* were studied. Specimens were collected from the Bulgaria Black Sea coast between September 2011 and November 2011 during the migration movements of Atlantic bonito. A total of 474 specimens (176 males and 298 females) were investigated. Mean ± S.E. values for total length and body weight are (36.4±1.01; 511±71.42) for females and (34.6±0.89; 506.48±50.48) for males respectively. The values of allometric coefficient *b* were larger than 3. Estimates of the Von Bertalanffy growth parameters were L_∞ = 84.25 cm and k = 0.38 year^{-1} in females, and L_∞ = 81.63 cm and k = 0.49 year^{-1} in males. The growth performance index (ø`) was found to be 3.43 and 3.51 for females and males, respectively.

Keywords: Biological aspects, Sarda sarda, Black Sea, Bulgarian coast

1. Introduction
Atlantic bonito (*Sarda sarda* Bloch, 1793) [1] is distributed along tropical and temperate coasts of the Atlantic Ocean, the Mediterranean, and the Black Sea (Collette and Chao, 1975; Yoshida, 1980) [7, 44]. It is an epipelagic, neritic, schooling scombrid that can adapt to gradual changes in the environment (Collette and Nauen, 1983) [8]. In the eastern Mediterranean Sea, Atlantic bonito migrate toward the Black Sea for spawning, after which a reverse migration takes place (Nümann, 1954). Atlantic bonito plays a major role as top predator in the Black Sea ecosystem and has high commercial importance (Prodanov, *et al*, 1997) [33]. While total catches of Atlantic bonito from all Black Sea coastal states reached the maximum of 20,000 tons in 1969, thereafter no Atlantic bonito catches have been recorded from any country, other than Turkey and Bulgaria (Sampson, *et al*, 2014) [37]. This was mainly due to pollution in northwest Black Sea, problems with migration routes (alteration of oceanographic conditions) and heavy fishing impact on Atlantic bonito stocks (Daskalov, 2002; Eremeev and Zuyev, 2007) [9, 13].
The biological knowledge of *S. sarda* is mainly focused on the Turkish Black Sea (Nümann, 1955; Nikolsky, 1957; Türgan, 1958; Kutaygil, 1967; Ateş, *et al*, 2008; Oray and Karakulak, 1997; Zengin, *et al*, 1998; Ateş and Kahraman, 2002; Zengin, *et al*, 2005) [28, 26, 42, 21, 1, 30, 46, 2, 47].
As even the population dynamics of the species is not well documented for the Bulgarian Black Sea, I believe that the additional records in this paper will illuminate the information of the species in the region.
In the present study, fishery studies were carried out with the goal of assessing the biological aspects of *S. sarda* (population characteristics, growth, and sex ratio) in Bulgarian Black Sea coast.

2. Materials and Methods
2.1 Sampling
Samples were obtained from the Bulgaria Black Sea coast between September 2011 and November 2011 during the migration movements of Atlantic bonito, using handlines and gill nets. Specimens were measured to the nearest 1 mm (total length) and weighed to the nearest 1 g (total weight). The 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.

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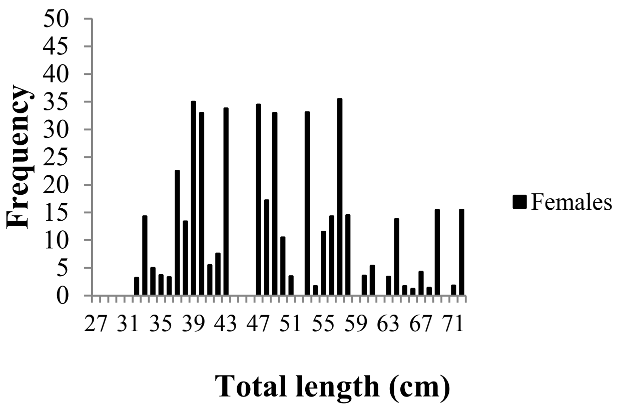
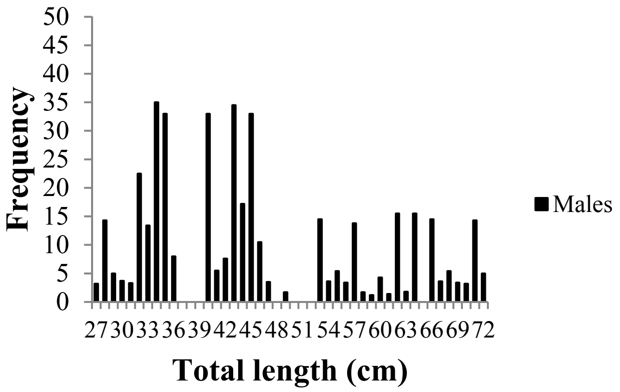
The length–weight relationship was calculated using the equation $W = aL^b$, where W is the total weight, L is the total length, and a and b are the parameters of the equation (Ricker, 1973) [36]. The growth type was identified by Student's t-test. Age was determined by reading the sagittal otoliths. 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) [1]. The von Bertalanffy growth equation was calculated according to $L_t = L_\infty [1 - e- k (t - t_o)]$ 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) [41]. The growth performance index (ø`) 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.

