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Research Article

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Reproductive Biology of Bogue, *Boops boops* Linneaus, 1758 in the Aegean Sea and Sea of Marmara, Türkiye

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Abstract Bogue (*Boops boops* Linnaeus, 1758) is one of the most economic and common species in Türkiye. The bogue individuals were obtained monthly from the commercial catches of gillnet fisheries from May to August 2024 and purse seine fisheries from September 2024 to April 2024 around the Northern Aegean Sea and Southwest Sea of Marmara, Türkiye. The 378 total individuals consisted of 176 females, 201 males and 1 unspecified in the Aegean Sea. The 370 total individuals consisted of 214 females, 154 males and 2 individuals unspecified in the Sea of Marmara. The female:male ratio was calculated as 0.9:1.0 in the Aegean Sea and 1.4:1.0 in the Sea of Marmara. The total length and weight of individuals varied from 10.6 to 28.6 cm (17.52±0.15) and 8.1 to 236.86 g (54.20±2.43) in the Aegean Sea, respectively, and the total length was 10.8 to 28.5 cm (17.92±0.18) and the weight was 13.08 to 399.88 g (76.54±3.14) in the Sea of Marmara. The positive allometric growth was found for females, males and all sexes in both seas. The first maturity length was determined as 12.2 cm TL for females, 15.8 cm TL for males in the Aegean Sea, whereas it was 12.8 cm TL for females, 15.1 cm TL for males in the Sea of Marmara. The reproductive period is estimated between January and May in the Aegean Sea, while February to May in the Sea of Marmara. The total fecundity varied between 2770-85112 (mean:20021±2027) in the Sea of Marmara, while it was 2740-309457 (mean:42834±9194) in the Aegean Sea. As results of this study, some differences were determined in sex ratio, spawning period, and fecundity from the reproductive characteristics between the Sea of Marmara and Aegean Sea. Due to the limited scientific data on the reproductive biology of *B.boops* in Türkiye, the results of the present study should contribute to the strategic assessment, management, and sustainability of *B.boops*.

Keywords Length-weight relationship · First maturity length · Gonadosomatic index · Fecundity · Reproductive period

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INTRODUCTION

Many fish stocks are either fully exploited or overexploited in the world (Vuorinen et al., 2021; Gaillet et al., 2022). The reproductive biology assessment of a species is important for the protection, sustainability, and management of exploited fisheries resources. The reproductive traits, such as sex composition, first maturity length, spawning season, fecundity, gonadosomatic index, condition factor and length-weight relationship must be determined and monitored for stock management (Gebremedhin et al., 2021). These characteristics also vary depending on the abiotic and biotic factors from region to region and over time (İnnal, 2019). The human impacts such as fishing pressure, pollution, and climate change can affect the reproductive characteristics of a species over a lifetime (Vinagre & Cabral, 2015). Specific to a species, understanding reproductive characteristics will contribute to the continuity of the species. Without these valuable data, the implementations for fisheries management become impossible.

Bogue *Boops boops* (Linneaus, 1758) is a teleost fish species belonging to the Sparidae family, widely found in the Mediterranean Sea, and distributed in the eastern Atlantic from Norway to Angola, oceanic islands, from Biscay Bay to Gibraltar, the western Atlantic in Mexico and the Caribbean Sea. Bogue lives in the bottom and middle waters of coastal areas with muddy, rocky, sandy bottom structures or seagrass areas. *B.boops* can be found at depths of up to 200 m in the Mediterranean Sea and 300 m in the Atlantic Sea (Bauchot and Hureau, 1986). So, this species can catch with different fishing gears such as gillnets, trawls and purse seines in the world seas. Bogue, shown in shoals, has economic and commercial value. The fluctuations in the catch amounts of *B.boops* are observed from year to year. The mean annual catch rates of the bouge between 2000 and 2023 were reported as 50 tonnes and 2027 tonnes from the Sea of Marmara and Aegean Sea, respectively (TUIK, 2024). The maximum length of *B.boops* can reach up to 36 cm, usually 15-20 cm total length (Bauchot & Hureau, 1986).

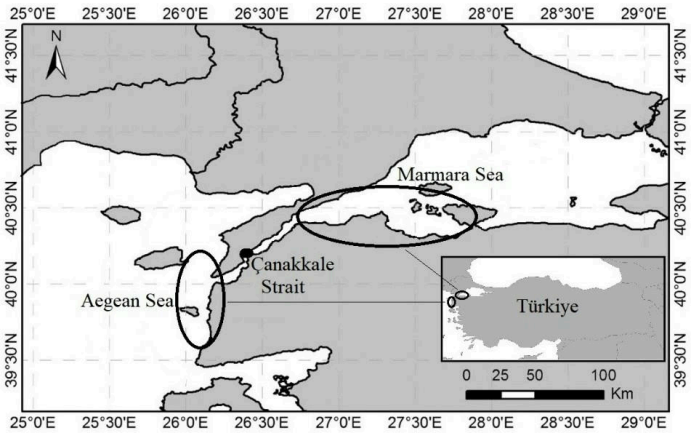
Although the reproductive biology of *B.boops* was investigated in the Aegean Sea (Bilge, 2008; Kara & Bayhan, 2015; Andsoy, 2015; Soykan et al., 2015; Cengiz et al., 2019, Cengiz, 2022; Koca, 2023), no study has investigated in the Sea of Marmara, yet. Therefore, this study is important as it presents the first findings of reproduction parameters of *B.boops* in the Sea of Marmara, and also provides important and current findings in terms of monitoring *B.boops* stocks in the Aegean Sea. Also, this study will enable us to compare *B.boops* stocks between adjacent seas and contribute to the sustainability and management of these stocks.

MATERIAL AND METHODS

A random sampling of minimum 30 individuals of *B.boops* were monthly collected from commercial catches of gillnet fisheries using 18, 20, 22, 23 mm mixed mesh sizes and purse seine fisheries using 8-10 mm mesh sizes in the Sea of Marmara and Aegean Sea. Due to the fisheries ban for purse seine between 15th April and 1st September in the Türkiye seas, the samples were collected from the gillnets fisheries between May 2024 and August 2024. After the end of the fisheries ban closure for purse seine fisheries, individuals were obtained from purse seine fisheries from September 2024 to April 2024. A total of 370 and 378 individuals were obtained in the Southwest of Sea of Marmara and the North of Aegean Sea, respectively (Figure 1). These samples were transferred to the laboratory immediately.

Figure 1.

