Turk. J. Fish.& Aquat. Sci. 22(8), TRJFAS21016
http://doi.org/10.4194/TRJFAS21016

PROOF
RESEARCH PAPER

Turkish Journal of FISHERIES and AQUATIC SCIENCES

Age, Growth, Mortality and Reproduction Biology of the Black Seabream, *Spondyliosoma cantharus* in North Aegean Sea, Turkey, Mediterranean Basin

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How to cite

Daban, İ.B. (2022). Age, Growth, Mortality and Reproduction Biology of the Black Seabream, *Spondyliosoma cantharus* in North Aegean Sea, Turkey, Mediterranean Basin. *Turkish Journal of Fisheries and Aquatic Sciences*, *22(4)*, *TRJFAS21016.* http://doi.org/10.4194/TRJFAS21016

Article History
Received 22 November 2021
Accepted 02 March 2022
First Online 04 March 2022

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Keywords
Growth
Mortality
Spawning
Fecundity
Spondyliosoma cantharus

Abstract

In the present study, the population parameters (length-length and length-weight relationships, age, growth, mortality) and reproductive biology (sex ratio, GSI, condition, length at first maturity, spawning period, fecundity) of black seabream (*Spondyliosoma cantharus* Linnaeus, 1758) were investigated. The length-length relationship and length-weight relationship were calculated as FL=0.911TL-0.0433 and $W=0.0123TL^{3.0614}$ (R^2=0.97), respectively. Parameters of the von Bertalanffy growth equation were: L_∞=33.21 cm, K=0.21 per year, t_0= −1.84 year and age varied between 0 and 8 years. The instantaneous rates of total mortality (Z) and natural mortality (M) were 0.64 and 0.47 per year, respectively. Rates for fishing mortality (F) and exploitation (E) were 0.17 and 0.27 per year, respectively. The spawning season extended from February to May and peaked in March and April. The female/male ratio was found to be 3.49/1 and sex inversion from female to male occurred after the 24 cm TL length group. Total lengths at 50% maturity were 22.25 cm for males and 20.59 cm for females. The mean absolute fecundity (F) was 109,457±8,011 oocytes, ranging from 59,666 to 182,589.

Introduction

Sparidae is a family of the order Perciformes and contains 164 species in 38 genera (Eschmeyer's Catalog of Fishes, 2020). Recently, the sister family Centracanthidae (picarels) was merged with the Sparidae (Santini et al., 2014), while they were previously listed as distinct and separate (Nelson, 2006; Golani et al., 2006; Mater et al., 2011). As far as known, 24 Sparidae species within 13 genera (*Boops*, *Centracanthus*, *Dentex*, *Diplodus*, *Evynnis, Lithognathus*, *Oblada*, *Pagellus*, *Pagrus*, *Sarpa*, *Sparus*, *Spicara* and *Spondyliosoma*) were reported from Turkish territorial waters (Mater et al., 2011). There are two more species (*Crenidens* and *Rhabdosargus haffara*) in the Eastern Mediterranean (Golani et al., 2006) which are lessepsian (Paruğ & Cengiz, 2020). Among the teleost fish commonly distributed in the littoral zone, Sparidae are one of the most important taxa around the entire Mediterranean, except the Baltic Sea, with high economical value, wide range of distribution and being able to be caught with various fishing gear.

According to the General Fisheries Commission for the Mediterranean (GFCM), 83% of the total fishing fleet consists of small-scale vessels, especially around the central and eastern Mediterranean and Black Sea. In the Eastern Mediterranean and Black Sea, 87.600 fishing vessels are registered legally; 21,425 of which belong to small-scale fisheries. Among the countries operating in GFCM area, Turkey is a major producer of 273.977 tons

(23.3%) of the total catch (GFCM, 2020). Small-scale fisheries, such as gillnet, trammel net, handline and longline, operating in Turkey target mostly Sparidae fish species.

Black seabream, *Spondyliosoma cantharus* (Linnaeus, 1758), is defined as a marine, benthopelagic and subtropical fish species (Riede, 2004) which has a wide distribution range from Scandinavia to northern Namibia (Heemstra, 1995), including the Strait of Gibraltar, Mediterranean and the Black Sea, Madeira, Canary Islands, and Cape Verde (Bauchot & Hureau, 1990). It mostly found on seagrass beds and rocky and sandy habitats up to 300 m depth and the feeding type was identified as omnivorous (Bauchot & Hureau, 1990). *S. cantharus* is known as a single Sparidae species, which has demersal eggs. Sex reversal in consequence of progynic hermaphroditism occurs at approximately 24.3 cm TL (Boughamou et al., 2015). Great fishing pressure on the stocks is known and the species was assessed as LC (least concern) status (Nieto et al., 2015; IUCN, 2020).

S. cantharus is distributed in all the seas of Turkey and is included in the fish fauna of the Levantine coasts (Başusta & Erdem, 2000; Keskin et al., 2011; Saad, 2005) and Northern Aegean Sea (Keskin & Ünsal, 1998; Torcu & Aka, 2000; Eryılmaz, 2003; Cengiz et al., 2011; Cengiz et al., 2012; Çoker & Akyol, 2018). Although it is mentioned in the Black Sea fish fauna (Keskin, 2010), it was not included in the benthic fish fauna of the western Black Sea (Yıldız et al., 2019), central Black Sea (Gönener & Özdemir, 2012) and eastern Black Sea (Ak et al., 2008; Ak et al., 2011).

Knowledge about population and reproductive biology including age, growth, mortality, sex ratio, sexual maturity, spawning season and fecundity is a major component of fisheries management due to providing important data for stock status and structure (Marshall, 2009). For implementation and enforcement of management rules and issues, managers firstly need qualified scientific and statistical data (O'Brien, 2009). Some valuable studies were conducted on population and reproduction biology of *S. cantharus* around the Canary Islands (Pajuelo & Lorenzo, 1999), Algeria (Boughamou et al., 2015), Tunisian coast (Mouine-Queslati et al., 2015), Adriatic (Dulcic & Kraljevic, 1996; Dulcic et al., 1998) and southwestern Portugal (Gonçalves & Erzini, 2000). However, no scientific study was found in the eastern Mediterranean, Aegean Sea and Turkish territorial waters.

Thus, the aim of the present study was to determine the first results about age, growth, mortality, reproduction and fecundity of *S. cantharus* around the North Aegean Sea, eastern Mediterranean.

