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Length-weight relationships, growth parameters, mortality and condition factor of Atlantic bonito (*Sarda sarda* Bloch, 1793) from the Southern Black Sea

Güney Karadeniz'de yayılış gösteren Palamut Balığı (*Sarda sarda* Bloch, 1793)'nın boy-ağırlık ilişkileri, büyüme parametreleri, ölüm oranları ve kondisyon faktörü

Türk Denizcilik ve Deniz Bilimleri Dergisi
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Yaşar Genç[1], Murat Dağtekin[1,*], Nimet Selda Başçınar[1], Elvan Tercan[2]
[1] *Central Fisheries Research Institute, Trabzon, Türkiye*
[2] *The General Directorate of Fisheries and Aquaculture, Ankara, Türkiye*

ABSTRACT

The small tuna known as the Atlantic bonito (*Sarda sarda*) is one of the most important fishery species on the Black Sea coast of Türkiye. In this study, we sought to define some population parameters of Atlantic bonito based on indirect ageing using length frequency distributions. The aim of this study is to provide data that will serve the management of the bonito fishery. For analysis, the ELEFAN routine in the LFDA and FiSAT programs was utilized. During the migration period, we collected 2110 samples from purse seine (n=1009), gillnet (n=867) and hand lines (n=234) fishing in the Black Sea waters of Türkiye. The fork length varied between 13.1 and 60 cm, and the female-to-male ratio was 1:0.79. The length-weight relationships (LWRs) were calculated $W=0.0037FL^{3.3784}$ and Fulton's K:1.01±0.001. The growth was found to be positive allometric (Student's t-test, $p < 0.05$). von Bertalanffy Growth Parameters (VBGP) were computed as L∞:71.59 cm, K:0.56 year-1, t0:-0.18 year. The seasonal oscillation in growth rate was calculated (C: 0.98) and winter point (WP): 0.54, growth performance index of Ø': 3.46, natural mortality (M: 0.74 yr^{-1}), fishing mortality (F: 2.81 yr^{-1}), total mortality (Z: 3.55 yr^{-1}) and exploitation coefficient (E: 0.79 yr^{-1}). As a result, the exploitation rate of *S. sarda* in the study area was found to be high.

Keywords: *Sarda sarda*, Black Sea, LFDA, ELEFAN, Condition factor, Growth parameters.

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*(corresponding author)
E-mail: muratdagtekin998@gmail.com; murat.dagtekin@tarimorman.gov.tr

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ÖZET

Atlantik palamudu olarak bilinen küçük orkinoslardan *Sarda sarda*, Türkiye'nin Karadeniz kıyılarının en önemli balıkçılık türlerinden biridir. Bu çalışmada, boy frekans dağılımları kullanılarak boya dayalı olarak palamut balığının bazı popülasyon parametrelerini tanımlamaya çalışıldı. Bu çalışmanın amacı palamut balıkçılığının yönetimine hizmet edecek sonuçlar sağlamaktır. Çalışmada verilerin analizi için LFDA ve FiSAT programlarındaki ELEFAN rutini kullanıldı. Palamut balığının Türkiye'nin Karadeniz sularında göçü boyunca gırgır (n=1009), uzatma ağları (n=867) ve olta (n=234) ile avlanan 2110 örnek toplanıldı. Örneklenen bireylerin çatal boyu 13,1 ile 60 cm arasında değişmekte olup, dişi/erkek oranı 1:0,79'dur. Boy-ağırlık ilişkileri (LWRs) $W=0,0037FL^{3,3784}$ ve Fulton's K:1,01±0,001 olarak hesaplanmıştır. Çalışma sonucunda büyümenin pozitif allometik olduğu bulunmuştur (Student's t-test, $p < 0,05$). von Bertalanffy Büyüme Parametreleri (VBGP) $L\infty$:71,59 cm, K:0,56 $yıl^{-1}$, t0:-0,18 yıl olarak hesaplanmıştır. Büyüme oranındaki mevsimsel salınım (C: 0,98) ve kış noktası (WP): 0,54, Ø' büyüme performansı indeksi 3,46 olarak hesaplanmıştır. Doğal ölüm (M: 0.74 yr^{-1}), balıkçılık ölüm (F: 2,81 yr^{-1}), toplam ölüm (Z: 3,55 yr^{-1}) ve sömürü katsayısı (E: 0,79 yr^{-1}) olarak hesaplanmıştır. Çalışma sonucunda Karadeniz boyunca *S.sarda*'da işletme oranının yüksek olduğu tespit edilmiştir.

Anahtar sözcükler: *Sarda sarda,* Karadeniz, LFDA, ELEFAN, Kondisyon faktörü, Büyüme parametreleri.