Sampling areas in the Sea of Marmara and Aegean Sea



The total length (TL) was measured to the nearest 1 mm interval measuring board and total weight (TW) to the nearest 0.01 g precision scale. All individuals were dissected and then sex determination was assessed by macroscopic observation from the gonads. The female to male (F:M) ratio was calculated. The Chi-square (χ^2) test used with the IBM SPSS 25 (IBM Corp 2017) program to assess statistically difference between the female to male ratio. Gonads weight (GW) was recorded to the nearest 0.01 g precision scale. The sexual maturity stages from the gonads were determined by macroscopic examination according to Holden & Raitt (1974) with five maturity stages as; Stage I (Immature), Stage II (Maturing), Stage III (Ripening), Stage IV (Ripe), Stage V (Spent).

The length-weight relationship was estimated by the exponential regression equation:

$TW=a*TL^b$

where a and b were constants that were estimated by least square linear regression after log transformation (Ricker, 1975). Growth type was determined by the one-sample t-test of the

"b" value for comparison of the slope (Sokal & Rohlf, 1987; Zar, 1996),

$Ts=(b-3)/SE(b)$

The gonadosomatic index (GSI) value was calculated using the formula by Gibson and Ezzi (1980):

$GSI=(GW/(TW-GW))\times100$

The spawning period of *B.boops* was estimated by evaluating the highest GSI values coinciding the highest percentage of sexually mature individuals. The condition factor (CF) was determined from the equation by Htun-Han (1978):

$CF=TW/TL^3$

The length at first maturity (L_{50}) was estimated as the length at which 50% of males and females become mature during the months of maximum reproductive activity. The percentage mature by length class and sex by fitting a logistic function using the Newton algorithm, which is defined as:

$P(1)=1/1+e^{-(a+b1)}$

where P(l) is the proportion of mature specimens at length 1, and a and b are the parameters of the logistic equation (Piñeiro & Saínza, 2003).

The fecundity (F) was determined by using the gravimetric method. 57 mature female individuals from the Sea of Marmara and 61 mature female individuals from the Aegean Sea were used to estimate fecundity. A subsample of 0.05 g from 3 parts (anterior, middle and posterior) of each ovary was taken and weighed. The number of oocytes was counted from each ovary and their diameters were measured under stereomicroscope from 181 oocytes of 3 individuals in the Sea of Marmara and 209 oocytes of 8 individuals in the Aegean Sea. The absolute fecundity was calculated with Bagenal's formula (Bagenal 1978);

$F=Nx(GW/TW)$

where N is the mean number of oocytes ((anterior+middle+posterior oocytes)/3) in each gonad. The total length-fecundity and the total weight-fecundity relationships were estimated for females using linear and and exponential regression.

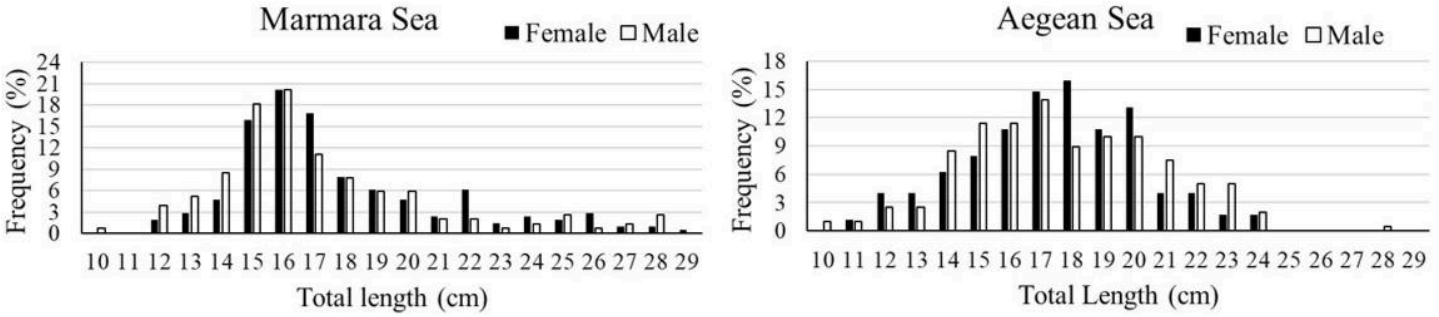
RESULTS AND DISCUSSION

In the present study, a total of 378 and 370 individuals of Bogue were examined from the Aegean Sea and from the Sea of Marmara, respectively. 176 of 378 individuals (46.6%) were detected as females, 201 individuals as males (53.2%) and 1 individual was not sexed (0.3%) in the Aegean Sea. In the Sea of Marmara, 2 individuals were not sexed (0.6%). Besides, 214 of 370 individuals were detected as female (57.8%) and 154 individuals as males (41.6%) in the Sea of Marmara.

The sex ratio (female:male) was determined as 1.39:1 in the Sea of Marmara and 1:0.88 in the Aegean Sea. According to the results of Chi-square tests, a statistically important variation was detected in the sex ratios of the individuals obtained by Sea of Marmara (χ^2calc 9.783>χ^2table 3.841, p:0.002<0.05), whereas statistically important variation was not detected from the individuals obtained by Aegean Sea (χ^2calc 1.658<χ^2table 3.841, p:0.198>0.05). The sex ratio of species can generally vary from 1:1 to 1:3 in natural populations. However, this rate varies over time, even within the same population due to the temporary behavior such as migration observed in the population over time, and may even exceed this rate from time to time. So, it is necessary to determine the sex ratio in populations by sampling throughout the year (Avşar, 2016). In previous studies stated that the males are dominant in the Aegean Sea, Kara and Bayhan (2015), 1.17:1; Soykan et al. (2015), 3.57:1; Cengiz et al. (2019), 1.55:1; Seyhan Öztürk (2024), 1.67:1; Andsoy (2014), 1:0.26 the parallel in the Aegean Sea in our study. Also, El Samman et al. (2022) reported that the male:female ratio of *B.boops* was 1:0.49 on the Egyptian coast. On the contrary, Kara and Bayhan (2008) determined that females were dominant in the Aegean Sea. Koca (2023) stated that females were dominant (1:0.97) in the Gulf of Antalya in the Mediterranean Sea. The females were more dominant than males, Kasalica et al. (2011) in the Adriatic Sea (1:0.4); Massaro & Pajuelo (2018) in Canary islands of Spain (1:0.852); Dobroslavić et al. (2017) in the Adriatic Sea (1:0.85); Azab et al. (2019) coast of Alexandria, Egypt (1.03:1); Farah & Mavruk (2024) in the Mediterranean Sea (1.04:1) the parallel in the Sea of Marmara in our study.