Materials and Methods

The northern Aegean coasts of Turkey are divided into sub-regions of Saros Bay, Gallipoli Peninsula, Gökçeada Island, Bozcaada Island, and Edremit Bay (Cengiz & Paruğ, 2021) and these are known to be important fishing areas with many commercial fishing ports and small-scale fishery vessels. The area has great biodiversity due to the various coastal types such as sandy, rocky and vegetated (Gönülal & Güreşen, 2014). In the present study, specimens from Gökçeada Island, North Aegean Sea (Figure 1), were obtained from small-scale handline and longline fishermen with random sampling between August 2020 and July 2021.

In total, 355 individuals were sampled, total length (TL) and fork length (FL) were measured to the nearest mm, and total weight and gonad weight were recorded

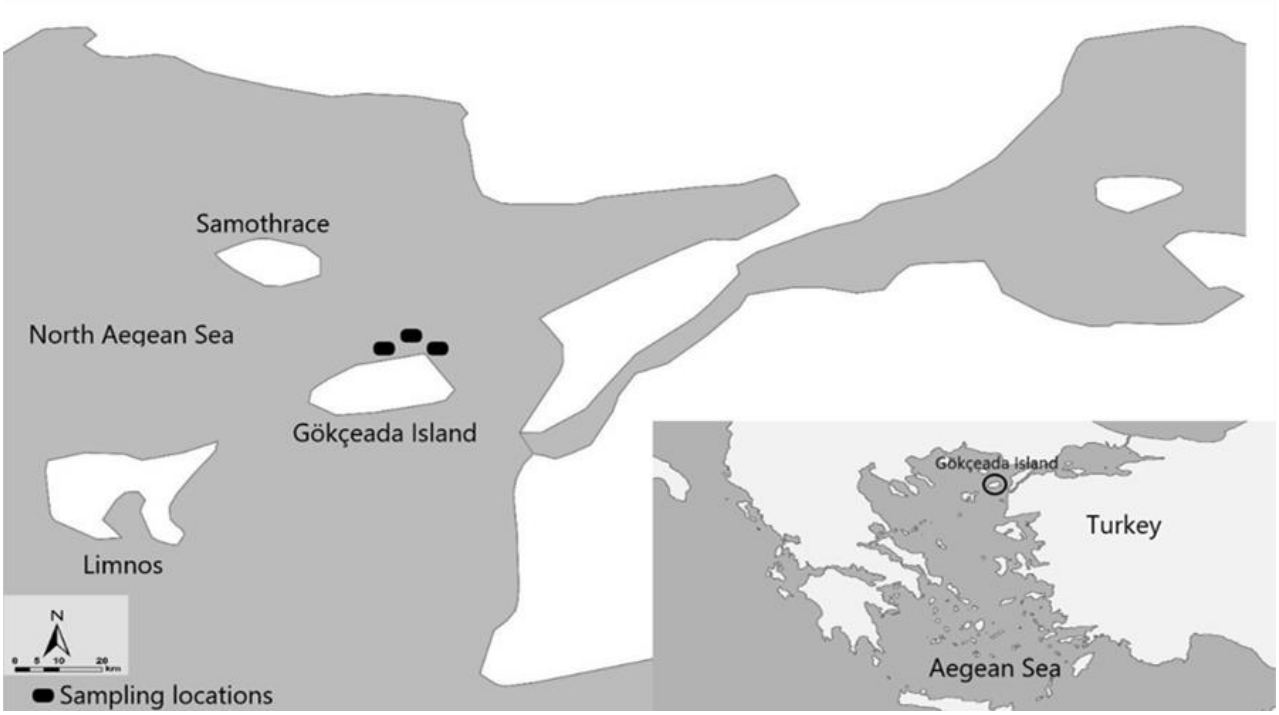


Figure 1. Study area and sampling locations

to the nearest g with precision scales. Sex and the 5-staged maturity scale (Holden and Raitt, 1974) were determined by macroscopic observation of male and female gonads. Sexual inversion length was estimated by aggregating the length frequency distribution where females and males overlap (Shapiro, 1984; Gonçalves & Erzini, 2000).

As described by Ricker (1975), the length-weight relationship was estimated by the exponential regression $W=a*TL^b$, where W is the total weight (g) and TL is the total length (cm). The constants a and b were estimated by least square linear regression after log transformation. Growth type was determined by the t-test of the value "*b*" that reflects allometry of growth. To test for possible significant difference between sexes, the Student's t-test was used for comparison of the slopes (Zar, 1996).

Age was estimated by interpreting annual growth rings of scales belonging to 355 black seabream specimens. Scales from the back of the pectoral fin were removed, cleaned with 4% KOH solution, then rinsed with distilled water and subsequently put in 96% alcohol for 15-20 min and stored dry in individually labelled eppendorf tubes. They mounted between glass slides for determining age by interpreting growth rings. Readings were made by three independent researchers. Scales from the back of the pectoral fin were removed and cleaned to determine age by interpreting growth rings. Measurements were always made along the longest axis of the scale. Growth parameters were estimated for the whole population (both sexes together), for males and for females using the von Bertalanffy growth equation (von Bertalanffy, 1938):

$$L(t)= L_\infty \ [1-\exp(-k(t-t_0))$$

where L(t) is total length at time t, L_∞ is the asymptotic length (cm), K is the growth coefficient (t^{-1}) and t_0 is the hypothetical age when the size of the fish is zero. Growth parameters were estimated using the FAO-

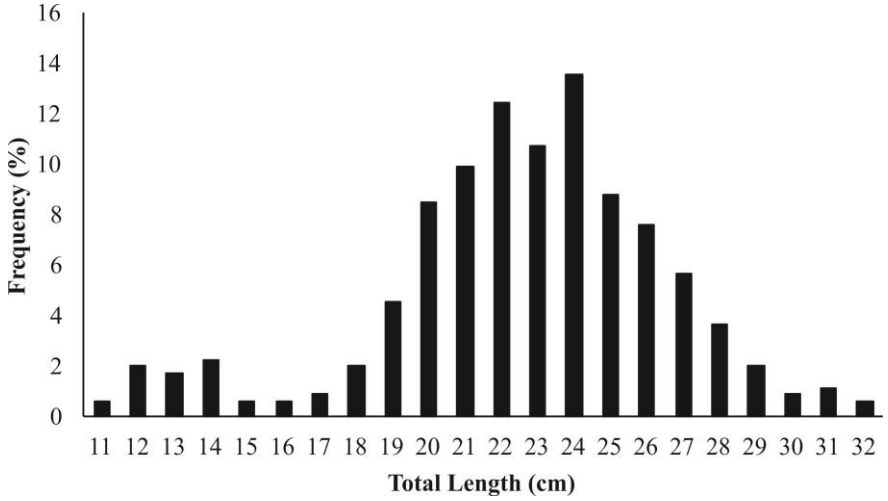


Figure 2. Length - frequency distribution of the Black Seabream, *Spondyliosoma cantharus.*