1. INTRODUCTION

The small tuna known as the Atlantic bonito (*Sarda sarda,* Bloch, 1793) belongs to the Scombridae family (URL-1, 2023). It inhabits schools along the neritic area and can enter estuaries. Its distribution encompasses large temperate and tropical regions in the Atlantic, Gulf of Mexico, Black Sea, and Mediterranean on both hemispheres (URL-2, 2024). It grows rapidly and has a short lifespan. According to Cayré *et al*. (1993), *S. sarda* can grow up to a maximum fork length of 91.4 cm and a maximum weight of 11 kg. *S. sarda* has a high commercial value and has been an important top predator in the Black Sea basin (Prodanov *et al.* 1997; FAO 2013; Cengiz 2013). *S. sarda* has primarily been caught along the Turkish Black Sea coastlines since 1950 (Prodanov *et al.*, 1997). According to reports dating back over sixty years (STECF, 2014), almost all of the *S. sarda* caught in the Black Sea comes from Turkish waters. However, long-term data indicate significant fluctuations in Black Sea *S. sarda* landings in Türkiye (Figure 1).

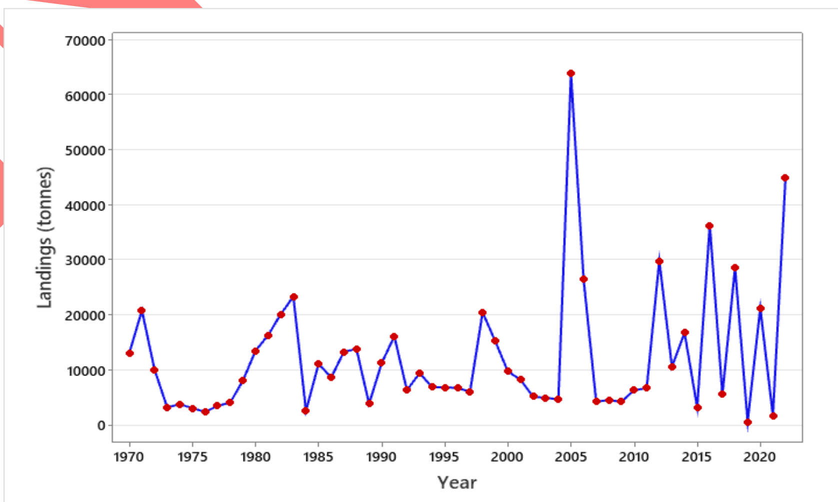

Figure 1. The landings of *S. sarda* on the Turkish coasts of the Black Sea (TURKSTAT, 2022)

It is seen that the world fisheries production of *S. sarda* caught in Türkiye was around 40% between the years 1950-2011. According to TURKSTAT (2022), approximately 75% of Türkiye's *S. sarda* comes from the Black Sea, even though this fish species is widely distributed and can be found in the Aegean, Mediterranean, Black, and Marmara seas. The fish migrate back to the Marmara and Aegean Seas to spend the winter after entering the Black Sea in the spring and feeding there until late autumn. During its migrations to the Black Sea, *S. sarda* primarily feeds on anchovies and horse mackerel, sprat, and other fish species to a lesser extent (Genç *et al.,* 2019). Age determination, growth, fecundity, feeding habits, reproductive biology, and genetics of *S. sarda* have been studied several researchers (Nümann, 1954; Demir and Demir, 1961; Tanakol *et al*., 1999; Zengin *et al*., 2005; Ateş *et al.,* 2008; Cengiz 2013; Kahraman *et al.,* 2014; Turan *et al*., 2015; Samsun *et al*., 2017; Genç *et al.,* 2019). The biology of *S. sarda* and other small tuna species is poorly understood in many regions. Research on these species is rare due to the difficulty of sampling small-scale fisheries, which constitute a large proportion of small tuna source fisheries (ICCAT 2000). Therefore, investigations should be conducted at the local or sub-area scale (Zaboukas *et al.,* 2006). This study aims to determine some population parameters of *S. sarda* in the Southern Black Sea during its migration period. The findings of this study are expected to help with the stock assessment of this species and the management of fisheries in the region.

2. MATERIALS AND METHODS

The study area was from Hopa (Artvin) to İğneada (Kırklareli), (latitude: 41.52414 E, 41.51670 N, longitude: 41.94051 N, 28.14820 E). Samples were taken at random from ports in the Black Sea during the *S. sarda* fishing season between July 2012 and February 2013 (Figure 2).

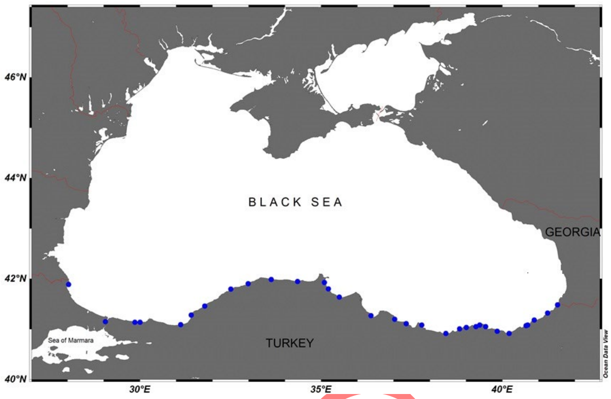

Figure 2. Sampling stations in the study area between Hopa and İğneada on the Turkish Black Sea coast