In the Aegean Sea, the total lengths ranged between 10.6 cm and 28.6 cm (mean:17.19±0.22 cm TL) for females and distributed from 11.1 cm to 24.9 cm (mean:17.91±0.21 cm) for males. The total weights varied from 8.1 g to 236.86 g (mean:54.2±2.43 g) for females, and ranged between 10.55 g and 210.26 g (mean:63.51±2.47 g) for males. In the Sea of Marmara, the total length ranged between 10.8 cm and 28.5 cm (mean:17.52±0.29 cm TL) for females and distributed from 12.6 cm to 29.1 cm (mean:18.21±0.24 cm TL) for males. The total weight varied from 13.08 g to 399.88 g (mean:68.9±4.69 g) for females, and ranged between 19.04 g to 339.11 g (mean:81.52±4.22 g) for males. A significant difference with the Independent Samples T-test was found in the Aegean Sea between male and female individuals for total length (F:3.726, df:375, P<0.05) and weight (F:0.808, df:375, P<0.05), whereas a significant difference was not found in the Sea of Marmara for total length (F:0.160, df:366, P>0.05) and weight (F:2.13, df:366, P>0.05). The majority length groups were 16 cm TL for females (20.13%) and males (20.09%) in the Sea of Marmara, while the

Figure 2.
Sampling areas in the Sea of Marmara and Aegean Sea



18 cm TL for females (15.1%) and 17 cm TL males (13.93%) in the Aegean Sea (Figure 2).

Although the total length of *B.boops* can be up to 36 cm (Bauchot & Hureau, 1986), the largest individual reported that the total length of 40.2 cm and weight of 986 g was caught from Güllük Bay in the Mediterranean Sea (Türkiye) at a depth of 55 meters with gillnet. The proximity of the catching area to fish farms and the consequent good feeding may explain this size (Ceyhan et al., 2018). Bauchot and Hureau (1986) reported that *B.boops* is generally observed 15-20 cm in length. When previous studies are analyzed in Table 1, the mean total length of *B.boops* is close to the stated values. Babaoglu et al. (2021) reported that the mean total length and weight 10.22 cm and 11.39 g of *B.boops* in 18 mm trammel nets on the Bakırçay River in the Çandarlı Bay of the Aegean Sea. El Samman et al. (2022), determined the mean total length and weight as 13.98 cm and 28.51 g of 880 individuals *B.boops* using gillnets from 14 mm to 18 mm mesh sizes on the coast of Alexandria, Egypt. In this study, the mean total length and weight of *B.boops* was determined to be 17.52 cm, 58.46 g and 17.92 cm, 76.54 g in the Aegean Sea and the Sea of Marmara, respectively, sampled with purse seine and gillnet. The total length and weight of *B.boops* were larger in the Sea of Marmara than in the Aegean Sea. It is thought that these differences in total length and weight due to the sampling method, number of individuals and study areas.

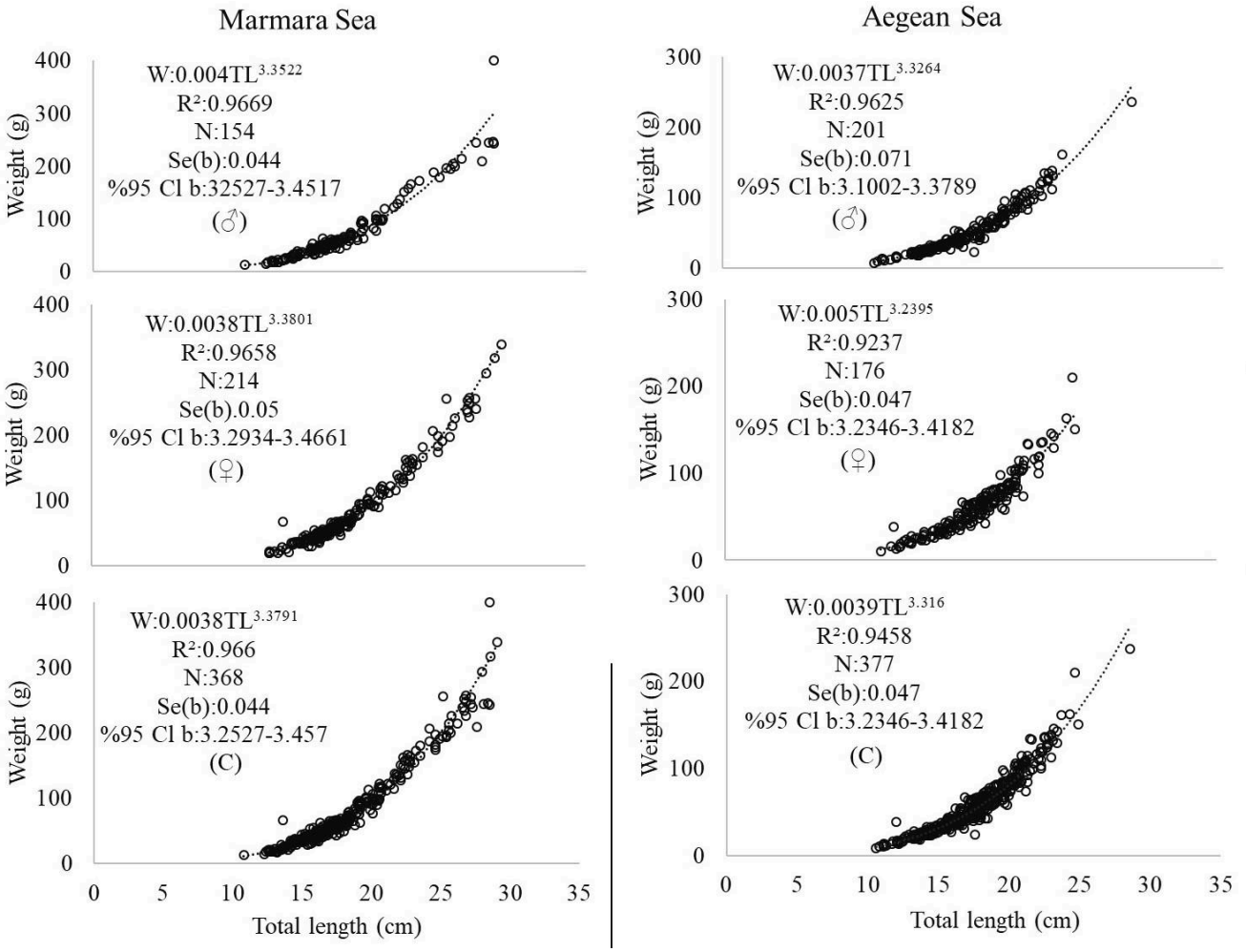
The total length-weight relationship parameters of female, male and all *B.boops* individuals for the Sea of Marmara and Aegean Sea were given in Figure 3. The exponent of the b value represented positive allometric growth in females, males and all sexes. The comparison of length-weight relationships and regression parameters of *B.boops* in this study and previous studies is given in Table 1. The "a" constant value is used as an indicator to determine the fattening degree, that is, the condition of the fish (Le Cren, 1991). The "a" values of *B.boops* showed close to each other in this study and previous studies. The "b" value is used to explain the growth type of the species according to its conditions. The “b” value of males is higher than females, indicating that males are in better condition in the Sea of Marmara and the Aegean Sea. While generally positive allometric growth from the "b" value was determined for *B.boops* in both areas, and previous studies in different areas of Türkiye. These differences in “b” values may be related to environmental conditions and sampling areas (Andreu-Soler et al., 2006; Olim & Borges, 2006). The sampling time, habitat, maturity, sex, feeding and stomach fullness may be effective in differences in the "b" value (Tesch, 1971; Hossain et al., 2006). The R^2 value of *B.boops* appears to have a high correlation value regardless of the sampling area and number of individuals. This shows that its condition is good. The differences between previous studies and this study are mainly related to the changes that may be seen in the populations due to temporal and spatial differences (Table 1).