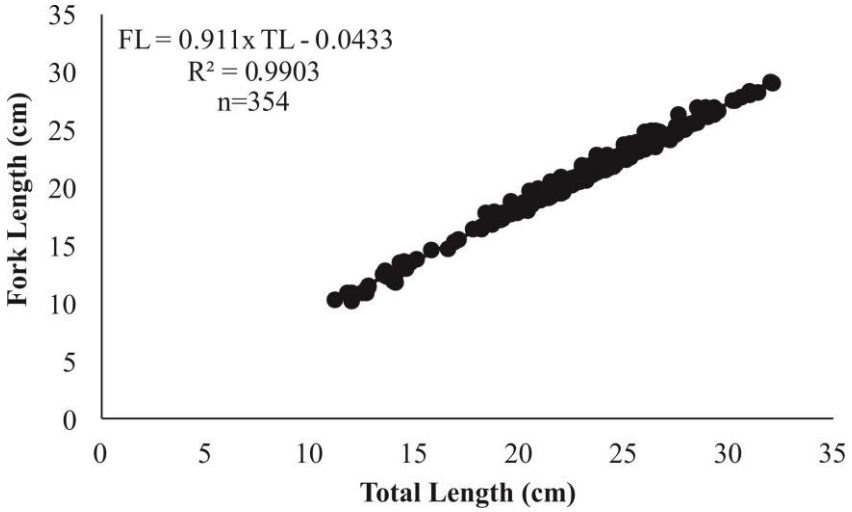


Figure 3. The total length (TL) – fork length (FL) relationship of the Black Seabream, *Spondyliosoma cantharus.*

ICLARM Stock Assessment Tool (FISAT II) software (Gayanilo et al., 2005). The growth parameters obtained in this study were compared with the parameters obtained in other studies from various geographical areas using the growth performance index (φ) (Pauly & Munro 1984).

Instantaneous total mortality (Z) was calculated with a length-converted catch curve using Pauly's method (Pauly, 1984). Natural mortality (M) was determined using Pauly's (1980) empirical formula which includes von Bertalanffy growth parameters and mean annual sea water temperature (15.7°C; Türkoğlu, 2010). Fishing mortality was calculated as the deduction of natural mortality (M) from total mortality (Z) (Bingel, 2002). The exploitation rate (E) was obtained using Gulland's (1979) formula, E=F/Z.

Spawning season of the species was estimated by evaluation of sexual maturity stages and gonadosomatic index (GSI). GSI was calculated according to Gibson and Ezzi (Gibson & Ezzi, 1980). For both sexes, length at first maturity (L_{50}) was estimated from the individuals collected during the spawning period with using the least square method (King, 1995).

Black seabream is known as an indeterminate spawner due to varied oocyte size classes being continuously distributed in the ovary. The size at which 50% oocytes showed vacuolation (Macer, 1974) was found to be 500 µm by Dulcic et al. (1998) for black seabream. A calculation of small sized non-vacuolated oocytes increases the error margin due to exposure to more physical damage, resulting in more counts and miscalculations (Balgueras et al.,1993). For the reasons explained, in this study, oocytes larger than 500 µm were used for fecundity calculations, as described by Balgueras et al. (1993). After the microscopic examination, the gonads containing eggs with a diameter larger than 500 µm were determined as mature. Thus, 19 ovaries meeting this criterion were

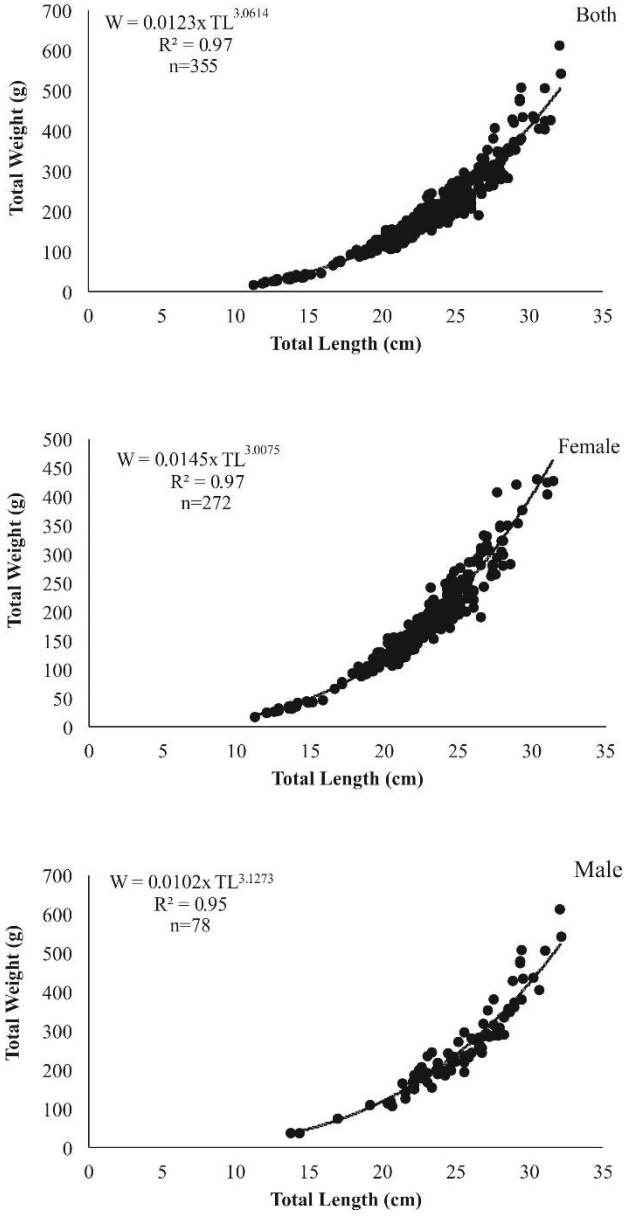


Figure 4. The total length (TL) – weight relationship of the Black Seabream, *Spondyliosoma cantharus.*

included in absolute fecundity analyses. The individuals with mature ovaries ranged between 20.4 cm and 26.7 cm TL in length, 136.12 g and 333.83 g in weight and 2 to 6 in age.

