



Length-Weight Relationships and Growth Parameters of Bogue, *Boops boops* (Linnaeus, 1758) from Didim, South-eastern Aegean Sea

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Abstract: In this study, length-weight relationships and growth parameters of *Boops boops* (Linnaeus, 1756) sampled from Didim coasts, South-eastern Aegean Sea were investigated. A total of 361 specimens (226 females and 135 males) were obtained from commercial trawlers and gillnets November 2021-2022. The mean length and weights were 18.57 ± 2.46 cm and 60.74 ± 23.60 g for females and 17.63 ± 3.63 cm and 60.50 ± 36.87 g for males, respectively. The overall sex ratio (F:M) was determined as 1:1.67 (χ^2 , $P < 0.05$). Length-weight relationships for all individuals were described by the parameters $a = 0.0113$, $b = 2.93$ and $r^2 = 0.974$. The exponent of the b parameter represented negative allometric growth in females, isometric growth in males and negative allometric growth in both sexes. Values were statically significant ($P < 0.05$). The von Bertalanffy growth parameters were calculated as $L_\infty = 35.34$ cm, $k = 0.156$ year⁻¹, $t_0 = -2.093$ years for females; $L_\infty = 33.23$ cm, $k = 0.184$ year⁻¹, $t_0 = -1.268$ years for males; $L_\infty = 41.23$ cm, $k = 0.117$ year⁻¹, $t_0 = -2.200$ years for both sexes. The growth performance index (Φ') was estimated for females, males, and both sexes as 2.291, 2.310, and 2.302, respectively. Age determinations varied from 1 to 5 years and age class III was found dominant in both sexes.

Keywords: Aegean Sea, Bogue, *Boops boops*, Growth parameters, Length-weight relationship.

Güneydoğu Ege Denizi, Didim'de bulunan Kupes, *Boops boops* (Linnaeus, 1758) Türünün Boy-Ağırlık İlişkileri ve Büyüme Parametreleri

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Öz: Bu çalışmada Güneydoğu Ege Denizi, Didim kıyılarından örneklenen *Boops boops* (Linnaeus, 1756)'un boy-ağırlık ilişkileri ve büyüme parametreleri incelenmiştir. Kasım 2021-2022 tarihleri arasında ticari trol ve uzatma ağlarından toplam 361 örnek (226 dişi ve 135 erkek) elde edilmiştir. Ortalama boy ve ağırlıklar sırasıyla dişiler için $18,57 \pm 2,46$ cm ve $60,74 \pm 23,60$ g, erkekler için $17,63 \pm 3,63$ cm ve $60,50 \pm 36,87$ g olarak saptanmıştır. Cinsiyet oranı (D:E) 1:1,67 olarak belirlenmiştir (χ^2 , $P < 0.05$). Tüm bireyler için boy-ağırlık ilişkileri $a = 0,0113$, $b = 2,93$ ve $r^2 = 0,974$ parametreleri ile tanımlanmıştır. Dişilerde negatif allometrik büyüme, erkeklerde izometrik büyüme ve her iki cinsiyette de negatif allometrik büyüme olduğu gözlenmiştir. Von Bertalanffy büyüme parametreleri dişiler için $L_\infty = 35,34$ cm, $k = 0,156$ yıl⁻¹, $t_0 = -2,093$ yıl; erkekler için $L_\infty = 33,23$ cm, $k = 0,184$ yıl⁻¹, $t_0 = -1,268$ yıl; her iki cinsiyet için $L_\infty = 41,23$ cm, $k = 0,117$ yıl⁻¹, $t_0 = -2,200$ yıl olarak hesaplanmıştır. Büyüme performansı endeksi (Φ') dişiler, erkekler ve her iki cinsiyet için sırasıyla 2,291, 2,310 ve 2,302 olarak tespit edilmiştir. Yaş tayinleri I ila V yıl arasında değişmiş ve yaş sınıfı III her iki cinsiyette de baskın bulunmuştur.

Anahtar kelimeler: *Boops boops*, boy-ağırlık ilişkisi, büyüme parametreleri, ege denizi, kupes.

