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Biological parameters of grey wrasse *Symphodus cinereus* (Bonnaterre, 1788) (Pisces: Labridae) along the coasts of Rize in the south-eastern Black Sea

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Abstract

The present study was designed to investigate the age distribution and growth properties of *Symphodus cinereus* in the south-eastern Black Sea. Data on the growth and age of *S. cinereus* were obtained by investigating sagittal otoliths. A total of 384 specimens (220 female, 164 male) were collected between June 2015 and May 2016 in the south-eastern Black Sea. Total lengths of male specimens ranged from 10–16.4 cm, whereas they ranged from 8.2–15.8 cm for females. The von Bertalanffy growth curve was used to describe length at age and considerable differences were seen between females ($t_0 = -2.85$, $k = 0.296$ and $L_\infty = 16.46$ cm) and males ($t_0 = -2.84$, $k = 0.272$ and $L_\infty = 17.23$ cm). The maximum age was 5 years. The relationship for males was $W = 0.009L^{3.2596}$ ($r^2 = 0.9174$, $P < 0.005$) and that for females was $W = 0.0011L^{3.1821}$ ($r^2 = 0.9012$, $P < 0.005$). While the highest condition (K) value was calculated in spring, the lowest value was determined in winter for both sexes. The obtained data also revealed monthly changes in the gonadosomatic index and maturity stages of male and female specimens, and the annual spawning season of this population began in March and ended in June. Fecundity ranged between 1375 and 5493 eggs/individual (mean: 2868.11 ± 36–59.69 eggs), and the relationship between total length and egg production was highly statistically significant ($P < 0.0001$). This study provides the first data on the growth and reproduction of *S. cinereus* along the south-eastern Black Sea coast of Turkey.

Introduction

Labridae is a large family with eight species living in the Black Sea (Keskin, 2010), 20 species along the Turkish coasts (Bilecenoğlu *et al.*, 2014) and 594 species around the world (Parenti & Randall, 2011). Labrids, or wrasses, are small territorial marine fishes inhabiting algal and rocky inshore areas (Costello, 1991). The species of the labrid genus *Symphodus* are found at depths of 1–50 m, inhabiting eelgrass beds and rocky areas in the Mediterranean, Eastern Atlantic and Black Sea. Sexual dimorphism and sex reversal can be seen in some species of *Symphodus* (Whitehead *et al.*, 1986). However, it was reported that sex reversal does not occur in *Symphodus cinereus* (Bonnaterre, 1788) (Remacle, 1970). *Symphodus cinereus* generally aggregates in eelgrass beds and littoral areas, but these fish are occasionally found on soft bottoms (1–20 m); they are frequently present in lagoons and estuaries with abundant vegetation and detritus. They feed on small gastropods, isopods, amphipods, shrimps and bivalves. The males guard the females during spawning in built nests (Whitehead *et al.*, 1986). The males of the genus *Symphodus*, which build and guard nests, defend their territory against other species and protect demersal eggs until hatching, expend significant energy on reproduction (Warner & Lejeune, 1985; Taborsky, 1998). The wrasse is not considered a commercial fish in the Black Sea. It is generally caught and discarded by small-scale commercial fisheries. As a result, similarly to many other non-commercial species, insufficient information is available about the biology of *S. cinereus.* The first study reporting the general characteristics of the species was conducted in the Mediterranean by Quignard & Pras (1986). Subsequently, Ghorbel-Ouannes & Bouain (2001) reported age and growth characteristics and Ghorbel-Ouannes *et al.* (2007) reported the reproductive biology of the species from the Gulf of Gabes (Tunisia). Apart from these studies, information about the growth characteristics of *S. cinereus* is limited. The present study is the first detailed study conducted in the south-eastern Black Sea with the aim of revealing basic biological parameters such as the sex ratio, growth properties, age distribution, spawning period, fecundity, condition factor and length-weight relationship (LWR) of *S. cinereus.* It is expected that the findings will fill an important gap in the literature and provide a better understanding of the life history of this species.

Materials and methods

Fish sampling

Samples were obtained from fishermen engaged in commercial fishing. A total of 384 specimens (164 male and 220 female) of *S. cinereus* were collected between June 2015 and May 2016 with trammel nets of 36-mm and 40-mm mesh size settled at depths of 10–40 m off the coast of Rize, Turkey, in the south-eastern Black Sea (Figure 1). The collected samples were carried to the laboratory and length (accuracy of 0.1 cm), total weight (accuracy of 0.001 g) and gonad weight (accuracy of 0.001 g) were measured. The specimens were dissected and sagittal otoliths were removed.

Length-weight relationship (LWR)

The LWR of the samples was determined by applying the formula $W = aL^b$ (Ricker, 1975), where L is total length (cm), a is the intercept, b is the slope and W is total weight (g). The degree of association between variables was computed with r^2 values (King, 1995) (Figure 2). The variation of the b value from $b = 3$ (isometric growth) was tested with the one-sample t-test, and Pauly's t-test was used for comparisons of the differences of slope values from $b = 3$ (Pauly, 1984).