The fish sampled were caught using commercial purse seine boats (mesh size: 32 mm) and gillnet boats (mesh size: 64–88 mm). For every specimen, measurements of the fork length (FL, sensitivity 0.1 cm) and total body weight (TW, sensitivity 0.1 g) were taken. After the gonads were extracted, they were weighed (0.01 g), and a macroscopical determination of the sex was made (Macías et al., 2005). There were 2110 individuals in the *S. sarda* sample in total. The following equation was used to look at the length-weight relationships of *S. sarda* (Le Cren, 1951).

$$W = aFL^2 \qquad (1)$$

where FL refers to fork length (cm), W refers to total body weight (g), a: intercept, and b: slope are the regression coefficients. Regression analysis was used to find the values a and b and to figure out the growth pattern for the length and weight. Based on the estimated 'b' value, it was concluded that the growth was either allometric [$(ts = (b - 3) / Sb)$ Sokal and Rohlf, 1987] or isometric (H_0, b = 3). In this formula, ts is the student t-test value, *b* is the slope, and Sb is the standard error of the "b" value. The chi-square test was used to examine the overall sex ratio, and an independent-samples t-test was utilized to look for any potential significant differences in the mean length of males and females (Zar, 1996). Utilizing R for statistical analysis, a significance level of 0.05 was chosen (URL- 3, 2023). The Fulton's condition factor (K) was obtained from $K = 100 x W / L^3$ where W and FL stand for total weight and fork length. The von Bertalanffy growth (VBG) equation is used in various manners. The VBG equation, as given by Somers (1988), was used to define seasonal growth.

$$L_t = L_\infty \left[1 - e^{\left[-K(t-t_0) + \left(C\frac{K}{2\pi} \right) sin 2\pi (t-t_s) - \left(C\frac{K}{2\pi} \right) sin 2\pi (t_0 - t_s) \right]} \right] \quad (2)$$

where,
L_∞ = the asymptotic fork length (cm),
K= the growth coefficient (year^{-1}),
t_0= the nominal age at which the fork length is zero,
L_t= the fork length at age t (cm),
C is the oscillations' amplitude. The equation has no seasonal variation when C=0 when, during the low growth season, C=1 growth becomes zero. ts is the beginning time of the sinusoidal growth oscillation. Here, WP (winter point), the time of year when growth is at its slowest, was substituted for ts, with WP = ts+0.5. Due to the ELEFAN only estimating two of the three growth parameters (L_∞ and K), we used Froese and Binohlan's (2003) empirical equation for growth fitting to calculate the third parameter (t_0).

$$log(-t_0) = -0.3922 - 0.2752 \times logL_\infty - 1.038 \times logK \quad (3)$$

Seasonal VBG curves were fitted to the length distributions to provide the best goodness of fit values (Rn). The formula Rn= (10 ESP/ASP)/10 was used to calculate the quality of fit. ESP stands for the explained sum of peaks, the total of all the peaks and troughs that the VBG curve has hit. The best values of the available peaks are added to determine the available sum of peaks, or ASP. T_{max} formula, as mentioned earlier, estimates the maximum age of fish based on growth parameters. The formula often referenced in this context is (Ricker,1975):

$$Tmax = t0 + 0.2996 / K \quad (4)$$

Where:
T_{max}: Maximum age of the fish
t_0: Theoretical age at which the fish's length is zero,
K: Growth coefficient from the von Bertalanffy growth model.

The length data analysis was fitted to length-frequency distributions grouped in 2 cm fork length size classes using the ELEFAN procedure in the based computer package, The Length Frequency Distribution Analysis (LFDA), version 5.0 (Kirkwood *et al*., 2001). It preferred this method instead of using L and K separately when comparing the phi prime index (Φ') of *S. sarda* (Pauly and Munro, 1984). This parameter made this equation.

$$\Phi' = log(K) + 2log(L_\infty) \quad (5)$$

The instantaneous natural mortality coefficient (M) was determined using Pauly's (1980) empirical model as follows:

$$lnM = -0.0066 - 0.279 lnL_\infty + 0.6543 lnK + 0.463 lnT \quad (6)$$

in which T is the annual mean temperature of the environment in degrees Celsius (16 °C), (URL-4). The instantaneous total mortality coefficients were calculated by applying the length-converted catch curve developed by Pauly (1990) and Pauly *et al*. (1995) using the length-frequency data (Z). The fishing mortality ($F = Z - M$) is represented by the formula F * Z^{-1}, which equals the exploitation ratio (E).

3. RESULTS

A sample of 2110 *S. sarda* specimens—576 males, 730 females, and 804 undetermined formed the basis of the current investigation. In this study, the presence of individuals at the juvenile stage in some cases, along with the fact that certain specimens were not bought, resulted in the collection of only length and weight data at the point of landing. Consequently, this has led to a higher number of specimens for which sex could not be determined. Overall FL ranged from 13.2 to 60.8 cm (mean length: 29.78±0.13 cm), and total W ranged from 26.92 to 3950 g (mean weight: 419.28±7.1 g). Furthermore, 730 females measuring 13.2 to 40.0 cm (mean:

27.84±0.22 cm), 576 males measuring 13.6 to 37.9 cm (mean: 27.33±0.24 cm), and 804 unidentified specimens measuring 24.5 to 60.8 cm (mean: 33.28±0.17 cm) were examined (Table 1; Figure 3).