For fecundity estimates, the gravimetric method was used (Bagenal, 1978). In order to calculate absolute fecundity, a subsample of 0.05 g from 3 parts (anterior, mid and posterior parts) were taken from each ovary. These subsamples were weighed and mature oocytes were counted three times under a stereozoom microscope. The subsample fecundity was determined according to Yeldan and Avşar's (2000) formula; $F_1=(W_g \times N) \times W_s^{-1}$, where F_1 is the total number of eggs in the ovary sub-sample, Wg is the gonad weight, N is the number of eggs in the sub-sample, and Ws is sub-sample weight. Finally, absolute fecundity, which is the number of mature oocytes spawned by a female in a single spawning, was determined by averaging the total number of eggs in each ovary subsample (F1, F2 and F3).

The total length-fecundity, total weight-fecundity and age-fecundity relationships were estimated for females using linear and exponential regression to determine which equations fit best.

Results

Population Parameters

Specimens ranged from 11.2 cm TL to 32.1 cm TL and 10.2 cm FL to 29.1 cm FL, weighing from 11.43 g to 613.73 g, total weight (TW). The mean TL, FL and TW of the whole population were 23.03±0.21 cm TL, 20.93±0.19 cm FL and 199.31±5.10 g, respectively. The total length of males ranged between 13.7 cm and 32.1 cm (mean: 25.22±0.40 cm TL), and their weight between 39.36 g and 613.73 g (mean: 213.35±7.57 g), whereas females ranged between 11.2 cm and 31.4 cm (mean: 22.50±0.20 cm TL) in length, and 11.43 g and 431.1 g

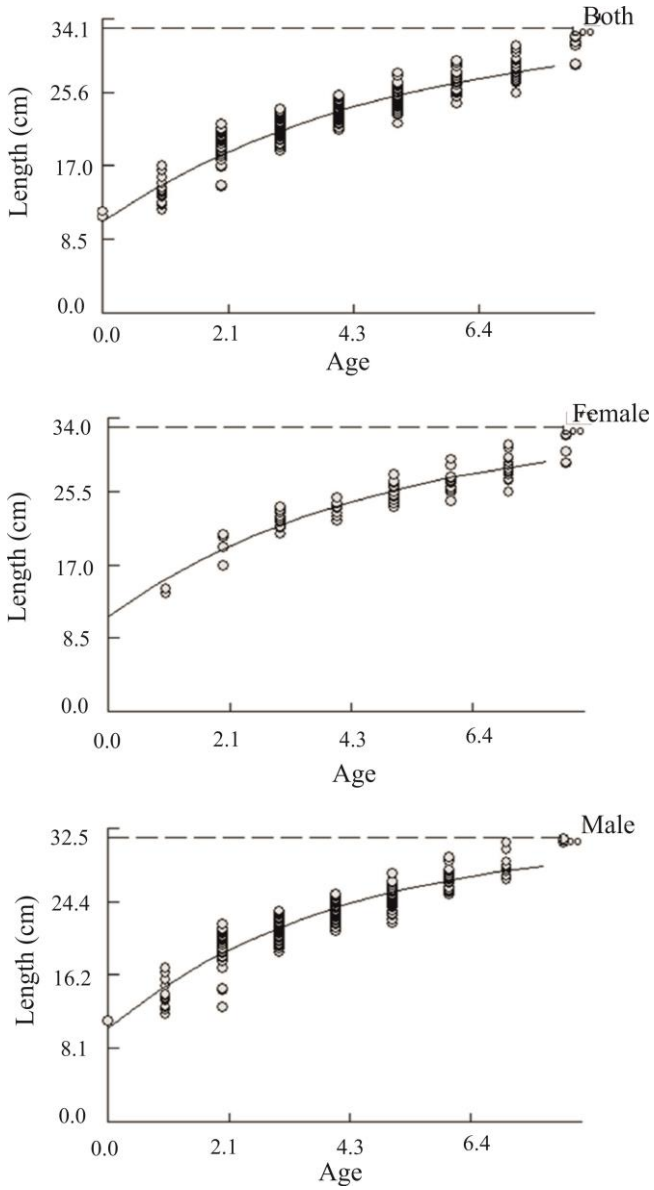


Figure 5. The growth parameters of Von Bertalanffy fitted to back calculated size at age data that estimated with FISAT II in the Black Seabream, *Spondyliosoma cantharus*

(mean: 183.11±4.87 g), in weight. The mean lengths (Mann-Whitney test: U: 5997, p<0.0001) and weights (Mann-Whitney test: U: 5864, p<0.0001) of males and females were significantly different. According to monthly variations of length distribution, the largest sized individual (32.1 cm TL) was observed in March, whereas the smallest specimen was obtained in May (11.2 cm TL). The highest mean TL was found in June (24.8±0.3 cm TL) and lowest mean TL was observed in May (18.1±0.4 cm TL).

According to the length - frequency distribution (Figure 2), the common length group was determined as 24 cm TL (13.5%) with 38.6% of the population in the 22 and 24 cm TL length groups. It was observed that smaller length groups (11-16 cm TL) were represented by limited specimens due to the data set comprising commercial longline catch.

The total length–fork length regressions indicated a strong linear relationship (r^2=0.99; n=355) with the formula FL=0.911*TL-0.0433 (Figure 3). The length-weight relationship was calculated as $W=0.0145*L^{3.0075}$ (r^2=0.97) for females, $W=0.0102*L^{3.1273}$ (r^2=0.95) for males and $W=0.0123*TL^{3.0614}$ (r^2=0.97) for both sexes (Figure 4). The length–weight regressions indicated positive allometric growth in males and the whole population, whereas females had isometric growth (Table 1).