Age determination

For age determination, the otoliths of the 384 collected fish were removed and cleaned of blood and tissues, and then they were stored in Eppendorf tubes containing 96% alcohol. Age was determined by counting the number of opaque and transparent parts with the help of light reflected on the sagittal otoliths. Otoliths were imaged with a Nikon SMZ1000 stereomicroscope connected to a Nikon SMZ1000 digital camera with magnification from 0.8× to 8.0× (Figure 3). Ages were determined by a single reader.

Growth

Size frequency

The monthly size frequency distributions of female and male specimens were calculated at class intervals of 0.5 cm for total length. The Kolmogorov–Smirnov two-sample test was applied to analyse size frequency distributions for females and males and t-tests were used to compare mean total lengths between females and males. The χ^2 test was used to calculate the sex ratio and data were recorded as male:female ratios. Deviations from 1:1 were tested using χ^2 analysis (Dagnelie, 1991).

Growth model

The von Bertalanffy growth equation was used to calculate growth in both weight and length (King, 1995; Sparre & Venema, 1998). The age-length relationship is expressed as $L_t = L_\infty[1-e^{-k\,(t-t0)}]$, as explained in the Ford–Walford method of Sparre & Venema (1992). In this formula, t represents time (or age), L_t represents length at age t (cm), L_∞ represents the asymptotic average length (cm), k is the growth rate parameter (year^{-1}) and t_0 is the theoretical age when the fish would have been at zero total length. The growth performance index (Φ') was calculated as $\Phi' = \log(K) + 2\log(L_\infty)$ for comparisons of growth performance (Pauly & Munro, 1984).

Condition factor (K)

To compare the conditions of sampled fish from different periods or locations, a single LWR for all fish from all periods and locations was used to estimate aL^b. The index was calculated as $K = W/aL^b$, where K is Le Cren's condition factor, W is the gutted weight (g), L is the total length (cm) and a and b are constants of the model (Le Cren, 1951).

Gonad maturity, spawning time and fecundity

Sex was recorded for all specimens and the wet weight of the gonads and liver were obtained to the nearest 0.01 g. Monthly values of the gonadosomatic index (GSI), calculated as $GSI = W_{gonad}/W_{fish} \times 100$, were obtained for both females and males