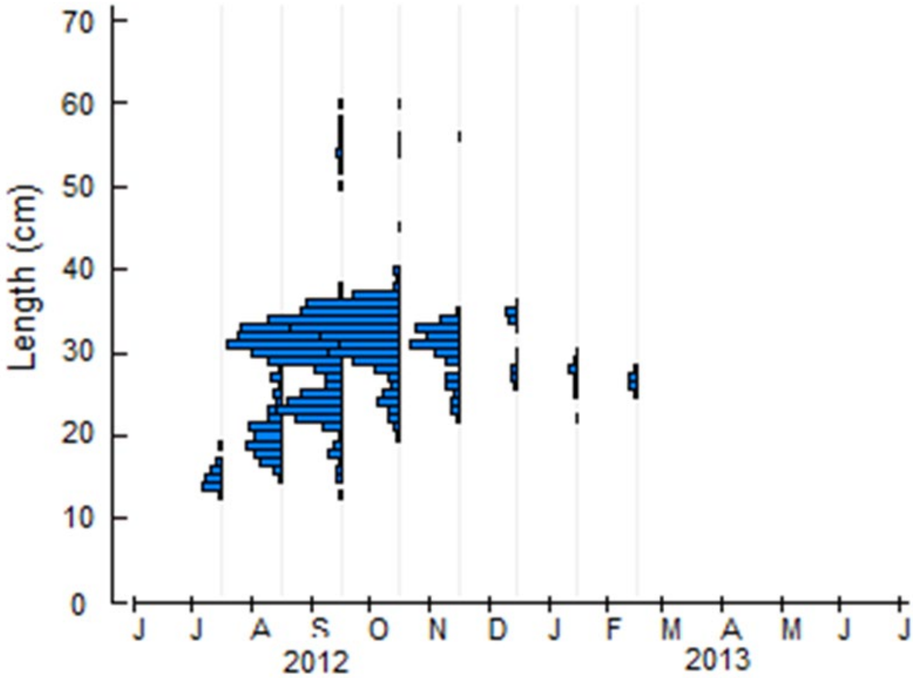

Figure 3. Length frequency distribution of the *S. sarda*, during migration periods in landings on the Turkish Black Sea Coast

Table 1. The number of individuals, mean fork length (cm), weight (g) and condition factor (K) by months in the 2012-2013 fishing season

Months	N	FL [Mean±S.E, (min-max)]	W [Mean±S.E. (min-max)]	Condition factor (K) [Mean±S.E, (min-max)]
July-2012	47	15.53±0.19*(13.2-19.8)*	41.77±1.91(27.22-89.53)	1.04±0.01(0.86-1.23)
August-2012	187	20.74±0.21(15.4-28.9)	116.76±4.28(37.4-313.33)	1.05±0.01(0.91-1.34)
September-2012	808	29.62±0.21(13.6-60.8)	415.62±13.88(26.92-3950)	1.02±0.001(0.82-1.36)
October-2012	776	32.75±0.14(20.3-59.8)	532.45±9.32(97.84-3750)	1.02±0.001(0.81-1.3)
November-2012	211	30.78±0.24(22.5-56.6)	401.5±14.38(133.75-2850)	0.96±0.01(0.76-1.18)
December-2012	38	31.97±0.56(26.2-36)	447.95±27.43(210.76-665)	0.94±0.01(0.79-1.07)
January-2013	21	27.4±0.38(22.9-30.1)	261.39±11.99(132-350)	0.97±0.01(0.87-1.09)
February-2013	22	26.95±0.17(25.6-28.4)	211.43±4.77(165.98-258.82)	0.84±0.01(0.76-0.92)
Total	2110	29.78±0.13(13.2-60.8)	419.28±7.1(26.92-3950)	1.01±0.01(0.76-1.36)

The one-way ANOVA revealed that monthly mean lengths varied significantly. ($F=213.43$; $df=7$, $p<0.05$). Table 1 and Figure 4 demonstrate the mean FL, mean W and Fulton's K values for all samples.

The sample contained more females than males (sex ratio 1:0.79). Females dominated almost all length classes when sex ratios varied with length class. Females had a mean weight of 332.87±7.47 g, and males had a weight of 314.34±8.22 g. The difference between the length distribution of males and females was insignificant. Female and male Fulton's condition factors ranged from 0.76 to 1.29 (with a mean of 1.01±0.08)–and 0.76 to 1.34 (with a mean of 1.01±0.08), respectively. In February 2013, the lowest average monthly Fulton's K values for the males and females were stated. Established in July 2012, the highest average monthly Fulton's K values were noted. Between the sexes, there were no statistically significant differences (H=1.48; df=1, p=0.22). All specimens were determined that the values of a and b were 0.0037 and 3.3784, respectively. The relationship between the two variables was significant (p < 0.05). Furthermore, positive allometric growth was noted, and the t-test indicated no significant differences (p >0.05) between the slopes (b) estimated for males and females (Table 2).