INTRODUCTION

Boops boops (Linnaeus, 1758) known as bogue, is an important Sparid species in the Mediterranean fisheries. It inhabits both a demersal and semi-pelagic area and all types of bottoms (sand, seagrass beds, mud, rocks) to depths of 350 m. It is distributed along the entire East Atlantic coast from Norway to Angola and all coasts of the Mediterranean Sea (Bauchot & Hureau, 1986). According to fisheries statistics of Türkiye, the catch yield of bogue is quite high (2310.6 tonnes) and it is an economically important species that is consumed abundantly in Türkiye, especially in the Aegean region (TurkStat, 2022).

Some biological parameters of bogue have been studied from different areas in Mediterranean basin (Gordo, 1996; Allam, 2003; El-Haweet et al., 2005; Khemiri et al., 2005; Monteiro et al., 2006; Matasin & Vucnic, 2008; El-Okda, 2008; Kara & Bayhan, 2008; 2015; Kasalica et al., 2011; Bottari et al., 2014; Layachi et al., 2015; Ceyhan et al., 2018; Azab et al., 2019; Cengiz et al., 2019; Cengiz, 2022; Koca, 2023). Some of these studies were carried out in the different parts of the Aegean Sea many years ago (İşmen et al., 2007; Kara & Bayhan, 2008; 2015; Cengiz et al., 2019; Cengiz, 2022)

This study provides the length-weight relationships and growth parameters of *B. boops* from Didim for sustainable stock management plans of this commercially important species.

MATERIAL AND METHOD

The specimens of bogue were collected by commercial trawlers and gillnets with various mesh sizes along the Didim coast between November 2021 – November 2022 (Figure 1). The total length of the samples was measured to the nearest 0.1 cm and the weight to the nearest 0.01 g.

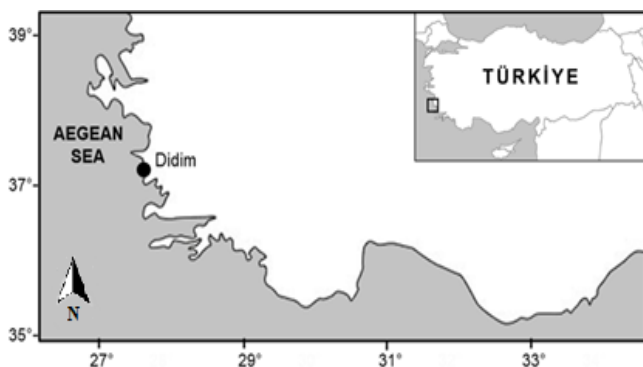


Figure 1. Sampling location of *Boops boops*

The length-weight relationships (LWRs) were independently estimated for all individuals with the formula $W = a \times L^b$ (Ricker, 1975). W is total body weight (g), L is the total length (cm), and a is a coefficient relative to body

form, and exponent b is the allometry coefficient of the linear regression equation representing isometric ($= 3$), positive allometric (> 3) and negative allometric (< 3) growth in length. The significance of the regression was tested by analysis of variance ANOVA. Student's t -test with a $\pm 95\%$ confidence interval was applied to verify whether the b values obtained in the linear regressions were significantly different from the null hypothesis of isometric growth ($H_0: b = 3$) and for possible variations in the length-weight of females, and males, and chi-square test used to assess the overall sex ratio (Zar, 1999).

Age readings were taken by counting growth annuli from all sagittal otoliths, as suggested by Holden and Raitt (1974). All otoliths were cleared with ethanol to remove organic residues and then immersed in glycerine to improve their optical properties and provide clear readings. Opaque and translucent bands were read with a stereoscope.

Theoretical growth patterns for all individuals were calculated using the von Bertalanffy growth function (VBGF) (Beverton & Holt, 1957) $L_t = L_\infty [1 - e^{-k(t-t_0)}]$, where L_t is the fish length (cm) at the time t (year), L_∞ is the mean asymptotic length (cm), k is the growth coefficient (year⁻¹), and t_0 (year) is the theoretical time at which the length equals to zero.

The growth performance index (Φ') was estimated using the formula $\Phi' = \log k + 2 \log L_\infty$ (Munro & Pauly, 1983).