3. Results

A total of 474 individuals were collected between September 2011 and November 2011 using handlines and gill nets off the Bulgarian Black Sea coast. Of the 474 specimens, 298 were females and 176 were males. The mean total length and total weight of females were 36.4 ± 1.01 cm (32.0–72.0 cm) and 511.99 ± 71.42 g (142.1–890.00 g); of males, 34.6 ± 0.89 cm (27.0–72.0 cm) and 506.48 ± 50.48 cm (258.78– 670.00 g); and of all samples, 33.7 ± 0.55 cm (27.0–72.0 cm) and 439.20 ± 37.88 g (302.00–910.00 g) (Figure 1).





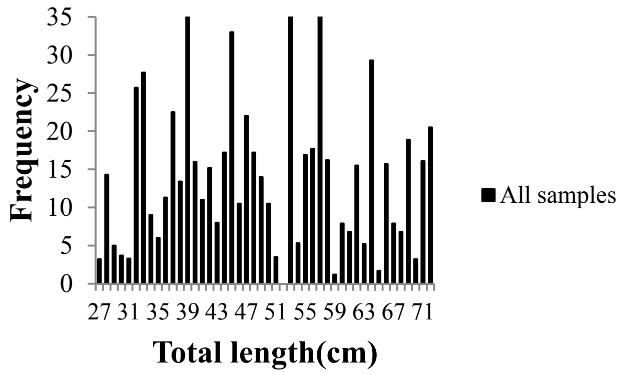


Fig 1: The length–frequency distributions for females, males, and all samples of *S. sarda* from Bulgarian Black Sea coast.

No significant difference was found between mean total lengths and total weights of the sexes ($P > 0.05$; $P = 0.172$). The sex ratio was calculated as 1:0.68 (F:M). Although the sex ratio was in favor of females, it did not significantly deviate from the expected hypothetical distribution ($\chi^2 = 1.75$, df = 1, $P = 0.1743$). The length–weight relationship was estimated as $W= 0.0020TL^{3.41}$ ($r^2 = 0.96$) for females, $W = 0.0029TL^{3.38}$ ($r^2 = 0.97$) for males, and $W = 0.0028TL^{3.32}$ ($r^2 = 0.97$) for all samples. 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 1 to 4 years. Year class 2 (58.85%) was dominant, followed by year classes III (30.09%), II (4.42%), I (6.64%) and IV (4.42%).

The von Bertalanffy growth parameters were computed as L_∞ = 84.25 cm, k = 0.38 year^{-1}, t_0 = –0.54 years for females; L_∞ = 81.63 cm, k = 0.49 year^{-1}, t_0 = –0.62 years for males; and L_∞ = 80.4 cm, k = 0.67 year^{-1}, t_0 = –0.34 years for all samples. The growth performance index (ø`) was found to be 3.43, 3.51, and 3.64 for females, males, and all samples, respectively.