The gonadosomatic index (GSI) of *B.boops* were recorded maximum in March for females and February for males and minimum in August for both sexes in the Sea of Marmara, whereas maximum in April for both sexes and minimum in July for both sexes in the Aegean. Sea (Figure 4). No significant difference for GSI with the Independent Samples T-test was detected between females and males in the Sea of Marmara (F:0.002, df:22, P>0.05) and Aegean Sea (F:0.046, df:22, P>0.05). Also, no significant difference for GSI was detected between the Sea of Marmara and Aegean Sea for females (F:0.034, df:22, P>0.05) and males (F:0.003, df:22, P>0.05).

The condition factor (CF) of *B.boops* was recorded maximum in October for both sexes and minimum in March for both sexes in the Sea of Marmara, whereas maximum in May for both sexes and minimum in March for both sexes in the Aegean Sea (Figure 5). No significant difference for CF with the Independent Samples T-test was detected between females and males in the Sea of Marmara (F:0.079, df:22, P>0.05), whereas significant difference was detected in the Aegean Sea (F:4.563, df:22, P<0.05). Also, no significant difference for CF was detected between the Sea of Marmara and Aegean Sea for females (F:0.578, df:22, P>0.05) and males (F:0.212, df:22, P>0.05).

Figure 3.

Total length-weight relationship parameters of B.boops in the Sea of Marmara and Aegean Sea (♂: Male, ♀: Female, C: All individuals).



The monthly sexual maturity stages were provided in Figure 6. The sexual maturity stages, GSI and CF values were evaluated together, the spawning period of *B.boops* was determined from January to May in the Aegean Sea and February to May in the Sea of Marmara. Also, the resting time of *B.boops* was determined from June to December in the Aegean Sea from June to January in the Sea of Marmara.

This study showed that the reproductive period of *B.boops* starts in January and ends in May in the Aegean Sea, while it starts in February and ends in May in the Sea of Marmara. The spawning period was generally concentrated in the spring and winter periods, when GSI is highest and CF is lowest, in the previous studies conducted in different areas (Table 2). The main reason for this temporal difference observed during the spawning period is sea temperature. Otero et al. (2013) emphasized that sea temperature has an effect on the reproductive period. Kalıpçı et al. (2021) stated that although sea temperature varies by month, it is on average 3.06 °C higher in the Aegean Sea than in the Sea of Marmara between 1970 and 2019. Some differences were observed in the spawning period in Bottari et al. (2014) in the Tyrrhenian Sea, Mediterranean Sea, Kara & Bayhan (2015) in the Izmir Bay, Aegean Sea, Layachi et al. (2015) in the Nador-Saidia, Morocco, Azab et al. (2019) in Alexandria, Egypt, Koca (2023) in the Antalya Bay, Mediterranean Sea studies. The main differences in these studies are due to the study areas and sampling time (Table 2).

The first maturity lengths (L_{50}) of *B.boops* were calculated as 12.5 cm TL in females and 15.8 cm TL in males in the Aegean Sea and 12.8 cm TL in females and 15.1 cm TL in males in the Sea of Marmara. The first gonad formation was observed at 11.1 cm TL for females and 12.6 cm TL for males in the Aegean Sea and 11.6 cm TL for females and 12.9 cm TL for males in the Sea of Marmara. The first sexual maturity length of *B.boops* was determined to be lower in female individuals than in male individuals. While the first maturity length was found to be higher in female individuals in the Sea of Marmara than Aegean Sea, while it was higher in male individuals in the Aegean Sea than Sea of Marmara. Also, the first maturity length of females was larger than males in the both seas.

Table 1.
Comparison of total length-weight relationship parameters of B.boops with previous studies.