Age, Growth and Mortality

Measurements of 355 scales showed that the age distribution of the sampled individuals varied between 0 and 8. Table 2 shows the length-age distribution of the 355 individuals. The peak age distribution was observed in age group 3 including 24.6% of the individuals. The majority of individuals (61.1%) ranged in age between 3 and 5. The growth parameters of von Bertalanffy fitted to back-calculated size with age data were L_∞=33.21 cm TL, K=0.21 and t_0= -1.84 per year for all individuals, L_∞=32.9 cm TL, K=0.22 and t_0= -1.83 per year for females and L_∞=31.49 cm TL, K=0.25 and t_0= -1.59 per year for males (Figure 5). The growth performance index (φ') was

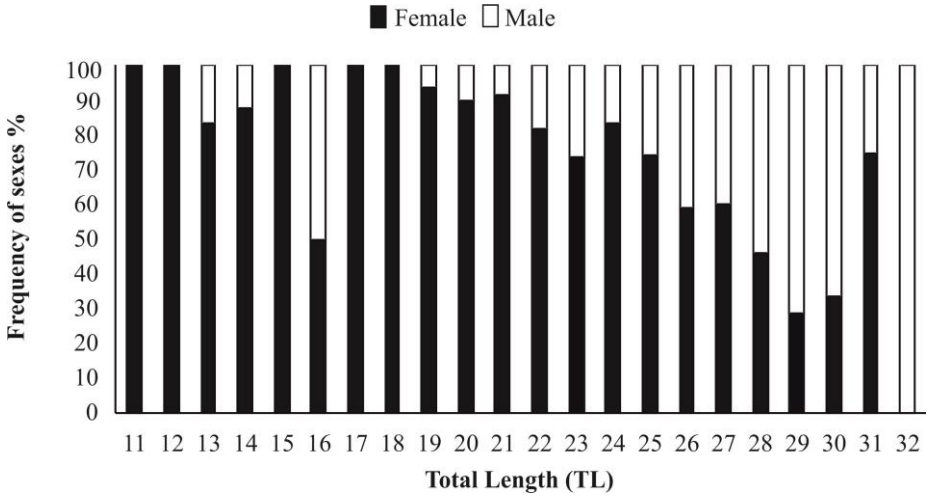


Figure 6. The sex reversal of the Black Seabream, *Spondyliosoma cantharus* according to length.

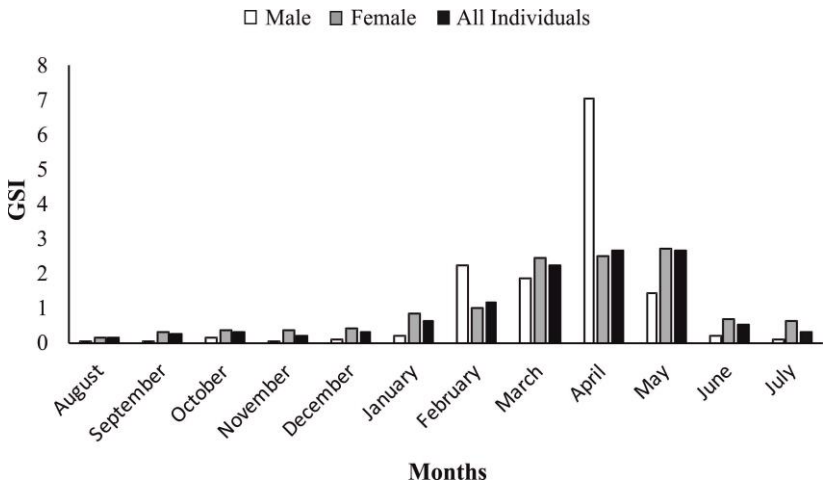


Figure 7. Temporal variations of the gonadosomatic Index (GSI) of the Black Seabream, *Spondyliosoma cantharus*

2.3648. For all individuals, instantaneous total mortality (Z) and natural mortality (M) were determined as 0.64 and 0.47 per year, respectively. The fishing mortality (F) was calculated as 0.17 per year and exploitation rate (E) was 0.27 per year.

Reproductive Biology

Of all specimens examined, 272 (77.7%) were females and 78 (22.3%) were males. The sex of the remaining 5 fish could not be identified macroscopically because they were immature with very thin and translucent gonads. Thus, the overall ratio of female to male was determined as 3.49:1 ($\chi 2$ test, $p<0,05$, N=350). The sex ratio were statistically different in April and May compared to other months due to the disappearance of male individuals. Females predominated in smaller size intervals and males had larger sizes. The males dominated the 28 cm TL and larger length groups with 71% of total individual number. The sexes of two individuals larger than 32 cm TL were male. The sex reversal occurred after 24 cm TL (Figure 6).

Highest condition factor (CF) values were determined in February and March for males and October for females. The minimum gonadosomatic index (GSI) values were observed between June and December for males, females and all individuals, whereas the highest monthly GSI values were found between March and May for females and April for males (Figure 7). Mature gonads (4th stage) were found between February and May for males. The greatest number of mature females were observed in March and April (Figure 8). According to the CF, GSI values and the timing of mature individuals, the spawning season of *S. cantharus* was estimated to be between February and May, peaking from March to April. First sexual maturity

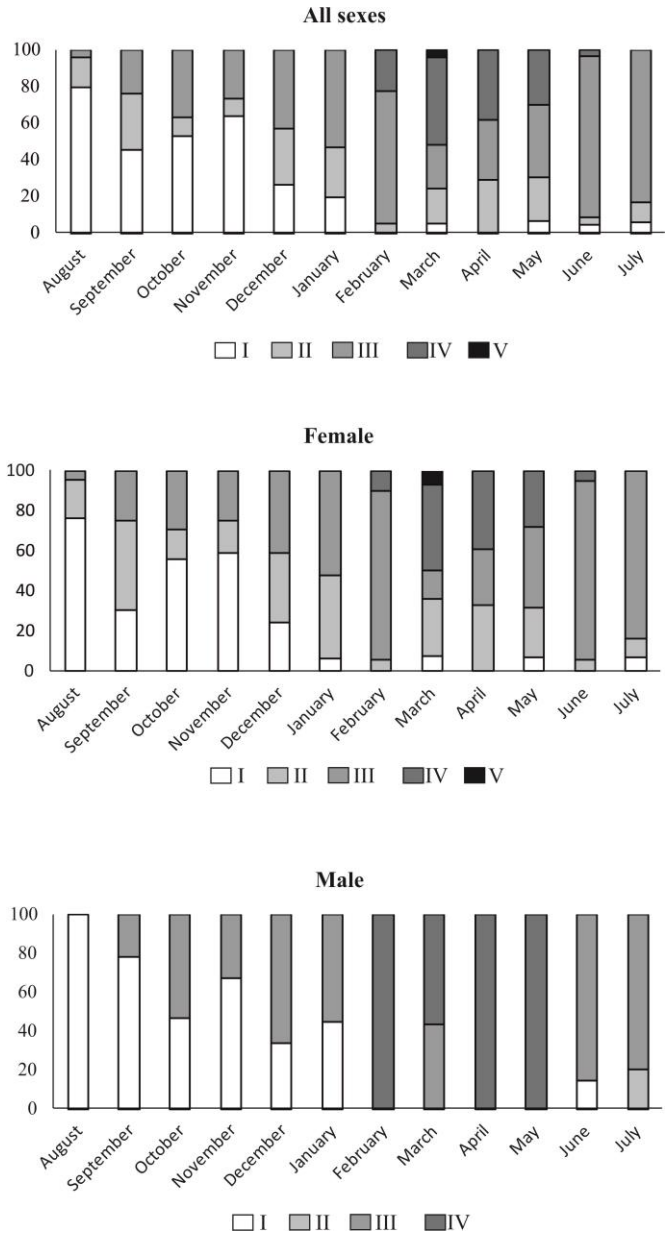


Figure 8. Monthly percentage of each maturity stage for males, females and all sexes of Northern Aegean Sea population of the Black Seabream, *Spondyliosoma cantharus*. I: Immature, II: Maturing, III: Mature, IV: Spawning, V: Post-Spawning

length was determined as 22.25 cm TL for males and 20.59 cm TL for females.