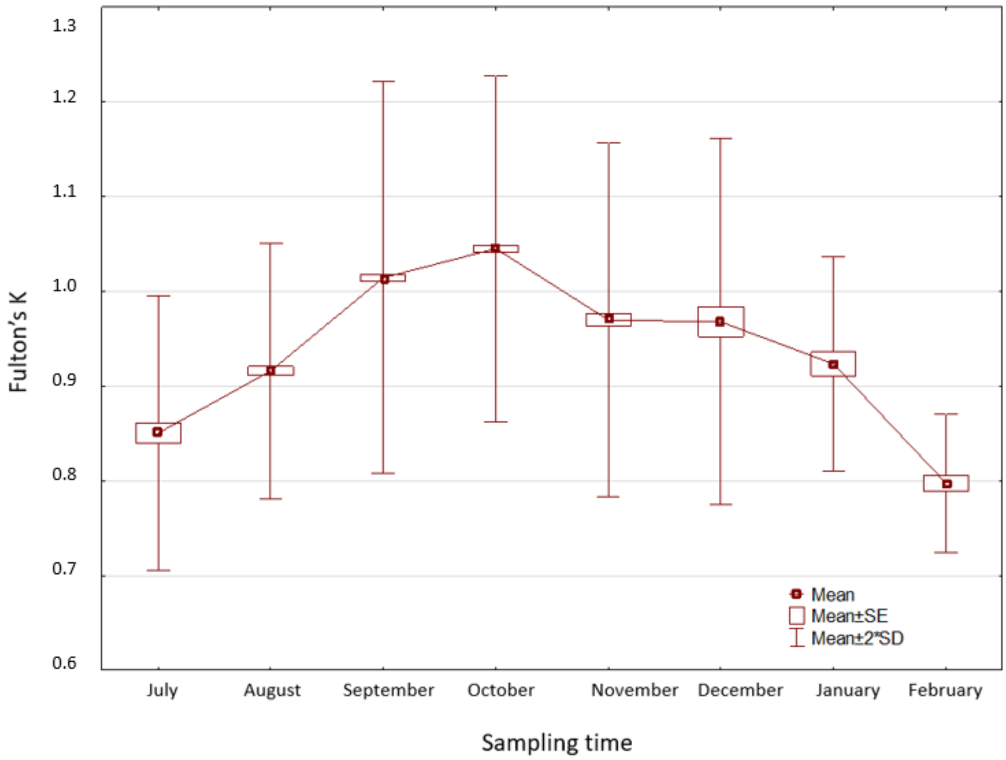

Figure 4. Monthly changes in the mean Fulton's condition factor estimated in *S. sarda*

Table 2. Parameters of the length-weight relationship of *Sarda sarda* in the 2012-2013 fishing season (N: sample size, FL: Fork Length (cm), SE: standard error, CI: confidence interval, *a*: intercept, *b*: slope, r^2: determination coefficient)

Sex	N	FL_{min}–$FL_{max.}$	W_{min}–$W_{max.}$	Length-weight relationship			
				LWR equation	S.E. of *b* (95% CI of *b*)	r^2	Growth Type
F	730	13.2-40.0	27.2-947.5	$W=0.0039L^{3.3621}$	0.013(3.337-3.388)	0.989	Allometric (+)
M	576	13.6-37.9	26.5-887.0	$W=0.0040L^{3.3604}$	0.015(3.331-3.390)	0.989	Allometric (+)
Unidentified	804	24.5-60.8	172.0-3950.0	$W=0.0035L^{3.3962}$	0.021(3.354-3.438)	0.970	Allometric (+)
All	2110	13.2-60.8	26.9-3950	$W=0.0037L^{3.3784}$	0.008(3.363-3.394)	0.989	Allometric (+)

The seasonalized VBG curve with the following parameters was obtained by the ELEFAN analysis: L_∞: 71.59 cm, K: 0.56 year^{-1}, t_0: -0.18, C: 0.97, and WP: 0.54. Figures 5 demonstrate *S. sarda*'s growth patterns. The lifespan and phi prime index of *S. sarda* was calculated to be 3.46 and t_{max}: 5.17 years, respectively. Table 3 shows the FL and W data for both sexes according to fishing season. The sex ratio was 1:0.79, favouring females, and there was a significant difference between the sexes ($\chi 2$= 18.159; df= 1; p < 0.001).