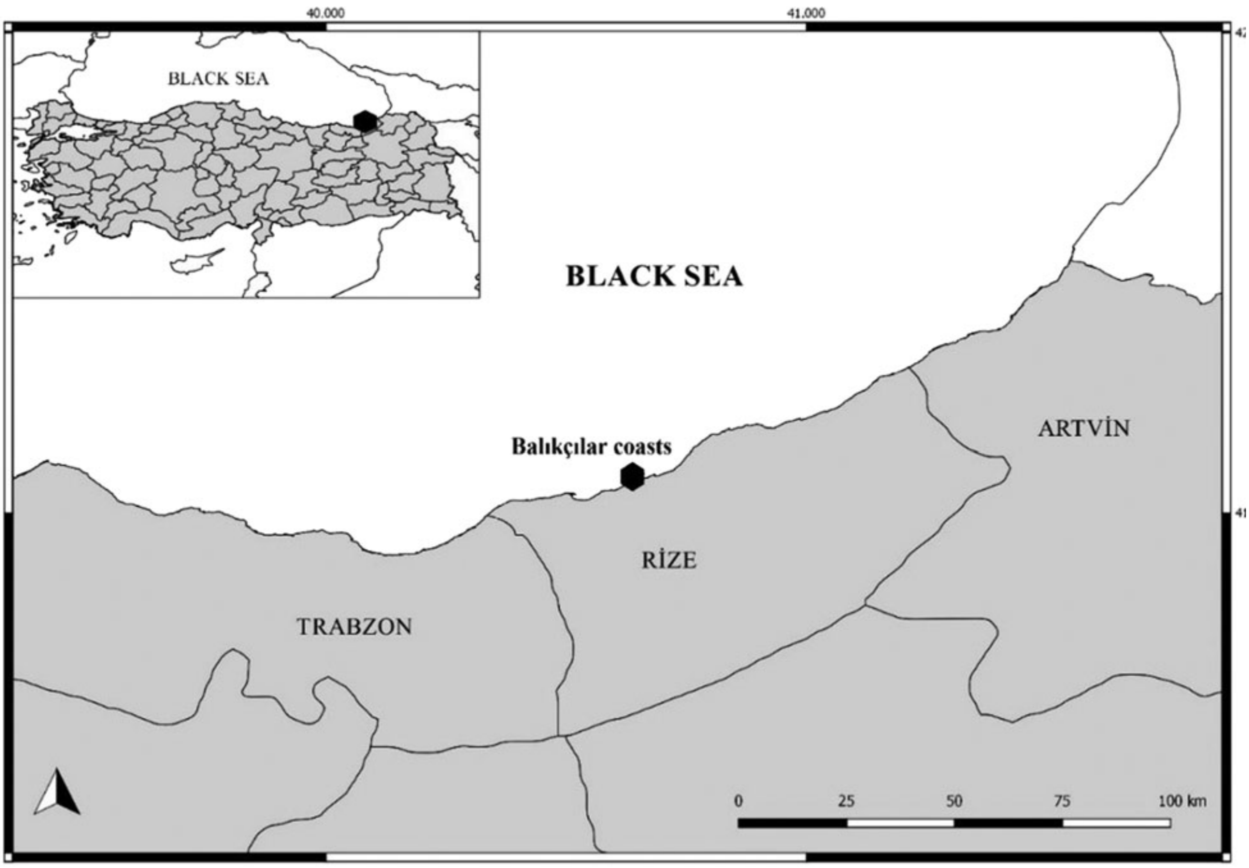

Fig. 1. Study area.

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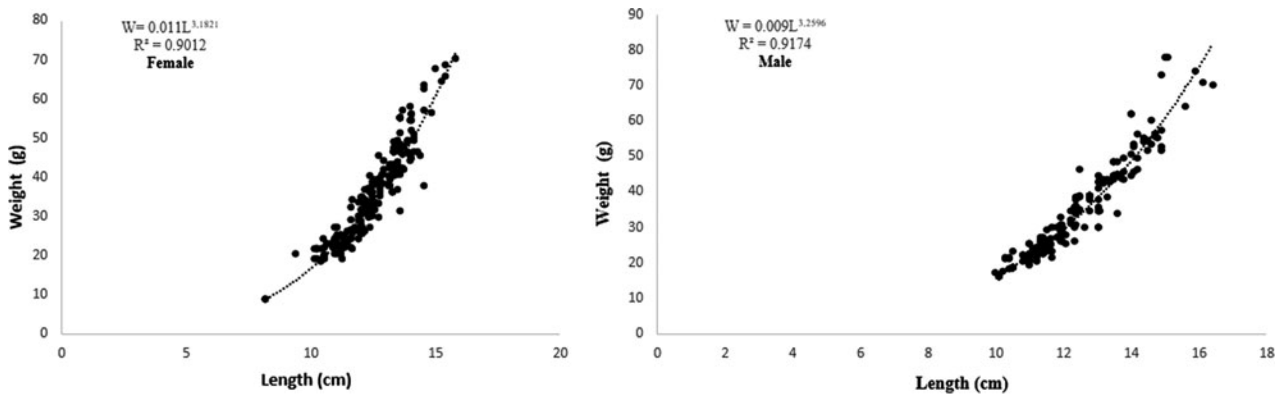

Fig. 2. Length-weight relationships by sex of *Symphodus cinereus.*

(Avşar, 2005). In this equation, W_{gonad} is gonad weight (g) and W_{fish} is body weight (g). According to their macroscopic characteristics, the ovarian tissues of the fish were categorized as belonging to one of the following five maturity stages (Hostetter & Munroe, 1993): 5, spent; 4, spawning; 3, ripe; 2, developing; 1, resting. A total of 11 mature ovaries (4th stage) were used for evaluations of fecundity. Mature ovaries were placed in plastic cups of 50 ml and Gilson's fluid solution was added to cover the ovaries. Samples were then shaken at intervals for 15 days and the eggs separated from the membranes. Total fecundity was calculated according to Ismen (1995) using log-transformed fecundity and length data as follows: $\text{Log}(F) = a + b \times \log(\text{TL})$, where a and b are the slope of the regression line, TL is total length (cm) and F is total fecundity.

Results

Composition by sex and sex ratio

A total of 384 grey wrasse (220 female and 164 male) were sampled between June 2015 and May 2016. Total length ranged between 8.2–16.4 cm (mean: 12.4 ± 0.06 cm) for all individuals; it was 10–16.4 cm (mean: 12.4 ± 0.10 cm) for male fish and 8.2–15.8 cm (mean: 12.46 ± 0.06 cm) for female fish (Figure 4). Total weight ranged between 8.51–77.49 g (mean: 35.28 ± 0.65 g) for all individuals; it was 15.54–77.49 g (mean: 35.57 ± 0.010 g) for males and 8.51–70.2 g (mean: 35.07 ± 0.086 g) for females. There were no significant differences in size frequency distributions between females and males (Kolmogorov–Smirnov two-sample test: $d = 0.699$, $P < 0.001$). The overall sex ratio (male: female) was 1.34:1, differing significantly from the expected value of 1:1 ($\chi^2 = 8.167$, $P > 0.05$) according to the results of the χ^2 test. Numbers of *S. cinereus* specimens collected per month by sex are shown in Table 1. No female specimens were identified in December.