Area	N	Sex	TL (cm) mean (min-max)	TW (g) mean (min-max)	a	b	R^2	Growth type	References
Türkiye, Mediterranean Sea	-	♀	8.2-19.5	-	0.008	3.046	0.93	A (+)	Manaşarlı et al (2006)
	-	♂	8.9-18.85	-	0.010	2.978	0.96	A (-)	
	314	C	8.2-19.5	3.52-75.9	0.008	3.03	0.95	-	
Türkiye, Saros Bay	189	C	10.5-22.0	11-91	0.005	3.241	0.96	-	Ismen et al (2007)
Türkiye, Izmir Bay	640	♀	19.14 (11.3-27.6)	75.62 (12.1-261.8)	0.004	3.272	0.95	A (+)	Kara & Bayhan (2008)
	514	♂	20.28 (13.6-27.0)	91.41 (17.7-281.7)	0.002	3.522	0.93	A (+)	
	1190	C	19.55 (9.2-27.6)	81.74 (7.18-281.8)	0.004	3.419	0.95	A (+)	
Egypt, Alexandria	920	C	-	-	0.025	2.660	0.97	I	El-Okda (2008)
Montenegrin, Adriatic Sea	496	♀	12.7-22.4	-	0.015	2.828	0.89	A (-)	Kasalica et al (2011)
	325	♂	13.3-26.6	-	0.011	2.889	0.88	A (-)	
Algeria, Mediterranean Sea	1372	C	9.0-29.0	22.8–80.18	0.016	2.798	0.99	I	Rachid et al (2014)
Türkiye, Edremit Bay	297	♀	7.9–23.9	3.52–154.4	0.004	3.295	0.97	A (+)	Andsoy (2015)
	78	♂	7.7–20.9	3.81–110.7	0.004	3.304	0.98	A (+)	
	389	C	7.7–23.9	3.52–154.4	0.004	3.299	0.97	A (+)	
Türkiye, Izmir Bay	429	♀	11.3-27.9	12.2-261.7	0.007	3.128	0.95	-	Kara & Bayhan (2015)
	503	♂	12.2-27.0	17.7-241.6	0.003	3.42	0.96	-	
	932	C	19.6 (11.3-27.9)	82.7 (12.2-261.7)	0.005	3.237	0.96	A (+)	
Türkiye-Izmir Bay	82	♀	17.1 (12.8-21.3)	-	0.004	3.358	-	A (+)	Soykan et al (2015)
	293	♂	14.9 (11.2-23.8)	-	0.006	3.138	-	A (+)	
	421	C	15.5 (11.0-23.8)	37.9	0.005	3.25	0.97	A (+)	
Türkiye, Izmir Bay	51	C	10.5 (8.5-13.8)	13.13 (5.9-25.7)	0.009	3.021	0.99	I	Kara et al (2015)
Adriatic Sea	311	♀	18.41 (13.3-29.3)	-	0.013	2.884	0.91	A (-)	Dobroslavić et al (2017)
	365	♂	(18.29) 15.1-26.3	-	0.011	2.963	0.88	A (-)	
	676	C	13.3-29.3	-	0.011	2.911	0.90	A (-)	
Spain, Canary Islands	1069	♀	10.0-30.5	-	0.009	3.047	0.99	A (+)	Massaro & Pajuelo (2018)
	902	♂	8.5-34.5	-	0.008	3.079	0.99	A (+)	
	2893	C	4.0-34.5	-	0.007	3.153	0.99	A (+)	
Egypt, Alexandria	684	♀	13.81 (10.0-23.1)	27.12 (7.4-133.1)	0.012	2.912	0.91	I	Azab et al (2019)
	683	♂	13.4 (9.3-21.6)	24.4 (7.7-116.9)	0.010	2.978	0.92	I	
	1367	C	13.6 (9.3-23.1)	25.8 (7.4-133.1)	0.011	2.960	0.92	I	
Türkiye, Saros Bay	374	♀	19.8 (13.4-27.)6	97.43 (24.13-259.6)	0.009	3.11	0.96	A (+)	Cengiz et al (2019)
	564	♂	20.5 (13.7-25.6)	105.93 (25.93-20.4)	0.010	3.07	0.95	I	
Türkiye, Izmir Bay	30	C	15.9 (13.0-19.0)	39.6 (21.4-65.0)	0.005	3.209	0.97	I	Bayhan & Uncumusaoğlu (2022)
Algeria, Mediterranean Sea	1434	C	10.1-30.9	13.47-268.2	0.016	2.815	0.93	A (-)	Dahel et al (2019)
Türkiye, Çandarlı Bay	65	C	10.22 (6.8-13.8)	11.39 (3.05-25.7)	0.006	3.015	0.99	A (+)	Babaoglu et al (2021)
Türkiye-Saros Bay	363	C	16.9 (11.3-24.1)	60.4 (14.61-165.3)	0.008	3.13	0.98	A (+)	Cengiz. (2022)
Egypt, Alexandria	880	C	13.98 (13-15)	28.51(14-88)	0.012	2.945	0.99	I	El samman et al (2022)
Algeria, Mediterranean Sea	2068	C	9.7-27.4	5-212	0.004	3.28	0.92	A (+)	Handjar et al (2022)
Türkiye, Antalya Bay	316	♀	10.8-24.9	12.99-141.1	0.013	2.897	-	A (-)	Koca (2023)
	325	♂	10.9-23.0	13.47-119.6	0.014	2.867	-	A (-)	
	641	C	10.8-24.9	12.99-141.1	0.013	2.882	0.95	A (-)	
Türkiye, Aegean Sea	226	♀	18.57 (10.7-25.2)	60.74 (10.65-141.0)	0.011	2.930	0.97	A (-)	Seyhan Öztürk (2024)
	135	♂	17.63 (11.6-23.5)	60.5 (14.66-137.5)	0.010	3.005	0.99	I	
	361	C	10.5-25.2	10.65-141.0	0.011	2.933	0.97	A (-)	
Türkiye, Mediterranean Sea	488	♀	17.3 (11.9-27.8)	14.1-210.0	0.002	3.52	0.95	A (+)	Farah & Mavruk (2024)

Area	N	Sex	TL (cm) mean (min-max)	TW (g) mean (min-max)	a	b	R^2	Growth type	References
	466	♂	16.9 (11.6-28.4)	14.8-281.0	0.004	3.28	0.91	A (+)	
	967	C	15.9 (11.1-28.4)	12.1-28.1	0.003	3.38	0.94	A (+)	
Egypt, Mediterranean Sea	868	C	13.57 (8.4-23.0)	29.84 (6.1-138.2)	0.010	3.045	0.96	I	Mokbel et al (2024)
Türkiye, Marmara Sea	51	C	19.17 (15.4-25.8)	84.66 (37.12-186.6)	0.009	3.066	0.96	-	Şen et al (2024)
Türkiye, Aegean Sea	176	♀	17.91 (11.1-24.9)	63.51 (10.55-210.3)	0.005	3.240	0.92	A (+)	This study
	201	♂	17.19 (10.6-28.6)	54.2 (8.1-236.86)	0.004	3.326	0.96	A (+)	
	377	C	17.52 (10.6-28.6)	58.46 (8.1-236.86)	0.004	3.316	0.95	A (+)	
Türkiye, Marmara Sea	214	♀	18.21 (12.6-29.1)	81.52 (19.04-339.1)	0.004	3.380	0.97	A (+)	
	201	♂	17.52 (10.8-28.5)	68.9 (13.08-399.9)	0.004	3.352	0.97	A (+)	
	368	C	17.92 (10.8-28.5)	76.54 (13.08-399.9)	0.004	3.379	0.97	A (+)	

N: Number of individuals, TL: Total length, TW: Total weight, Min: Minimum, Max: Maximum, C: All individuals, ♀: Female, ♂: Male, A: Allometric growth, I: Isometric growth

Figure 4.