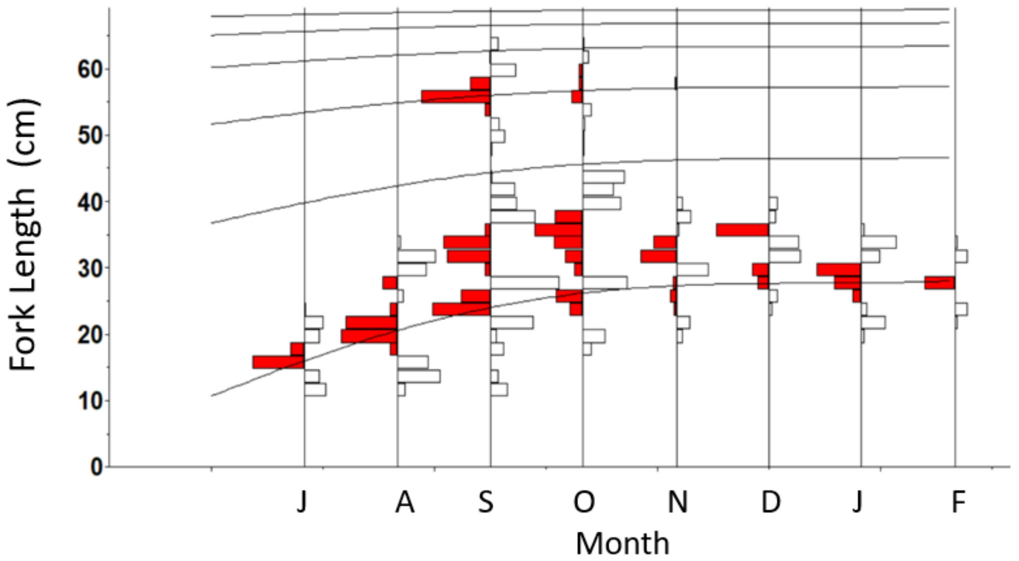

Figure 5. Seasonal growth curves superimposed on the restructured length-frequency histogram of *S sarda* (Bloch, 1793) (parameters: $L_\infty = 71.59$ cm Fork length, $K = 0.56$ year^{-1} $t_0 = -0.18$ year^{-1}, C = 0.97, winter point (WP) = 0.54)

Table 3. The monthly changes in male and female average length, weight, and female-male ratio in *S.sarda*

Months	Female			Male			Number	F:M	$\chi2_{est}$	$\chi2$ test
	N	FL_{mean}	W_{mean}	N	FL_{mean}	W_{mean}	(F+M)			(p=0.05)
July	29	15.71	43.92	18	15.23	38.32	47	1:0.62	2.57	0.1086
August	91	20.19	103.51	84	20.38	107.84	175	1:0.92	0.28	0.5967
September	320	28.34	335.78	234	27.73	318.84	554	1:0.73	13.35	0.0003
October	222	31.8	480.39	186	31.23	450.38	408	1:0.84	3.18	0.0747
November	36	28.3	287.26	28	26.86	242.48	64	1:0.78	1.00	0.3173
December	7	28.67	271.41	8	27.56	245.76	15	1:1.14	0.07	0.7963
January	11	27.69	270.83	10	27.08	251.01	21	1:0.91	0.05	0.8273
February	14	27.00	213.16	8	26.88	208.39	22	1:0.57	1.64	0.2008
Total	**730**	**27.84±0.216**	**332.87±7.468**	**576**	**27.33±0.24**	**314.34±8.22**	***1306**	**1:0.79**	**18.159**	**0.00002**

*The gender of all 2110 individuals sampled was not examined.

Total mortality determined by using the length-converted catch curve (n=2110) produced a result of Z = 3.55 year^{-1} (a=14.86, b=3.545; R^2=0.9883, n=4), confidence interval of Z = 2.37–4.72. The fishing mortality (F) was found to be 2.81 year^{-1}. Natural mortality (M) was estimated at 0.74 year^{-1}, according to the predicted exploitation rate of 0.79.

4. DISCUSSIONS

This study's findings indicated that the estimated length-weight relationship $W = 0.0037FL^{3.3784}$. The estimated slopes (b) for males and females did not differ significantly, according to the t-test, and positive allometric growth was also seen (Student's t-test $p < 0.05$). Similar findings were also reported by several other studies (Ret *et al.*, 1984; Oray *et al.,* 2004; Cengiz, 2013; Yankova, 2015; Kahraman *et al.*, 2014), while others reported contrasting results (Kara,1979; Rodriguez-Roda, 1966; Di Natale *et al.*, 2006) (Table 4). Several factors, which include the time of year, temperature, nutrition, surroundings, stomach fullness, age, maturity level, and sex, may affect the LWR parameters (Bagenal and Tesch, 1978).