RESULTS

A total of 361 *Boops boops* samples, 135 male (37.40%) and 226 female (62.60%) were collected from Didim coasts during the study. The overall sex ratio (F:M) was determined as 1:1.67. The chi-square test (χ^2) showed that the sex ratio was significantly different from the expected 1:1 ratio (χ^2 , $P < 0.05$). Total length varied 10.7-25.2 cm for females, 11.6-23.5 cm for males, and weight varied were 10.65-141.04 g for females, 14.66-132.58g for males. The mean length and weights were 18.57 ± 2.46 cm and 60.74 ± 23.60 g for females and 17.63 ± 3.63 cm and 60.50 ± 36.87 g for males, respectively. The maximum length and weight were measured in a female specimen which was 25.2 cm and 141.04 g. A statistically significant difference was found in overall length and weight values between male and female individuals (t_{test} , $P < 0.05$). The majority of females were in the length group of 17 cm (12.46% of females), while the males were in 16 cm (6.37% of males). It was determined that 17.72% of all specimens were in the length group of 16 cm, regardless of male and female. (Figure 2).

Computed LWRs for females, males, and both sexes of bogue from Didim coast are summarized in Table 1. The mean length and weight of females were higher than those of males. But the difference in lengths was found to be

statistically significant ($t_{test}, P < 0.05$), while the difference in weight was not found to be statistically significant ($t_{test}, P > 0.05$).

The exponent of the b parameter represented negative allometric growth in females, isometric growth in males and negative allometric growth in both sexes. Values were statically significant ($P < 0.05$).

Otolith examinations outlined that the age classes ranged from I to V years for both males and females. Table 2 represents the total length frequencies of *B. boops* from the Didim coast based on age classes. Age class III was dominant (39.82%) followed by age class II (33.63%) in females. Likewise, age class III (39.26%) was dominant, followed by II (33.33%) in males.

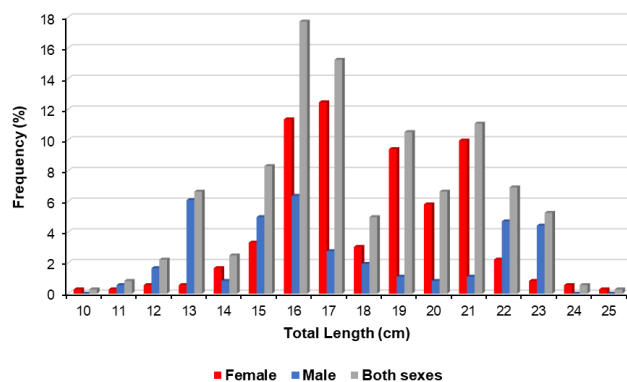


Figure 2. The distribution of frequency in length groups for female, male and both sexes *Boops boops* collected from the Didim coasts.

Table 1. General population statistics and LWRs of *Boops boops* from Didim coast.

Sex	N	Range of TL (cm) (L _{mean} ± SD)	Range of W (g) (W _{mean} ± SD)	LWR parameters				
				a	b	SE of b	95% CI of b	r ²
Female	226	10.7–25.2 (18.57 ± 2.47)	10.65–141.04 (60.74 ± 23.65)	0.0110	2.9299	0.0340	2.8781–2.9816	0.9719
Male	135	11.6–23.54 (17.63 ± 3.64)	14.66–137.51 (60.50 ± 37.01)	0.0096	3.0051	0.0259	3.0013–3.0088	0.9915
Both sexes	361	10.7–25.2 (18.22 ± 2.99)	10.65–141.04 (60.65 ± 29.32)	0.0113	2.9325	0.0350	2.8827–2.9822	0.9745

N, sample number; TL, total length; W, weight; SD, standard deviation; a, intercept; b, slope; SE, standard error; CI, confidence interval; r², coefficient of determination.

Table 2. Length key for each age group of female and male *Boops boops* individuals from the Didim coasts.

Length groups (TL)	Age groups									
	Females					Males				
	I	II	III	IV	V	I	II	III	IV	V
10	1									
11	1					2				
12	2					6				
13	1	1				4	18			
14	6						3			
15		12					17	1		
16		40	1				7	16		
17		23	21	1				10		
18			8	3				7		
19			24	10				4		
20			10	11				3		
21			26	10				4		
22				6	2			8		
23				1	2				9	
24					2				13	3
25					1					
Overall	11	76	90	42	7	12	45	53	22	3
Mean (TL)	13.37±1.32	16.62±0.75	19.54±1.56	20.54±1.34	23.70±1.13	12.70±0.55	14.73±1.14	18.65±2.22	23.00±0.48	23.48±0.07
Percentage %	4.87	33.63	39.82	18.58	3.10	8.89	33.33	39.26	16.30	2.22

TL, total length.