Comparison of monthly gonadosomatic index (GSİ) values of B.boops in the Sea of Marmara and Aegean Sea.

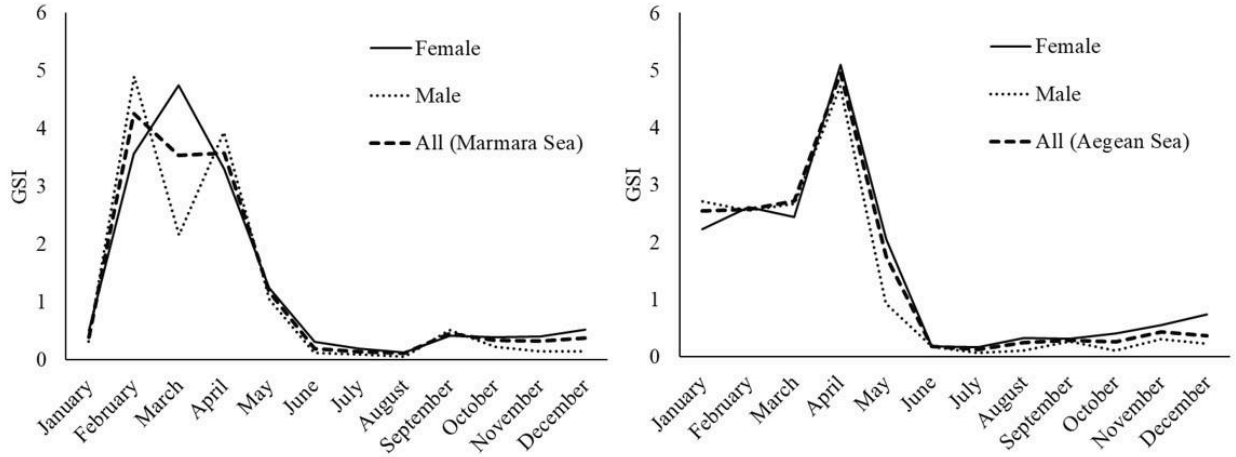


Figure 5.

Comparison of monthly condition factor (CF) values of B.boops in the Sea of Marmara and Aegean Sea.

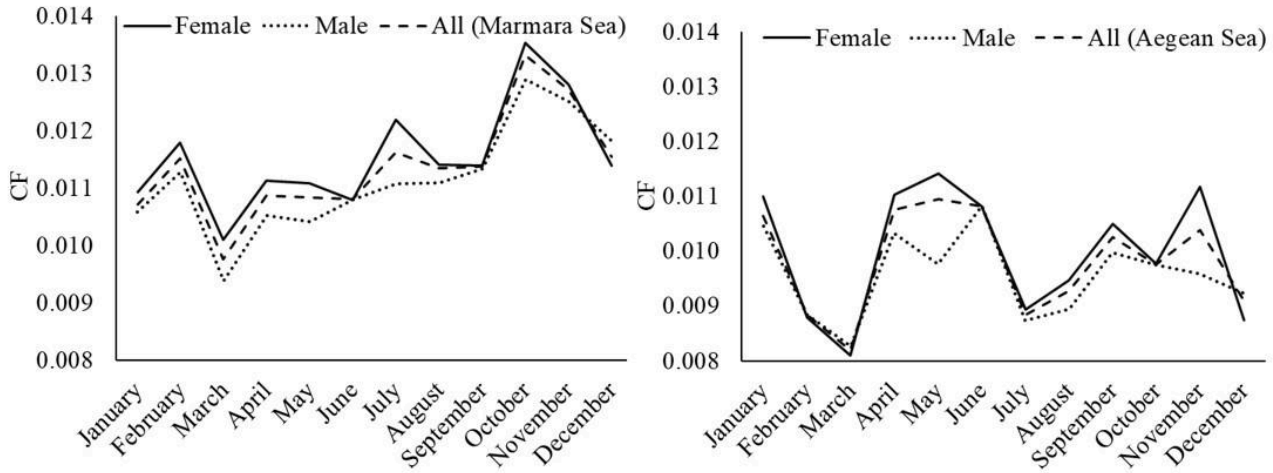
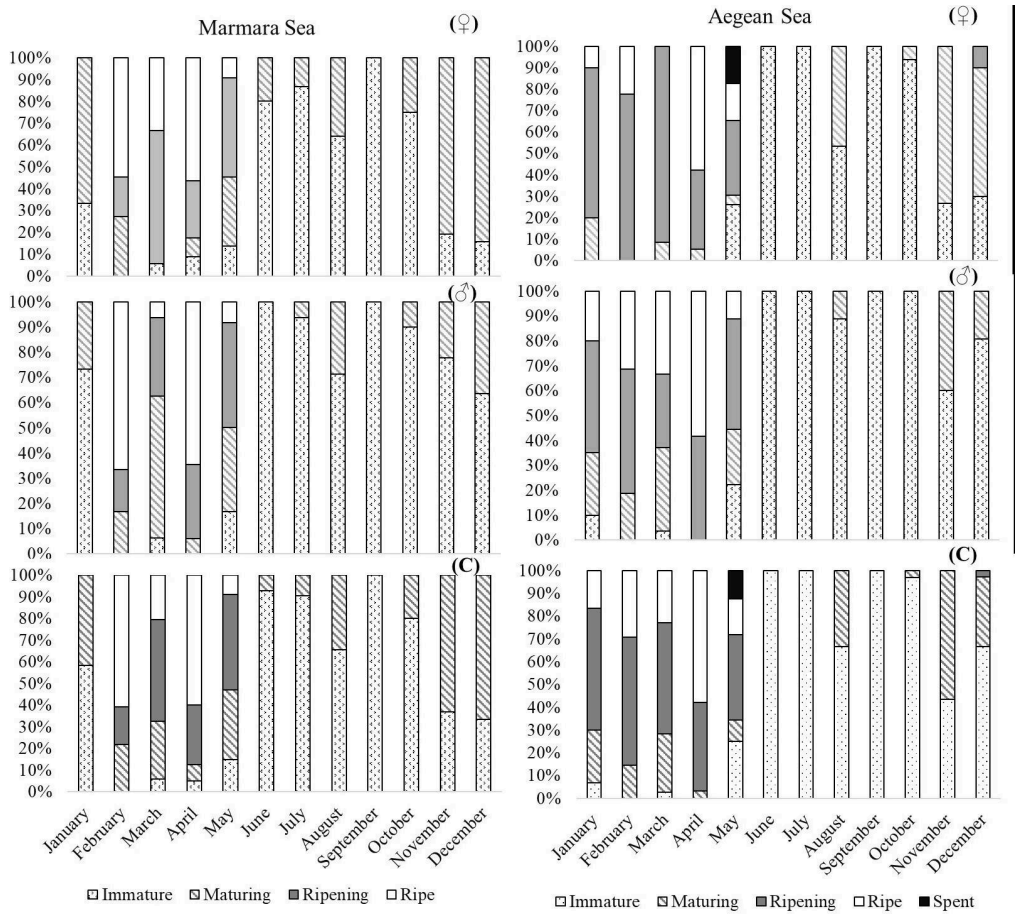


Figure 6.