Table 4. Comparison of the length-weight relationship estimated from previous studies for *Sarda sarda* (a: intercept, b: slope)

Source	Area	N	L_{min}-L_{max}	A	B
Dardignac,1962	Atlantic (Morocco)	-	-	0.0797	3.143
Kara, 1979	Turkish Black Sea and Sea of Marmara	1608	14-90	0.0236	2.870
Rodriguez-Roda, 1966	West Mediterranean Sea, Spain	165	40.0-55.0	0.0148	2.972
Rey *et al.,* 1984	West Mediterranean Sea, Spain	878	19.0-72.0	0.0072	3.164
Di Natale *et al.,* 2006	Tyrrhenian coast, Italy	240	35.0-82.0	0.0003	2.83
	Sicilian coast, Italy	109	35.0-67.0	0.0004	2.18
Francevic et al., 2005	Coast of the Adriatic Sea	665	33.0-67.0	0.0085	3.123
Oray *et al.,* 2004	Turkish Black Sea and Sea of Marmara	1168	23.0-66.0	0.0039	3.32
Ateş *et al.,* 2008	Turkish Black Sea and Sea of Marmara	694	23.5-71.0	0.0054	3.215
Cengiz, 2013	Northern Aegean Sea	238	23.8-72.0	0.0028	3.32
Yankova 2015	Black Sea, Bulgaria	411	27.0-72.0	0.0028	3.22
Kahraman *et al.,* 2014	Turkish Black Sea and Sea of Marmara	212	17.7-63.0	0.01	3.085
Present study	The Black Sea coast of Türkiye	2110	13.1-60	0.0797	3.3784

This VBG equation, K: 0.56, L_∞: 71.59 cm, C: 0.97, and WP: 0.54, describes the growth curve of *S. sarda.* Using Pauly's (1980) formula, the maximum longevity (t_{max}) was determined to be 5.17 years. During its first year of life, *S. sarda* in the Black Sea grew quickly, reaching 38 cm FL in just four or five months. VBG parameters for *S. sarda* were estimated in different areas, shown in Table 5, and the results of the studies carried out in various seas are given.

Table 5. Comparison of von Bertalanffy growth parameters and growth performance indices estimated from previous studies for *S. sarda*

Reference	**Growth parameter**			**Ø**	**Area**
	L_∞ (cm)	k	t_o		
Zusser (1954)	103.0*	0.132	–1.80	3.15	Black Sea, Russia
Nümann (1955)	67.8*	0.79	-	3.56	Turkish Black Sea
Majarova and Tkacheva (1959)	81.5*	0.525	-	3.54	Turkish Black Sea
Nikolsky (1957)	81.5*	0.52	-	3.54	Turkish Black Sea
Türgan (1958)	64.0*	0.86	-	3.55	Turkish Black Sea
Nikolov (1960)	95.6*	0.24	–1.24	3.34	Black Sea, Bulgaria
Dardignac (1962)	64.0*	0.69	–1.42	3.45	Atlantic, Morocco
Kutaygil (1967)	95.6*	0.237	-1.24	3.34	Turkish Black Sea
Rey *et al.* (1984)	80.8*	0.35	–1.70	3.36	West Mediterranean Sea, Spain
Santamaria *at al. (*1998)	80.6**	0.36	-1.37	3.37	Ionian Sea
Zaboukas and Megalofonou (2007)	82.9**	0.24	–0.77	3.22	Greece
Valeiras *et al.* (2008)	62.5*	0.719	-1.21	3.45	Ionian Sea
Ateş *et al.* (2008)	68.0*	0.82	–0.39	3.58	Turkish Black Sea and Sea of Marmara
Cengiz (2013)	69.8*	0.76	–0.44	3.57	Northern Aegean Sea
Kahraman *et al* (2014)	67.9*	0.46	–1.22	3.33	Turkish Black Sea and Sea of Marmara
Yankova (2015)	80.4**	0.67	-0.34	3.64	The Black Sea coast of Bulgaria
Petukhova 2020	75.6*	0.41		3.37	Black Sea (Russian Fed coast)
Present study	**71.59***	**0.56**	**-0.18**	3.46	The Black Sea coast of Türkiye

*Fork length, **Total length

In addition, the phi-prime value (Φ') from the current study did not differ significantly from that of previous studies (t-test -0.857, df:15, *p* >0.05). However, the sex distribution of *S. sarda* was determined and compared with other studies. (Table 6). As seen in Table 6, other studies, except for Ateş *et al.* (2008), found the frequency of females to be higher than males in the population.

Typically, the condition factor is used to compare the health, fatness, or condition of marine species. Its foundation is the theory that larger fish of a particular length have a higher physiological condition (Bagenal and Tesch. 1978). Fish condition factor (K) usually ranges from 0 to 2, with a normal fish's mean value being close to 1 (Heincke 1908). For both *S. sarda* sexes in this investigation, the K was quite near to 1.0. It is known that the condition factor of many fish species in the Black Sea is far below 1.0 (Dağtekin *et al*., 2022). Nonetheless, K that strongly correlates with a species's fat content, sex, size, season, and level of gonad development (Froese 2006). This is one way to express how this species is affected by generational migration. From mid-July onwards, the first juveniles of 10-15 cm in length and 30-50 g in weight enter the Black Sea and exhibit a rapid growth.