The growth pattern in mean lengths from each age class was estimated for individuals of *B. boops* from Didim coasts using the VBGF. The von Bertalanffy growth parameters were calculated as $L_{\infty} = 35.34$ cm, $k = 0.156$ year⁻¹, $t_0 = -2.093$ years for females; $L_{\infty} = 33.23$ cm, $k = 0.184$ year⁻¹, $t_0 = -1.268$ years for males; $L_{\infty} = 41.23$ cm, $k = 0.117$ year⁻¹, $t_0 = -2.200$ years for both sexes. The growth performance index (Φ') was estimated for females, males, and both sexes as 2.291, 2.310, and 2.302, respectively.

DISCUSSION AND CONCLUSION

Effective fisheries management is essential for the protection of natural resources and their sustainability. For sustainable fisheries, regular monitoring of the stocks is essential for optimal fishing stock management (Kara & Bayhan, 2015).

Over the years, many studies about the biology of bogue have been conducted in the Mediterranean region; these length-weight relationships, age distribution and growth parameters are summarized in Table 3.

Table 3. Length-weight relationships and growth parameters of *Boops boops*.

Sex	Length-weight relationship			Range of age		Growth parameters			Reference
	<i>a</i>	<i>b</i>	Range of TL	min-max	<i>L_∞</i>	<i>k</i>	<i>t₀</i>	<i>Φ'</i>	
♀+♂	-2.154	3.10	10.05-22.4	I-V	31.68	0.15	-1.78	2.19	Allam 2003
♀+♂	-	-	-	I-XIII ^a	26.7 ^a	0.22 ^a	-1.43 ^a	2.20 ^a	Khemiri et al. 2005
♀+♂	-	-	7.4-30.5	I-IX ^b	28.7 ^b	0.20 ^b	-1.41 ^b	2.22 ^b	(^a , eastern; ^b , northern coasts of Tunisia)
♀+♂	0.0080	3.04	7.5-21.4	0-XI	28.06	0.22	-1.42	2.24	Monteiro et al. 2006
♀+♂	0.0032	3.39	15.4-32.1	-	-	-	-	-	Cicek et al. 2006
♀+♂	0.0074	3.11	15.3-27.6	-	-	-	-	-	Karakulak et al. 2006
♀+♂	0.0048	3.25	10.32-32.1	-	-	-	-	-	-
♀+♂	0.0254	2.66	-	I-VI	30.11	0.15	-1.51	2.14	El-Okda 2008
♀+♂	-	-	-	-	30.66	0.30	0.00	2.45	Bouazizi et al. 2010
♀+♂	-	-	-	-	26.66	0.30	0.00	2.33	-
♀+♂	-	2.90	6.0-28.0	-	30.0	0.41	-0.30	2.54	Layachi et al. 2015
♀+♂	0.0069	3.12	11.3-27.9	I-V	30.79	0.23	-0.90	2.36	Kara&Bayhan 2015
♀+♂	0.0028	3.42	12.2-27.0	I-V	29.87	0.24	-0.98	2.33	-
♀+♂	0.005	3.25	11.0-23.8	-	29.58	0.27	-1.14	2.37	Soykan et al. 2015
♀+♂	0.012	2.88	11.2-32.3	-	34.1	0.26	-1.50	2.48	-
♀+♂	0.013	2.86	9.0-26.0	-	26.7	0.38	-0.75	2.43	Kherraz et al. 2016
♀+♂	0.012	2.91	10.0-23.1	-	-	-	-	-	-
♀+♂	0.010	2.97	9.3-21.6	-	-	-	-	-	Azab et al. 2019
♀+♂	0.011	2.96	9.3-23.1	I-IV	30.65	0.28	-0.16	2.42	-
♀+♂	0.0016	2.81	10.1-30.9	I-V	32.03	0.28	-0.58	2.45	Dahel et al. 2019
♀+♂	0.0085	3.11	13.4-27.6	-	-	-	-	-	-
♀+♂	0.0095	3.07	13.7-25.6	-	-	-	-	-	Cengiz et al. 2019
♀+♂	0.0080	3.13	11.3-24.1	I-IX	27.9	0.21	-1.57	2.21	Cengiz 2022
♀+♂	0.013	2.89	10.8-24.9	I-V	37.14	0.15	-1.33	2.32	-
♀+♂	0.014	2.86	10.9-23.0	I-V	29.95	0.22	-0.95	2.29	Koca 2023
♀+♂	0.013	2.88	10.8-24.9	I-V	37.50	0.15	-1.32	2.33	-
♀+♂	0.011	2.92	10.7-25.2	I-V	35.34	0.15	-2.09	2.29	-
♀+♂	0.009	3.00	11.6-23.54	I-V	33.23	0.18	-1.26	2.31	This study
♀+♂	0.011	2.93	10.7-25.2	I-V	41.23	0.11	-2.20	2.30	-