In total, absolute fecundity of black seabream ranged from 59,666 to 182,589, with a mean of 109,457±8,011. Linear relationships were found between absolute fecundity – total length (F=15912TL-273828; r^2=0.73), absolute fecundity – total weight (F=593.91TW-25705; r^2=0.86) and absolute fecundity – age (F=26271t+1624.5; r^2=0.77) (Figure 9).

Discussion

As in many Sparidae fish species, strong linear relationships were found between the total length and fork length. The results for length-weight relationship and growth type of black seabream are summarized and compared in Table 3. Positive allometric growth was found in 8 of 15 studies, which included rather different geographical areas. Although the eastern

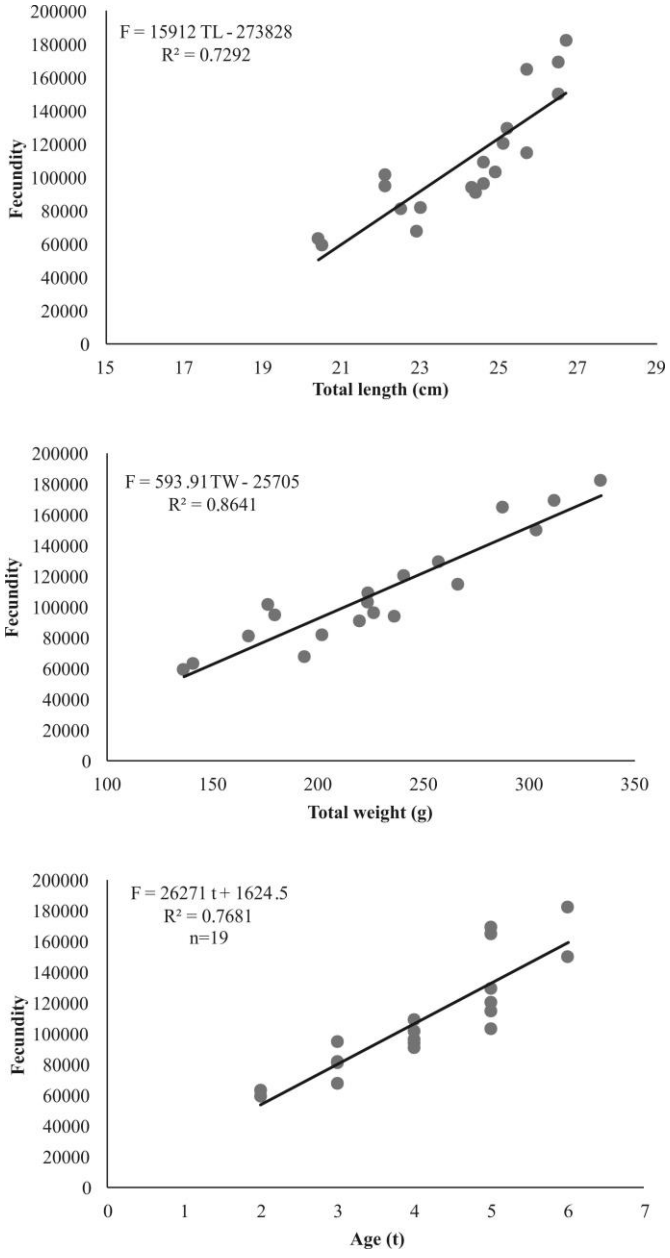


Figure 9. Fecundity-length, fecundity-weight and fecundity-age relationship of the Black Seabream, Spondyliosoma cantharus

Table 1. The length – weight relationship parameters of the Black Seabream, *Spondyliosoma cantharus.*

	Number of Specimen (n)	a	%95 Cl a		b	%95 Cl b		F	r^2	Growth
Female	272	0.0145	0.0118	0.0179	3.0075	2.941	3.074	7922.5	0.97	I
Male	78	0.0102	0.0058	0.0177	3.1273	2.955	3.299	1307.3	0.95	A(+)
All individuals	355	0.0123	0.0103	0.0149	3.0614	3.003	3.120	10577.5	0.97	A(+)

Mediterranean is stated to be one of the most unproductive areas in the world (Isari et al., 2008), the northeastern part of the Aegean Sea is considered to be the most productive area due to proximity with the Dardanelles, which enriches the area with discharge of low saline and temperate waters from the Black Sea. Isometric growth was detected in many studies for females due to the fact that they use most of their energy for reproductive activity.

As seen in Table 4, the growth coefficient in most studies was low, with the exception of the study conducted around the Gulf of Annaba (Boughamou et al., 2015). The K value of Boughamou et al. (2015) was relatively different from the studies conducted in nearby areas (Mouine-Oueslati et al., 2015; Bradai et al., 1998). Thus, it can be said that black seabream is a slow-growing fish species. According to age-length data from previous studies, 8 years maximum age with 32.1 cm TL in the present study coincided with most other studies. Among all studies, the findings of Neves et al. (2017) were distinctly different from others. This difference may be related to the aging method or inability to distinguish false rings arising from older ages. The asymptotic length (L_∞) was found to be slightly higher (33.2 cm TL) than the maximum length (32.1 cm TL) in the present work. The asymptotic length (L_∞) calculated in this study was slightly lower, whereas the growth performance index was more similar compared to those from other areas (Table 4). This difference may be due to the lack of larger individuals and size range of the sampled fish (Mouine et al., 2010). The results for total mortality rates are consistent with the findings of Neves et al. (2017), and lower than the findings of Pajuelo and Lorenzo (1999). This may be related with varied fishing efforts between the areas due to different fishing mortality rates occurred. If considered specifically, the number of fishing vessels using handline and longline around the Turkish coasts of the North Aegean Sea may be less than other regions, especially the western Mediterranean and the Canary Islands. The fishing effort mostly focuses on gillnets and bottom trawl in the area. Thus, limited fishing pressure may have contributed to this result.