4. Discussion

The minimum sizes of the sexes reported in this study were slightly larger than those reported from the Mediterranean (Kara, 1979) [30]; from the Eastern Tropical Atlantic (Diouf, 1980; Dardignac, 1962) [11, 10]; from the Azores (Morato, *et al*, 2001) [25]; from the Eastern Mediterranean (Oray, *et al*, 2004) [31]; from Black Sea and Marmara Sea (Ateş, *et al*, 2008) [1] and from the Gallipoli Peninsula and Dardanelles (Cengiz, 2013). As reported for most of the species, females showed a size predominance of seasonal size distribution over males. The results observed in this study on the size predominance of females are in accordance with those reported from the northeastern Mediterranean, Turkey waters (Cengiz, 2013) [5]. The maximum values of the sex ratio were observed during the late summer-early autumn period (September to October 2011), and these values were found to be distinctly higher than those reported by (Cengiz, 2013) [5] from the northeastern Mediterranean Sea. 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) [17], and the selectivity of fishing gear (İlkyaz, *et al*, 2010) [40]. The size selectivity of the sampling gear may also affect the length–weight relationships (İşmen, *et al*, 2007) [18]. Some previous studies on length–weight relationship and length range for *S. sarda* in different areas are represented in Table 1.

Table 1: Some previous studies on length–weight relationship (LWR) and length range for *S. sarda* in different areas.

Author(s)	Area	Sex	LWR
Kara, (1979)	Mediterranean (Turkey)	Σ	$W = 0.0236FL^{2.87}$
Giacchetta, *et al*, (1995)	Gulf of Taranto (Italy)	Σ	$W = 0.0252FL^{2.83}$
Oray, *et al*, (2004)	Eastern Mediterranean (Turkey)	Σ	$W = 0.0039FL^{3.32}$
Franičević, *et al*, (2005)	Adriatic Sea	♀	$W = 0.0056FL^{3.23}$
		♂	$W = 0.0038FL^{3.34}$
Di Natale, *et al*, (2006)	Strait of Sicily (Italy)	Σ	$W = 0.0004FL^{2.18}$
Ateş, *et al*, (2008)	Black Sea and Marmara Sea (Turkey)	Σ	$W = 0.0054TL^{3.21}$
Yankova, *et al*, (2011)	Black Sea (Bulgaria)	Σ	$W = 0.015TL^{2.984}$
This study	Black Sea (Bulgaria)	♀	$W= 0.0020TL^{3.41}$
		♂	$W = 0.0029TL^{3.38}$
		Σ	$W = 0.0028TL^{3.32}$

A comparison of the growth parameters estimated in the present study with those reported from the neighboring areas showed that the L_∞ lengths estimated in the present study were slightly lower than those reported for the Black Sea (Russia) (Zusser, 1954) [48]; for the Black Sea (Turkey) (Nikolsky, 1957) [26]; for the Black Sea (Bulgaria) (Nikolov, 1960) [27] and for Eastern Mediterranean (Greece) (Zaboukas and Megalofonou, 2007) [45] for both males and females.

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) [15].

The growth coefficient found by Zusser (1954) [48] was the highest value in the literature so far. The probable reasons for similarity between results from this study and those of Rey, *et al*, (1986) [34]; Cayre, *et al*, (1993) [4]; Santamaria, *et al*, (1998) [38] 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 2.

Table 2: The overview of growth parameters and growth performance indexes obtained from previous studies for S. sarda from different areas.

Author(s)	Area	L_∞ cm	k year^{-1}	t_o	ø`
Zusser, (1954)	Black Sea (Russia)	103.0	0.13	–1.80	3.14
Nikolsky, (1957)	Black Sea (Turkey)	81.5	0.52	-	3.54
Nikolov, (1960)	Black Sea (Bulgaria)	95.6	0.24	–1.24	3.34
Zaboukas and Megalofonou, (2007)	Eastern Mediterranean (Greece)	82.9	0.24		
Rey, *et al*, (1986)	Gibraltar Strait (Spain)	80.8	0.35	–1.70	3.36
Cayre, *et al*, (1993)	NE Atlantic	80.8	0.35	–1.70	3.36
Santamaria, *et al*, (1998)	Ionian Sea (Italy)	80.6	0.36	–1.37	3.37
This study	Black Sea (Bulgaria)	80.4	0.67	–0.34	3.64

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) [6]; gear selectivity (Ricker, 1969; Potts, *et al*, 1998) [35, 32]; 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) [19, 39, 22, 3]; a combination of sample characteristics (sample sizes and range of sizes); geographical differences; ageing methodology used (Monterio, *et al*, 2006) [24]; and inaccuracy of age interpretation (Matić-Skoko, *et al*, 2007) [23].

5. Conclusion

These studies are very important for understanding the biological characteristics of *S. sarda*, especially in the Bulgarian Black Sea territorial waters.

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