♀, female; ♂, male; *a*, intercept; *b*, slope; TL, total length; min, minimum age; max, maximum age; *L_∞*, asymptotic length; *k*, growth coefficient (year⁻¹); *t₀*, theoretical age at length equal to zero; *Φ'*, growth performance index.

Bio-ecological parameters including age data, are valuable sources about the species' life cycle, but the reliability and differences of age determination are generally dependent on the size of the sample and the interpretation of growth rings on the otoliths (Filiz et al., 2006). Age classes ranged from I to V for both males and females, of which ages II and III were dominant for both sexes. These findings are consistent with those given by Allam (2003) (between the ages of I–V (n = 421), with the dominant age of III); El-Haweet et al. (2005) (between the ages of I–VI (n = 319), with the dominant age of III); Bilge (2005) (between the ages of 0–IX (n = 1245), with the dominant age of II); Kara and Bayhan (2015) (between the ages of I–V (n = 932), with the dominant ages of II and III); Dahel et al. (2019) (between the ages of I–V (n = 1734), with the dominant ages of I and II), Cengiz (2022) (between the ages of I–IX (n = 363), with the dominant ages of II and III), and Koca (2023) (between the ages of I–V (n = 641), with the dominant ages of II and III). Monteiro et al. (2006) used long lines which can be selective for older and bigger individuals as the fishing gear, and they found the V age class was dominant in their study. On the contrary, Dahel et al. (2019) found dominant age classes of I and II but they didn't specify the gear. Sampling methods and times, temperature variations, feeding activity, fishing gear used for sampling, and selectivity of that gear have been found to affect length and weight ranges of the species (Özaydın et al., 2000; İşmen et al., 2007; İlkyaz et al., 2010; Kapiris & Kilaoudas, 2011; Cengiz, 2013; Cengiz et al., 2019). Similarly, the length-weight relationship depends on the sex, gonad development, annual changes in environmental factors, seasonal differences, conservation measures, the number of individuals caught and the size-weight ranges of

individuals. In this study, the exponent of the *b* parameter represented negative allometric growth in bogue individuals. The negative allometric growth was also recorded from Antalya coast (Özvarol, 2014; Koca, 2023), Morocco (Layachi et al. 2015), Algeria (Kherraz et al., 2016; Dahel et al., 2019) and Egypt (El-Okda, 2008; Azab et al., 2019). The variations in LWRs between this study and previous studies, can be explained by one or more of the above factors.

Table 3 represents the length and growth parameters calculated by the von Bertalanffy formula with other researchers. Kara and Bayhan (2015) indicated that lower *L_∞* values can be observed in environments with higher temperatures and sampling of a higher number of small individuals. Growth parameters are in agreement with the previous studies. The growth coefficient of females (*k* = 0.15) was slightly lower than males (*k* = 0.18), with the conclusion that females grow faster and live longer than males as in Kara and Bayhan (2015). However, higher *Φ'* values than Koca (2023) and Kara and Bayhan (2015) could indicate a fishing pressure in bogue populations in the southeastern Aegean Sea.

This study presents fundamental biological data on bogue that are valuable for the sustainable management of this species in Turkish waters. The study findings are similar to those determined in previous studies and also indicate fishing pressure on the species.

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