Length-weight relationship (LWR)

The LWR was calculated for a total of 384 specimens including 220 females and 164 males. The exponent (b) of the LWR was estimated to be 3.1821 for females and 3.2596 for males. The parameters of

Fig. 3. A sagittal otolith of 5-year-old *Symphodus cinereus.*

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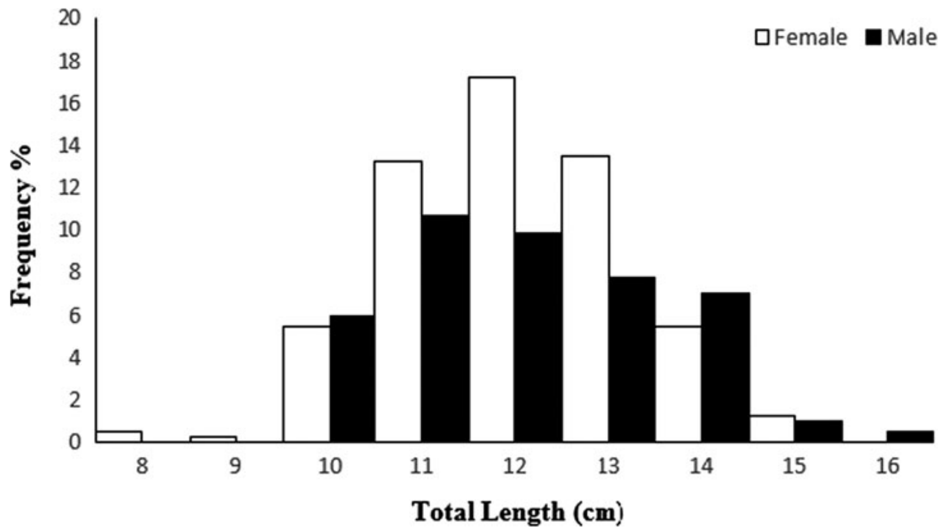

Fig. 4. Length-frequency distribution by sex of *Symphodus cinereus.*

Table 1. Number of specimens by sex and combined sexes collected per month of *S. cinereus* in the south-eastern Black Sea

Months	*J*	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*	All
Female	0	12	10	15	15	43	38	46	16	12	13	0	220
Male	0	3	11	13	13	43	22	18	8	12	5	16	164
All	0	15	21	28	28	86	60	60	24	24	18	16	384

Table 2. Age–length key of males and female of *Symphodus cinereus* in the south-eastern Black Sea

	Age											
Length (cm)	Female						Male					
	0	1	2	3	4	5	0	1	2	3	4	Total
8.5	2											2
9												0
9.5	1											1
10							1					1
10.5	3	7					3	15				28
11		17						10				27
11.5		24	3					21				48
12		12	10					14	9			45
12.5		15	25	2				6	13			61
13			20	3					15	3		41
13.5			18	11					9	4		42
14				25		1				5	7	38
14.5					11					1	9	21
15						6					14	20
15.5						3					1	4
16						1					2	3
16.5											2	2
Total	6	75	76	41	11	11	4	66	46	13	35	384

the LWR for each sex are shown in Figure 2. The relationship for males was $W = 0.009L^{3.2596}$ ($r^2 = 0.9174$, $P < 0.005$) and that for females was $W = 0.0011L^{3.1821}$ ($r^2 = 0.9012$, $P < 0.005$).

According to Froese (2006), if $b = 3$, it demonstrates that the specimens have an isometric growth. If $b > 3$, fish are heavier and have positive allometric growth. If $b < 3$, fish are thinner

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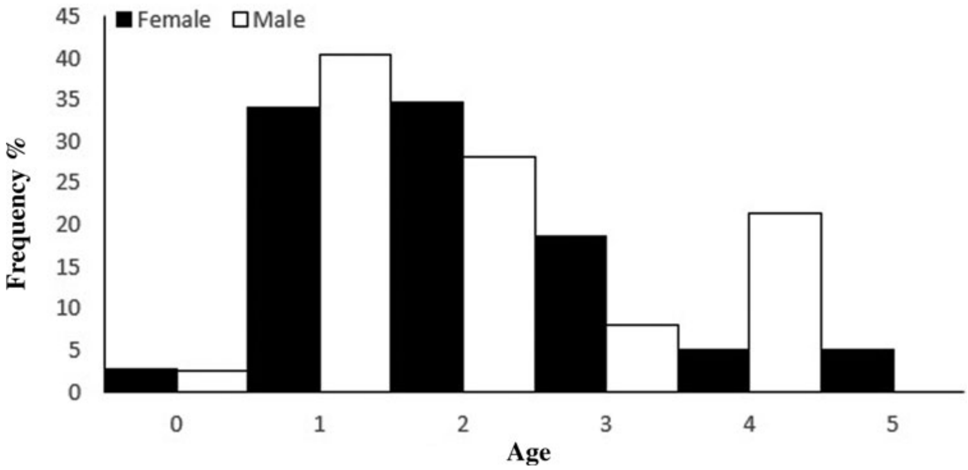

Fig. 5. Age composition of males and females of *Symphodus cinereus.*

Table 3. Von Bertalanffy growth parameters and size of *Symphodus cinereus* in the south-eastern Black Sea

Parameter	L_∞ (cm)	k (year^{-1})	t_o(year)	W_∞	Φ’
Female	16.46	0.296	−2.858	81.788	1.37
Male	17.23	0.272	−2.847	96.45	2.67
All specimens	17.21	0.235	−3.572	95.054	1.84

L_∞, asymptotic total length (cm); *k*, growth rate (year-1); Φ´, growth performance index.

with increasing length, showing a negative allometric growth. Both males and females showed positive allometric growth.