Table 5 shows that the sex ratio was relatively higher in favour of females in most of the studies. The biggest difference between the sexes was found by Mouine et al. (2011) as 22:1 (female:male) among the previous studies. The authors found that the sex ratio became equal after than 27 cm TL, which represented with only 5.5% of the total number of individuals. This may be a result of proterogynous hermaphroditism (Bauchot & Hureau, 1986). The differences in ratio between sexes is mostly related to the length interval of the data set. Sex inversion was found at 24 cm TL by Gonçalves & Erzini (2000), Balgueras et al. (1993) and in this study. However, Mouine et al. (2011) detected this value as 18.8 cm TL, in a data set comprising mostly smaller individuals. Although it seems like a handicap to have a small number of individuals from the largest size group in the data set of this study for determining the length where the sex becomes completely male, similar results were seen in previous studies in which larger individuals were included, confirming the finding that the stock becomes completely male after 32 cm TL.

Between all previous results on species biology, the most similar findings were determined in terms of spawning season. Almost all studies mentioned that spawning occurred between February and May, peaking from March to April (Table 5). Spawning occurred earlier only in a single study conducted around the Canary

Table 2. Age - length key of the Black Seabream, *Spondyliosoma cantharus*. (I: Immature, F: Female, M: Male)

	Age (t)																			
	0			1			2		3		4		5		6		7		8	
Sex / Length (TL)	I	F	M	I	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
11	2																			
12				3	3		1													
13					5	1														
14					5	1	2													
15					2															
16					1			1												
17					1		2													
18							6		1											
19							8	1	7											
20							10	2	17	1										
21							7		20	3	5									
22									19	6	15	2	2							
23									9	4	16	4	4	1						
24											16	2	24	5		1				
25											4		13	2	7	4		1		
26													6	6	8	4	2	1		
27													1	1	8	2	3	5		
28															1	1	4	4	1	2
29															2	1		4		
30																	1	1		1
31																	1	1	2	
32																				2
Total	2			22			40		87		64		65		39		28		8	

Table 3. Comparision of length–weight relationship of Black Seabream with previous studies.

Authors	Year	Region	Sex	N	Length Interval (TL;cm)	Weight Interval (g)	a	b	r^2	Growth
Karakulak et al.	2006	North-eastern Aegean Sea	Both	46	8.2 - 28.7		0.0192	2.87	0.89	I
Crec'hriou et al.	2012	French Catalan Coast	Both	18	19.0 - 45.0	125 - 1845	0.010	3.20	0.95	*
Kapiris & Klaoudatos	2011	Central Aegean Sea	F	12	13.8 - 17.1	40 - 79	0.00002	2.94	0.96	*
			M	24	13.3 - 15.2	37 - 56	0.000005	3.20	0.98	A (+)
			Both	36	12.7 - 15.4	37 - 79	0.00001	3.0	0.96	I
Cengiz	2013	Gallipoli Peninsula &Dardanelles	Both	156	9.4 - 31.7	13 - 659	0.0083	3.26	0.97	A (+)
Cengiz	2021	Northern Aegean Sea	Both	31	20.0 - 41.0	125 - 1050	0.0263	2.82	0.95	A (-)
Pajuelo & Lorenzo	1999	Canary Island, Atlantic	F	608	12.0 - 40.0	*	0.00714	3.25	0.97	A (+)
			M	278	18.0 - 40.0	*	0.00556	3.34	0.96	A (+)
			Both	1276	12.0 - 40.0	*	0.00732	3.25	0.99	A (+)
Mouine-Oueslati et al.	2015	Gulf of Tunis	F	330	13.4 - 31.6	39 - 564	0.012	3.09	0.99	I
			M	15	16.0 - 36.6	72 - 806	0.012	3.09	0.98	A (+)
			Both	369	13.4 - 36.6	39 - 806	0.012	3.10	0.99	A (+)
Karachle&Stergiou	2008	North Aegean Sea	F	40	9.7 - 14.0	*	0.0240	2.83	0.96	*
			M	42	9.8 - 13.5	*	0.0216	2.88	0.97	*
			Both	82	9.7 - 14.0	*	0.0224	2.86	0.97	*
Özaydın et al.	2007	İzmir Bay, Aegean Sea	Both	66	8.4 - 18.5 (FL)	*	0.0192	3.05	0.99	*
Boughamou et al.	2015	Gulf of Annaba (Algeria)	Both	501	13.4 - 40.0	36 - 1080	0.000044	3.23	0.96	A (+)
Espino et al.	2016	Canary Islands	Both	174	1.0 - 25.0	*	0.0120	3.09	0.99	A (+)
Dimitriadis& Fournari-Konstantinidou	2018	Southern Ionian Sea	Both	101	11.0 - 36.0	20 - 710	0.014	3.03	0.99	I
Gonçalves et al.	1997	Southern Portugal	Both	586	14.5 - 34.8	*	0.000020	2.95	0.96	
		Southwestern Portugal	Both	886	19.0 - 37.0	*	0.000009	3.07	0.88	
Neves et al.	2017	Peniche, Portugal	Both	758	2.6 – 38.0	0.19- 841	0.0073	3.19	0.99	A(+)
This Study	2021	North Aegean Sea	F	272	11.2 -31.4	11 - 614	0.01372	3.02	0.90	I
			M	78	13.7 -32.1	11 - 431	0.01017	3.13	0.95	A(+)
			Both	355	11.2-32.1	39 - 614	0.01171	3.08	0.92	A(+)

Table 4. Comparison of population parameters of the Black Seabream with previous studies.