Comparison of sexual maturity stages of B.boops in the Sea of Marmara and Aegean Sea (♂: Male, ♀: Female, C: All individuals).



This may be related to the decreasing population growth rate resulting from high exploitation in the Aegean Sea, which might lead to females individuals maturing earlier and younger age with small size (De Roos et al., 2006). The first maturity length of *B.boops* varies between 9.35 and 16.49 cm in previous studies, while it is generally similar to other studies (Table 2). The first maturity length of females was similar in in Soykan et al. (2015) in the Izmir Bay, Aegean Sea, whereas smaller in male individuals compared to this study. Cengiz (2022) calculated the first maturity length of *B.boops* in the Saros Gulf, Aegean Sea to be higher in all individuals compared to this study. Also, the first gonad formation was observed to be lower in males and females in the Aegean Sea than Sea of Marmara, and lower in females than males. These differences in this study with previous studies may be due to the structure of the sampled population, sampling methods, sampling areas and sampling times. The fishing pressure and stress on a species can make that species tend to mature earlier or cause the reproductive period to shift (Trippel, 1995; Aramayo, 2015). There are no regulations or restrictions regarding *B.boops* fishing in the commercial fisheries regulations in Türkiye (GDFA, 2024). The first maturity lengths calculated regarding *B.boops* in this study can be used as legal catch lengths in the Sea of Marmara and Aegean Sea (Table 2).

The oocyte counts of *B.boops* were obtained from the individuals which ranged from 12.6 cm TL to 29.1 cm TL (mean:18.66±0.66 cm TL) in length and from 10.6 g to 339.1 g (mean:95.2±11.8 g) in weight in the Sea of Marmara, while 11.1 cm TL to 24.8 cm TL (mean:18.55±2.38 cm TL) and these weights ranged from 19.04 g to 210.3 g (mean:72.77±9.32 g) in the Aegean Sea. The total fecundity varied between 2770-85112 (mean:20021±2027) in the Sea of Marmara, while 2740–309457 (mean:42834±9194) in the Aegean Sea. A statistically significant difference with the Independent Samples T-test for fecundity was detected between the Sea of Marmara and Aegean Sea ($F:41.511$, $df:117$, $P<0.05$). The oocyte diameters were measured from 3 mature females (181 oocytes) as 0.281–0.65 mm (mean:0.476±0.007 mm) in the Sea of Marmara, while from 8 individuals (209 oocytes) between 0.281 mm and 0.667 mm (mean:0.474±0.007 mm) in the Aegean Sea. No significant difference with the Independent Samples T-test for oocyte diameters ($F:1.135$, $df:388$, $P>0.05$) was detected between the Sea of Marmara and Aegean Sea. Also, fecundity–total length and fecundity–weight relationships were given in Figure 7.

Tablo 2.

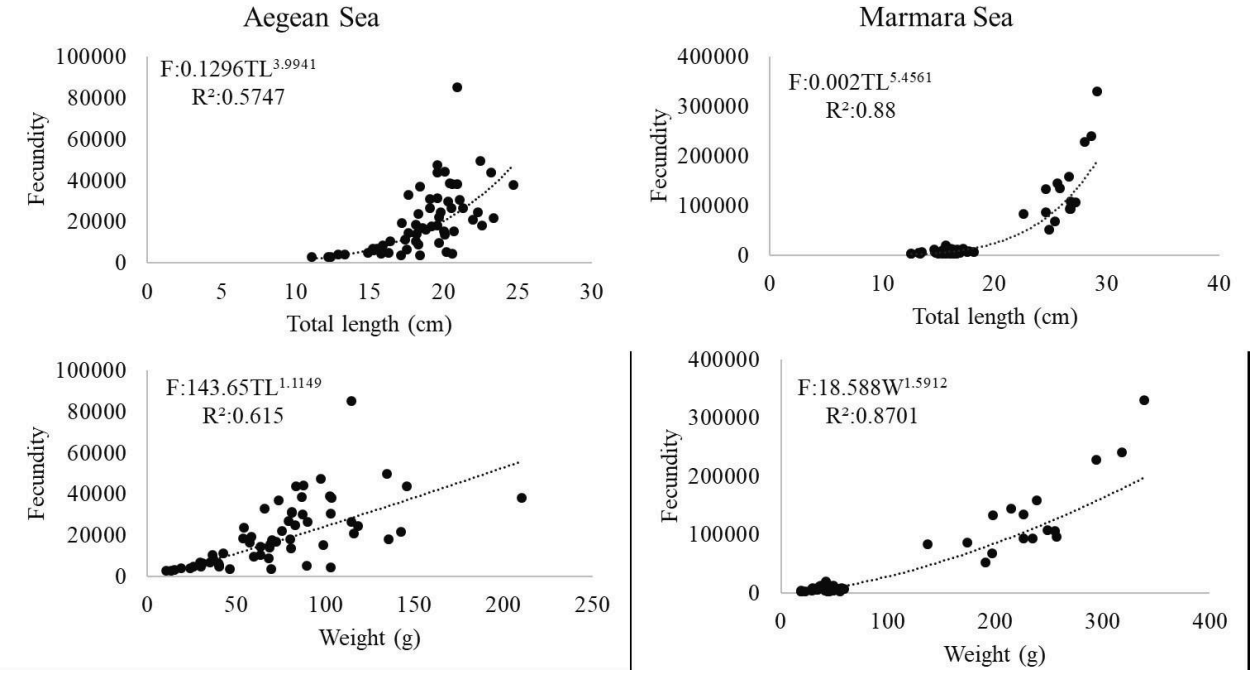
Comparison of spawning period and first maturity length of B.boops *with previous studies.*