Age composition

Age determination was successfully accomplished for a total of 384 grey wrasse otoliths (164 male and 220 female specimens). Table 2 shows the age-length key for both females and males. Ages ranged between 0 and 5 for females and between 0 and 4 for males. It was concluded that the dominant age group was 2 years for females (34.54%) and 1 year for males (40.24%). In the samples, individuals were found to be mostly between 1 and 2 years of age for both females (68.63%) and males (68.29%) (Figure 5).

Growth model

With the von Bertalanffy growth model, the asymptotic length (L_∞) of males was found to be greater than that of females with estimated L_∞ values of 17.23 cm for males and 16.46 cm for females. On the other hand, the growth rate, *k*, of females was estimated to be higher than that of males. The *k* values were estimated as 0.296 year^{-1} for females and 0.272 year^{-1} for males. The growth performance index, Φ’, derived from the growth model was 1.37 for females and 2.67 for males. These results showed that male grey wrasses had better growth performance than females (Table 3).

Condition factor

Mean seasonal *K* values are shown in Figure 6 according to the sexes. While the highest condition (*K*) value was calculated in spring, the lowest value was determined in winter for both sexes. The highest mean *K* value in the spring was 1.06 for females, whereas it was calculated as 1.03 for males. The lowest mean *K* value in winter was determined as 0.98 for females and 0.93 for males.

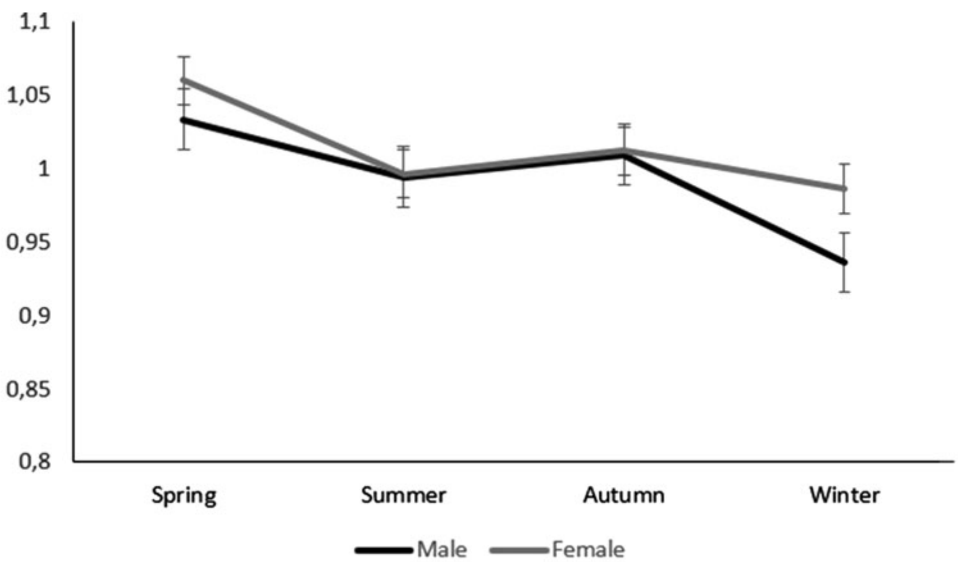

Fig. 6. Seasonal condition factor (*K*) values of all *S. cinereus* in south-east Black Sea.

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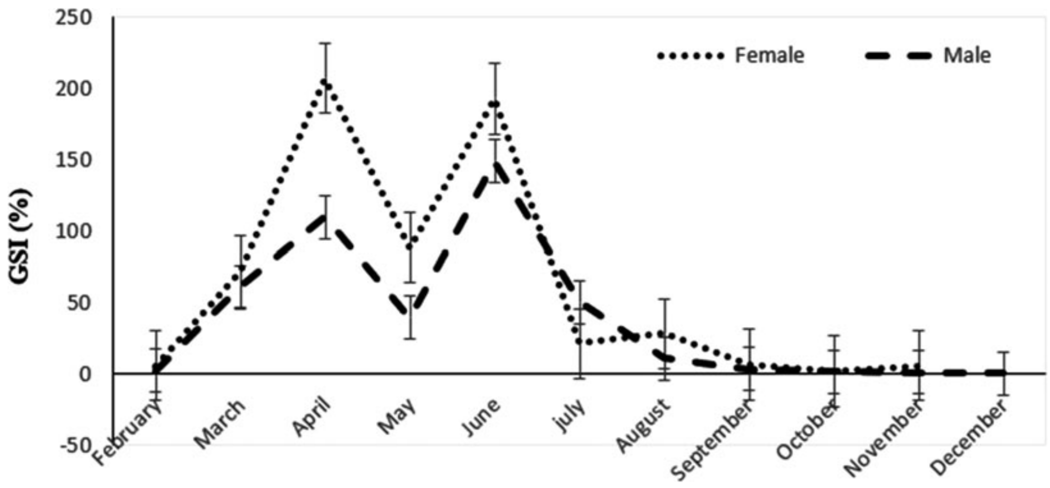

Fig. 7. Monthly gonadosomatic index (GSI) of females, males and all individuals.