Researcher	Region	Method	n	Length Interval (TL;cm)	Z	F	M	Max Age (t)	L_∞ (cm)	K ($year^{-1}$)	t_0	Phi Prime (φ)
Pajuelo & Lorenzo (1999)	Canary Island	Otolith	1272	8.0 - 40.0	1.36	0.84	0.52	10	43.35	0.24	-0.11	2.65
Mouine-Oueslati et al. (2015)	Gulf of Tunis	Otolith	366	13.4 -36.6	*	*	*	10	38.61	0.10	-1.14	2.17
Dulcic & Kraljevic (1996)	Adriatic	Scale	745	6.2 - 46.5	*	*	*	14	47.70	0.18	-0.27	2.61
Neves et al. (2017)	Peniche, Portugal	Otolith	535	2.8 - 38.0	0.65	0.37	0.28	17	40.66	0.12	-1.26	2.40
Boughamou et al. (2015)	Gulf of Annaba	Otolith	373	13.0 - 36.0	*	*	*	7	33.54	0.52	-0.04	2.76
Bradai et al. (1998)	Gulf of Gabes	Scale	109	8.3 - 27.0	*	*	*	6	35.73	0.14	-1.42	2.26
Abecasis et al. (2008)	Southern Potrugal	Scale	378	5.0 - 35.0	*	*	*	11	34.48	0.21	-1.22	2.41
		Otolith	905	4.0 - 40. 0	*	*	*	13	30.32	0.26	-1.20	2.37
This Study	North Aegean Sea	Scale	355	11.2 - 32.1	0.64	0.17	0.47	8	33.21	0.21	-1.84	2.37

Table 5. Comparison of reproduction parameters of the Black Seabream with previous studies (F: female, M: male; L_{50}: First sexual maturity length).

Researcher	Region	Sex Ratio (F/M)	Spawning Time	Peak Spawning	L_{50}	Fecundity
Pajuelo & Lorenzo (1999)	Canary Island, Atlantic	2.18:1	Autumn - Spring	January - February	F=17.3 M=22.7	*
Boughamou et al. (2015)	Gulf of Annaba (Algeria)	5.68:1	February-May	April	F=19.3 M=21.3	*
Mouine et al. (2011)	Gulf of Tunis	22:1	January -May	March - April	F=17.8	*
Gonçalves & Erzini (2000)	Portugal	2.28:1	February - April	March	F=19.98 M=22.41	37 506 - 112 074 (Mean=61 396)
Neves et al. (2018)	Western Portugal	1.66:1	February - May	March - April	F=18.41	5 041 - 95 398 (Mean= 42 513)
Dulcic et al. (1998)	Crotian Coasts					31 670 - 554 070
Balgueras et al. (1993)	Saharan Bank, Eastern Adriatic					36 926 - 143 900 (Mean=65 659)
This Study	North Aegean Sea	3.49:1	February - May	March - April	F=20.59 M=22.25	59 666 - 182 589 (Mean=109 457)

Islands (Pajuelo & Lorenzo, 1999). Wootton (1998) reported that the most influential variable on the spawning season of fish is different sea water characteristics between regions. The variation in spawning seasons between the results of Pajuelo & Lorenzo (1999) and this study may arise due to different water characteristics in the Atlantic and Northeastern Aegean Sea. Such a distinct range of seasonality for spawning was thought to indicate that the species requires very specific conditions for reproduction, especially in terms of water temperature. In the study area, sea surface temperature was measured between 12 and 14.4 °C (Daban et al., 2020) in March and April, when the spawning of black seabream peaked. The species was observed to spawn during early spring as with many teleost fish distributed in the Mediterranean (Tsikliras et al., 2010). The period of spawning ensures optimum conditions for growth and survival of black seabream in the early life stages; thus, they encounter lower mortality rates in this critical stage (Winemiller & Rose, 1992). Among Sparidae species, black seabreams were observed to reproduce later than *Sparus aurata* and *Diplodus vulgaris* but earlier than *Dentex macropthalmus* and *Pagellus acarne.* The reproduction period of the black sea bream coincided with those of *Diplodus sargus* and *Boops boops* (Soykan et al., 2015; Mehanna, 2007).

Male black seabream individuals reached first sexual maturity length at a larger size than females. The results of sexual maturity length coincided with the results of the previous studies (Table 5). This situation was reported for some protogynic hermaphrodite Sparidae species such as *Dentex macrophthalmus* (Soykan et al., 2015) and *Pagellus erythrinus* (Zarrad et al., 2010; Pajuelo & Lorenzo, 1998).

The mean absolute fecundity in the present study was higher than the previous studies completed around the eastern Mediterranean (Gonçalves & Erzini, 2000; Neves et al., 2018; Balgueras et al., 1993). Dulcic et al. (1998) found more total eggs per female (554,070). These differences may stem from the oocyte size threshold; the authors calculated fecundity from 0.20 to 0.80 mm oocyte diameter. In the present study, the oocyte size threshold was applied according to Balgueras et al. (1993), which was above 0.50 mm. The comparison of fecundity results cn between this study and Balgueras et al. (1993) may be more compatible due using similar methods. As in many studies, fecundity increased with the increases in the length, weight and age. Boufekane et al. (2021) revealed the mean absolute fecundity of co-occuring Sparidae species, *Diplodus sargus,* as 186,570±5,990, similar to our study.

Conclusion

The minimum landing size of black seabream was given as 23 cm TL, as ruled by Portuguese fishery and northwestern Inshore Fisheries and Conservation Authority. However, no valid data were found in EU technical regulations (Collins & Mallinson, 2012) and for Turkey. The length at first sexual maturity in the present study was determined as 20.59 and 22.25 cm TL for females and males, respectively. As seen in Table 5, in order to protect sexually mature males, the minimum landing size must be greater than 23 cm TL, which is the limit value just above the length at first sexual maturity. Due to male guarding behaviour of fertilized eggs on the nests around shallower (9-23 m depths) gravel substrates (Collins & Mallinson, 2012), male individuals are affected most by the fishing effort. In protogynous hermaphrodite species such as black seabream, since all of the larger individuals are male, it poses a negative situation such as sperm limitation (Alonzo & Mangel, 2004; Neves et al., 2017) in the case of stock collapse. Since longlines and handlines are extensively used in the commercial fishing of the black seabream, the selectivity parameters could be easily arranged in order to avoid catching fish that have not reached sexual maturity. According to purse seine regulations in communique no. 2020/39 on the regulation of commercial fishing in Turkey, purse seine fishing shall be performed deeper than 24 m. This depth may be a potential issue for management implementations due to damage to nesting sites of black seabream.

The results of the present study revealed the first findings around the eastern Mediterranean, which may be useful for fisheries management authorities and researchers.

Ethical Statement

Ethics committee certificate was not requested since experimental animals were not used in the study and sampling was made in the form of dead fish from the fishermen.

Funding Information

This work was supported by the Scientific Research Projects Coordination Unit of Çanakkale Onsekiz Mart University, Project number: FBA-2020-3295.

Author Contribution

This article was written by a single author.

Conflict of Interest

The author declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors thank Gençtan Erman Uğur and Buminhan Burkay Selçuk for their valuable help during the laboratory study. This work was supported by the Scientific Research Projects Coordination Unit of Çanakkale Onsekiz Mart University, Project number: FBA-2020-3295.

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