Area	Spawning Period	First Gonad Formation (cm)	First Maturity Length (cm)	References
Egypt, Alexandria	January-May	-	13 (♀), 12 (♂)	El-Agamy et al (2004)
Portugal, Algarve	February-May	15.22 (C)	15.7 (♀), 15.3 (♂)	Monteiro et al (2006)
Türkiye, Edremit Bay	January-May	12.5	13.92	Bilge (2008)
Türkiye, Izmir Bay	January-May	12.1	13.47	
Montenegrin, Adriatic Sea	February	-	11.49 (♀), 11.9 (♂), 13.02 (C)	Kasalica et al (2011)
Tyrrhenian Sea	February-April	-	13.1 (♀), 14.2 (♂), 13.8 (C)	Bottari et al (2014)
Türkiye, Izmir Bay	February-September	-	-	Kara & Bayhan (2015)
Türkiye, Edremit Bay	January-May	-	-	Andsoy (2015)
Morocco, Nador-Saidia	February- October	-	14.3 (♀), 13.3 (♂)	Layachi et al (2015)
Türkiye, Izmir Bay	January-March	11.2	12.96 (♀), 9.35 (♂)	Soykan et al (2015)
Adriatic Sea	January-May	-	-	Dobroslavić et al (2017)
Spain, Canary Islands	January-May	13.0 (♀), 12.0 (♂)	16.02 (♀), 16.49 (♂)	Massaro & Pajuelo (2018)
Algeria coast	February-June	10.5	12.65 (♀), 15.19 (♂), 14.75 (C)	Amira et al (2019)
Egypt, Alexandria	January-April	-	13.2	Azab et al (2019)
Türkiye, Saros Bay	March-May	-	-	Cengiz et al (2019)
Türkiye, Saros Bay	-	-	16.6	Cengiz (2022)
Algeria, Mediterranean Sea	-	-	9.7	Handjar et al (2022)
Türkiye, Antalya Bay	January-September	-	-	Koca (2023)
Türkiye, Aegean Sea	January-May	11.1 (♀), 12.6 (♂)	12.5 (♀), 15.8 (♂)	This study
Türkiye, Marmara Sea	February-May	12.6 (♀), 12.9 (♂)	12.8 (♀),15.1 (♂)	

C: All individuals, ♀: Female, ♂: Male

Figure 7.

The fecundity–total length and fecundity–weight relationships of B.boops in the Sea of Marmara and Aegean Sea.



The total fecundity of *B.boops* in the Aegean Sea was found to be almost twice as high in the Sea of Marmara. This situation may be related to the physical condition factor and gonadosomatic index values of *B.boops* and environmental parameters ofthese areas. Because, fish species can shift their life-history traits in order to facilitate populations to successfully continue against environmental changes (Riesch et al., 2020). In addition, fish species can migrate to reproduction (Jørgensen et al., 2008). If *B.boops* individuals were migrating from the Aegean Sea to the Sea of Marmara, they would have used up the energy. So, they consume energy for reproduction during the migration process, and this may cause them to produce fewer eggs. Also, ages of *B.boops* individuals in these areas may be affected by egg numbers due to the relationship of fish species between age and fecundity (Avşar, 2016). Taylan and Bayhan (2015) determined that the fecundity was 33072–66123 (mean:49008) eggs per female for 23.5 cm mean length of *B.boops* in the Aegean Sea. The high number of eggs in their study can be explained by the higher mean length of the individuals compared to this study. The fecundity was 5185 to 52208 eggs for 13.0-22.0 cm total length in Egypt (Hassan, 1990). El-Agamy et al. (2004) reported that 462 individuals with 10.6-20.8 cm total length in Egypt varied between 1296 and 51528 eggs. Gordo (1996) stated that number of eggs varied between 11550 and 357800 (14-36 cm total length) in the Portuguese coast. Bauchot and Hureau (1986) stated that the egg capacity was approximately 395000 eggs for 32 cm mean length. The fecundity varied 36600 to 445200 eggs (mean 133456) in Algeria (Amira et al., 2019). Dobroslavić et al. (2017) determined the number of eggs from 125802 to 251502 (15.8-27.8 cm total length) in the Adriatic coast. These differences in fecundity for the previous studies may be related to regional differences.

The oocyte diameters of *B.boops* were found to be almost similar in the Sea of Marmara (0.476 mm) and the Aegean Sea (0.474 mm). Taylan & Bayhan (2015) determined that the oocyte diameters were 0.60 mm mean (0.53-0.74 mm) in the Aegean Sea. The oocyte diameters were 0.51-0.68 mm in Egypt (El-Agamy et al., 2004) and 0.16-0.59 mm in the Adriatic coast (Dobroslavić et al., 2017). The oocyte diameters of *B.boops* were similar, except for the study by Amira et al. (2019). They found to be 0.11-0.185 mm the oocyte diameters in Algeria.

Length and weight differences affect fecundity (Amira et al., 2019). While partially low exponential relationships of *B.boops* were determined between fecundity and length (R^2:0.57), fecundity and weight (R^2:0.615) in the Aegean Sea, whereas high exponential relationship was determined between fecundity and length (R^2:0.88), fecundity and weight (R^2:0.87) in the Sea of Marmara. El-Agamy et al. (2004) calculated that total length-fecundity, and weight-fecundity relationships in Egypt as F:61688+TL^{5037}, and F:12398+$W^{730.33}$. Taylan and Bayhan (2015) stated that the fecundity-total length, fecundity-weight relationships in the Aegean Sea as F:8207.6$e^{0.075TL}$ (R^2:0.79), F:30297$e^{0.003TW}$ (R^2:0.71), respectively. They reported that there was a higher correlation between fecundity and length-weight in the Aegean Sea compared to our study.

CONCLUSION

As a result of this study, the reproductive biology of *B.boops* was determined for the first time in the Sea of Marmara. Also, current data on the reproductive biology of this species in the Aegean Sea were presented, and with these data from the Sea of Marmara adjacent to the Aegean Sea. The differences were determined in sex ratio, spawning period, fecundity from reproductive characteristics between the Sea of Marmara and Aegean Sea. Also, some differences in reproductive characteristics were also stated in the Aegean Sea compared with previous studies. The main reasons for these differences are thought to be not only the structure of the population, sampling methods, sampling areas and sampling times, but also biotic and abiotic factors and human impacts as fishing pressure. Additionally, effects of climate change and fishing exploitation may cause their biological characteristics of *B.boops* to change over time. This scientific knowledge of reproductive biology contributes to the regional management of *B.boops* stocks in both seas.

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