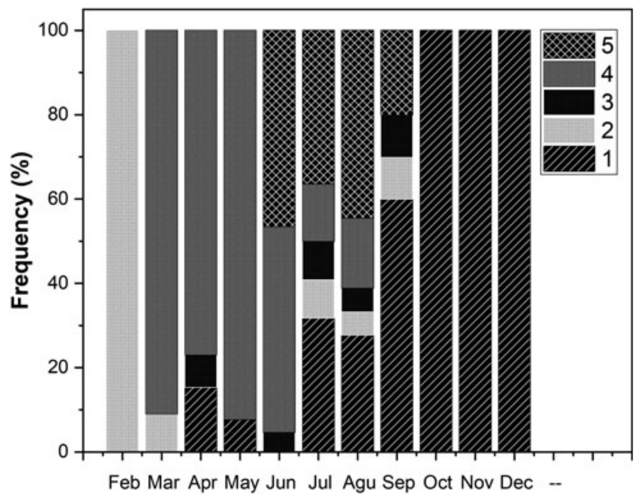

Fig. 8. Percentage rates of monthly gonad stage (1, immature; 2, developing; 3, mature; 4, spawning; 5, spent) of males of *Symphodus cinereus.*

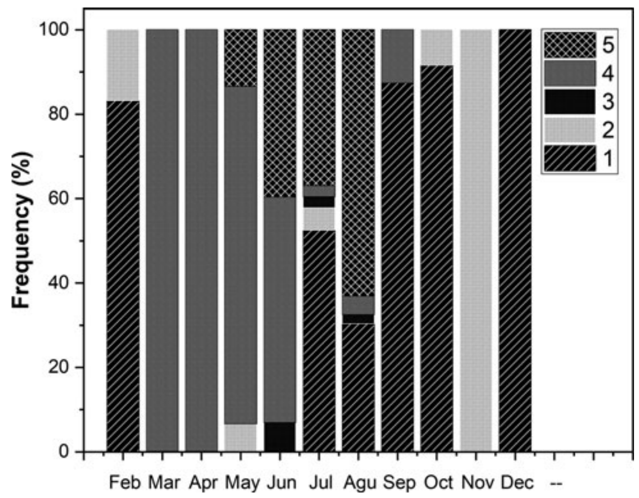

Fig. 9. Percentage rates of monthly gonad stage (1, immature; 2, developing; 3, mature; 4, spawning; 5, spent) of females of *Symphodus cinereus.*

Gonad maturity, spawning time and fecundity

Monthly fluctuations of the GSI for female, male and all sampled *S. cinereus* individuals are shown in Figure 7. The data revealed monthly changes in the GSI and maturity stages of male and female specimens, and the annual spawning season of this population began in March and ended in June. Stage 1 was observed between September and December for males, whereas stage 4 was seen between March and June for both sexes (Figures 8 and 9). The spent stage was observed for females between May and August. In males, the final stage was observed between June and September (Figure 8). Fecundity varied between 1375 and 5493 eggs/individual (mean: 2868.11 ± 36–59.69 eggs), and the relationship between egg production and total length was highly statistically significant ($P < 0.0001$) (Figure 10).

Discussion

Length-weight relationship (LWR)

In Table 4, the findings of other relevant studies in the literature are given. Altın *et al.* (2015) estimated LWR values from a wide range of lengths (1.5–15.8 cm); they reported the maximum length to be 15.8 cm. In the present study, on the other hand, an individual with a length of 16.4 cm was identified and the smallest obtained specimen was 8.2 cm. The *b* values in these previous studies are similar to the *b* value obtained in the present work. In addition, the values of the allometric coefficient '*b*' found in our study agree with the expected range (2.5–3.5) reported by Froese (2006) for teleost fishes. Both in the literature and in this study, *b* values were calculated as $b > 3$, meaning that *S. cinereus* showed positive allometric growth in all studies. Factors such as feeding habits, maturity, health, habitat, season (Tesch, 1968) and differences in the environment (Froese, 2006) can affect LWR values.