It is thought that optimum conditions for the species are of great importance here. This will result in a rapid increase in K due to the increase in weight and length. When K was used instead, since the change in condition factor is calculated from length-weight parameters, it is accepted as a more accurate estimate since the effect of fish size is eliminated in the change of condition factor. According to Fulton and K condition values, the condition decreased after October. November is the month in which a large amount of migration takes place of. A second cohort of individuals come to the Black Sea at the end of the breeding season, and some individuals rarely remain in the Black Sea. They mainly begin to appear in November. When the two cohorts are taken into consideration, the growth curve slope begins to decrease with the entry of the second cohort fish. The study determined a total mortality rate (Z) of 3.55 year^{-1}. Notably, this figure indicates a significant contribution of fishing mortality to the overall mortality rate. The natural mortality rate, which accounts for deaths due to natural factors such as predation, disease, and environmental conditions, was found to be 0.74 year^{-1}. This disparity between total mortality and natural mortality underscores the substantial impact of fishing activities on the fish population. In this context, the exploitation rate was determined to be 0.79. According to Gulland (1971), this value indicates that the stock is over-exploited. According to Petukhova (2020), the natural mortality rate is 0.695 year^{-1}. Our results are typical for short-lived species, as Petukhova (2020) reported.

Table 6. Comparison of sex ratio of Atlantic bonito from various regions of the Black Sea and Mediterranean

Reference	Area	Sex distribution				F:M	$\chi2_{est}$	$\chi2$ test (p=0.05)
		Female	Male	Undetermined	Total			
		N	N	N	N			
Ateş *et al.* (2008)	Turkish Black Sea and Sea of Marmara	62	80	106	278	1:1.29	2.272	0.131
Valeiras *et al.* (2008)	Western Mediterranean, Spain	77	59	12	148	1:0.77	2.382	0.123
Zaboukas and Megalofonou, (2007)	Eastern Mediterranean (Greece)	122	118	157	397	1:0.97	0.067	0.796
Kahraman *et al.* (2014)	Turkish Black Sea and Sea of Marmara	100	89	23	212	1:0.89	0.640	0.424
Nottesdat *et al.* (2013)	North Sea	40	31	-	71	1:078	1.141	0.286
Franicevic *et al.* (2005)	Adriatic Sea	353	285	27	665	1:0.81	7.248	0.007
Zorıca And Sınovčić, (2008)	Adriatic Sea	55	46	-	101	1:0.84	0.802	0.371
Yankova, (2015)	The Black Sea coast of Bulgaria	298	176	-	474	1:0.59	31.401	0.000
Fletcher *et. al.*, (2013)	The Northeast Aegean Sea	69	53	-	112	1:0.77	2.098	0.148
Cengiz (2013)	The Northeast Aegean Sea	100	82	56	238	1:0.82	1.780	0.182
This study	The Black Sea coast of Türkiye	730	576	804	2110	1:0.79	18.159	0.000

5. CONCLUSIONS

Sarda sarda exhibits significant fluctuations in population levels over the years. As noted historically by Demir (1961; 1963), these fluctuations have been documented and characterized, highlighting the dynamic nature of the atlantic bonito populations. Such variations may be influenced by a combination of ecological factors, fishing pressures, and environmental changes affecting their habitats. Understanding these fluctuations is crucial for effective management and conservation strategies for *Sarda sarda.*

According to Turkish Commercial Fishery Regulations 6/1, numbered 32629 (GDAR. 2024), S. *sarda* must measure at least 25.0 cm (TL). Nevertheless, no scientific data has supported this regulation. Therefore, additional studies must be done to precisely figure out *S. sarda*'s minimum landing size. When Exploitation rate (E) is less than 0.50, it suggests that the stock is under-exploited. Conversely, when E exceeds 0.50, the stock is considered over-exploited (Gulland, 1971). This situation can lead to overfishing, resulting in declines in fish populations, and can disrupt the ecosystem as well as economic stability for fisheries. Therefore, we recommend that management measures be taken to prevent the overexploitation of stocks. In addition, continuing to overfish bonito could eventually cause the spawning stock to fall below the levels needed to support the population. There is a need for a comprehensive study to be carried out simultaneously in the Aegean, Marmara, and Black Seas to solve some of the unanswered questions concerning *S.sarda*.

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AUTHORSHIP CONTRIBUTION STATEMENT

Yaşar Genç: Conceptualization, methodology, writing-review and editing, data curation, software, project administration, funding acquisition. **Murat Dağtekin:** Conceptualization, methodology, writing-original draft, writing-review and editing, data curation. **Nimet Selda Başçınar:** Editing and data curation, **Elvan Tercan:** Data curation.

CONFLICT OF INTERESTS

The authors confirm that they have no known financial or personal conflicts that would have appeared to impact the research presented in this study.

ETHICS COMMITTEE PERMISSION

No ethics committee permissions is required for this study.

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ORCID IDs

Yaşar Genç:
https://orcid.org/0000-0002-2353-3868
Murat Dağtekin:
https://orcid.org/0000-0003-0084-4433
Nimet Selda Başçınar:
https://orcid.org/0000-0002-6218-7291
Elvan Tercan:
https://orcid.org/0000-0002-0048-6595

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