Age and growth

The predicted age range in this study was up to 5 years for females and 4 years for males. According to Quignard & Pras (1986), 6 years was the maximum age, whereas it was 4 years in the lagoon of Thau (Quignard, 1966). According to Bach (1985), females reach 11.9 cm in total length and males reach 13.6 cm. In Tunisia, females reach a maximum age of 5 years at 10.8 cm in total length and males reach 6 years at 12 cm in total length (Ouannes Ghorbel & Bouain, 2001). Quignard (1966) and Bach (1985) reported that males as well as females reached the age of 4 years with respective total lengths of 15 and 14 cm in the lagoon of Thau. These differences between ages are likely related to

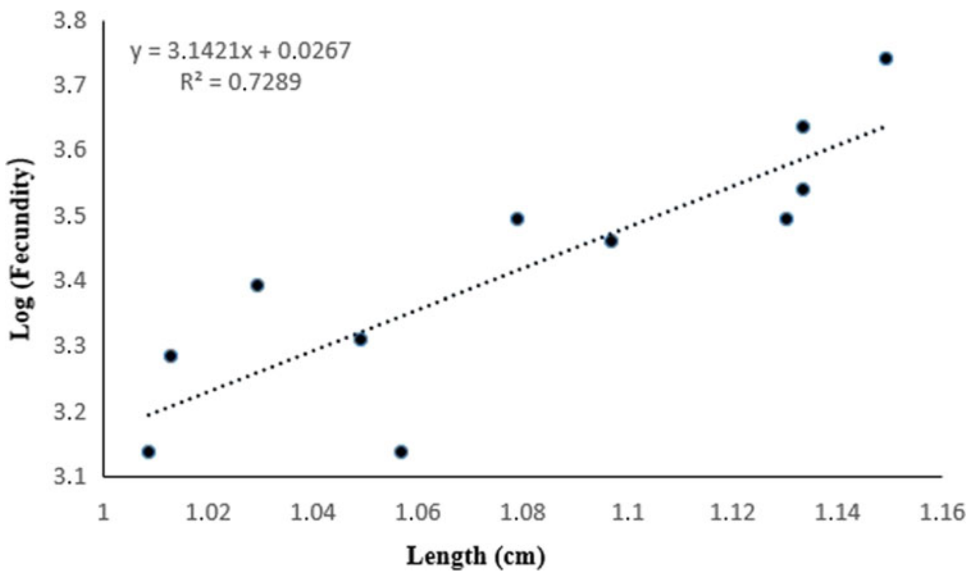

Fig. 10. Fecundity and total length relationships of *Symphodus cinereus* in south-east Black Sea.

Table 4. LWR parameters for *Symphodus cinereus* estimated from other areas

Mediterranean	N	$L_{\text{range (cm)}}$	*a*	*b*	r^2
Valle *et al.* (2003)	665	3.6–15.4	0.010	3.13	0.97
Verdiell-Cubedo *et al.* (2006)	20	4–7	0.011	3.11	0.99
Aegean					
İlkyaz *et al.* (2008)	8	6.6–8.9	0.008	3.26	0.99
İlhan *et al.* (2008)	92	4.5–10.1	0.023	3.03	0.86
Altın *et al.* (2015)	536	1.5–15.8	0.008	3.18	0.96
Marmara Sea					
Keskin & Gaygusuz (2010)	173	2.3–11.3	0.009	3.18	0.99
Black Sea					
This study					
Female	220	8.2–15.8	0.011	3.18	0.90
Male	164	10–16.4	0.009	3.25	0.91

differences in the lengths of sampled fish. Fish growth rate potential of fish may also vary with the environment as a result of changes in food density and water temperature (Tyler, 1998). A limited number of studies have provided relevant sex-based data for this species, as shown in Table 5. In the present study, the L_∞ value of male individuals was higher than that of females. Pauly (1978) and Ghorbel-Ouannes & Bouain (2001), however, estimated the L_∞ values of females to be higher than those of males along the Mediterranean. Ghorbel-Ouannes & Bouain (2001) and Quignard (1966) reported that, at a given age, males are always larger than females. This may be due to differences in oxygen consumption and different rates of maintenance metabolism of the two sexes (Pauly, 1994; Landa *et al.*, 2002). In addition, the L_∞ values reported by other studies as shown in Table 5 were smaller than the values calculated in the present work. The *k* value found here was smaller than that estimated by Kalinina (1963), but it was similar to the values previously reported by Pauly (1978) and Ghorbel-Ouannes & Bouain (2001). Considering the relationships that exist between the various parameters that constitute the growth equation together with their dependence on age, Zivkov *et al.* (1999) suggested that it would be more meaningful to use mean lengths in such comparisons. This is reflected in the larger length distribution obtained in the present study (Table 5). Similarly, *k* values are affected by the time period of sampling as well as the geographic region, and differences may be observed as a result of length and age distributions, as well as different biotic (e.g. presence of predators, prey availability or genetic variations) and abiotic factors (e.g. temperature, salinity levels or habitat structures) (Bilgin *et al.*, 2014). Among all studies of *S. cinereus* published to date in which the von Bertalanffy model was utilized in one of its possible forms, estimated values of t_0 have tended to be non-zero and negative (Table 5). This suggests that the von Bertalanffy model is not capable of providing accurate descriptions of growth for this species in the earliest stages of life (Pajuelo & Lorenzo, 2011). Negative t_0 values are frequently observed for demersal fish species that experience rapid spurts of growth in the first year of life with slower rates of growth in subsequent years (Dwyer *et al.*, 2003; Amaral & Cabral, 2004; Teixeira *et al.*, 2010). The growth performance index (Φ') is applicable for the assessment of growth

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Table 5. Von Bertalanffy growth parameters of grey wrasse, *Symphodus cinereus*. L_∞, asymptotic total length (cm); *K*, growth rate (year^{-1}); Φ´, growth performance index

Reference	Sex	*L* range	L_∞ (cm)	*k* (year^{-1})	t_o (year)	Φ´	Region
Kalinina (1963)	Σ	–	11.2	0.790	–	2.00	Ukraine
Bach (1985)	Σ	–	10.6	0.483	−0.74		France
	♂	–	11.6	0.485	−0.44		
	♀	–	9.6	0.483	−0.74		
Ghorbel-Ouannes & Bouain (2001)	♂	6.6–13.8	11.6	0.449	−0.59	1.78	Tunisia
	♀		14.1	0.265	−1.37	1.72	
Pauly (1978)	♂	3.9–14.1	14.3	0.291	–	1.77	France
	♀	3.5–12	15.5	0.348	–	1.92	
This study	♀	10–16.4	16.4	0.296	−2.85	1.37	Turkey
	♂	8.2–15.8	17.2	0.272	−2.84	2.67	
	Σ	8.2–16.4	17.2	0.235	−3.57	1.84	

under a variety of environmental conditions (Pauly, 1991). The present results for Φ' were comparatively higher than the values reported from previous research. Moreover, Ghorbel-Ouannes & Bouain (2001) found higher Φ' values for male fish than females, similar to the present results, while Pauly (1978) reported higher Φ' values for females. Weatherley & Gill (1987) reported that water temperature had a direct effect on fish growth by affecting the physiology of fish.

Growth rates vary according to the season, annual variations in growth, environmental differences and species (Brandt *et al.*, 1992; Horne *et al.*, 1996; Tyler & Brandt, 2001). In addition, differences between studies might arise as a result of variations in the number of samples, the sampling period and the sampling method. It is also possible that different populations of the same species or individuals of the same population may show variations in different years due to different feeding conditions (Erkoyuncu, 1995).

Condition factor

The condition factors of fish vary depending on growth, reproduction and seasonal food availability (Weatherley & Gill, 1987). A healthy population should have high growth and survival rates and display good reproductive potential (Vassilopoulou & Haralabous, 2008). Accordingly, condition factor analysis provides information about important ecological and physiological changes in fish populations (Vassilopoulou & Haralabous, 2008). In the present study, *K* values increased in spring and autumn in *S. cinereus*, while an opposite trend was observed in winter and summer. A decrease in *K* values was detected during the breeding season and in summer, and it increased again in autumn after breeding. Finding that the seasonal condition pattern in the populations of *S. cinereus* studied here matches with the general pattern in fishes (Le Cren, 1951; Froese, 2006) creates an interesting contribution to broaden the knowledge of its biology. These results are generally consistent with the findings of previous studies in the literature, but no research has been conducted to date regarding *K* values of *S. cinereus*.

Gonad maturity, spawning time and fecundity

The external appearance of the gonads is usually used in studies of fish reproduction. This approach is quick, but it is also the least certain. It is necessary to use histological techniques for more detailed analyses (West, 1990). García-Díaz *et al.* (1997) reported that macroscopic classification was more practical because of its ease of application despite the lower reliability of macroscopic examinations compared with histological examinations. In the present study, reproduction was evaluated with a macroscopic observation method.

The results obtained here revealed monthly variations in the GSI values and maturity stages of both male and female *S. cinereus*, and the annual spawning cycle of this species in the south-eastern Black Sea, off the coast of Rize, Turkey, was found to occur between March and June. Ghorbel-Ouannes *et al.* (2007) reported that gonad maturation begins in February and ends in June for this species in Tunisia. Differences in the timing of the spawning season may arise between different geographic locations as a result of variations in environmental factors, and particularly differences in temperature and salinity ranges (Zorica *et al.*, 2011).

In this study, 1375–5493 eggs were identified per individual (0.309–0.723 mm in diameter) for fish ranging from 10.2–14.1 cm in length and 21.7 to 35.72 g in weight. Ouannes-Ghorbel *et al.* (2007) reported total lengths between 7.8–10.5 cm, with egg counts of 4304–5089 eggs/individual from among mature oocytes (0.65–0.68 mm in diameter). The beginning and end of the spawning period may occur in different months for different populations because of different ecological and climate conditions (Nikolsky, 1980).

Conclusion

In the Black Sea, *S. cinereus* is not caught as a target species by fishermen. The current study has reported data on the spawning season, age and growth of this species and other factors that are essential for fishery management. Consequently, this study will serve as a source of baseline data on this fish species in the Black Sea and it should be helpful for the successful management of fisheries in the future. This study is the first detailed study of this species in the Black Sea.

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