

## Age, growth and reproductive biology of the saddled seabream (*Oblada melanura*) in the North Aegean Sea, Eastern Mediterranean

by

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### Abstract

This study determines the length distribution, length-weight relationship, age, growth parameters, mortality rate, sex ratios, length at first maturity and reproduction of saddled seabream (*Oblada melanura*) collected monthly by fishermen around the Northern Aegean Sea between November 2017 and October 2018. The length-weight relationship was calculated as  $W = 0.0091 \times L^{3.11}$  ( $R^2 = 0.95$ ) and positive allometric growth was found. The condition factor and GSI varied between 0.81–1.58 and 0.01–9.61, respectively. The spawning season extended from May to July and peaked in June. Total lengths at 50% maturity were 18.97 cm for males and 18.83 cm for females. Parameters of the von Bertalanffy growth equation were:  $L_{\infty} = 29.91$  cm,  $K = 0.27$  per year,  $t_0 = -0.82$  year and age varied between 1 and 8. The instantaneous rates of total mortality ( $Z$ ) and natural mortality ( $M$ ) were 1.36 and 0.58 per year, respectively. Rates for fishing mortality  $F$  and exploitation  $E$  were 0.78 and 0.57 per year, respectively. The mean absolute fecundity ( $F$ ) was  $117\ 075 \pm 23\ 243$  oocytes, ranging from 19 130 to 470 132.

**Key words:** saddled seabream, von Bertalanffy, mortality, spawning, fecundity

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## Introduction

The saddled seabream, *Oblada melanura* (Linnaeus, 1758), is a member of the Sparidae family that occurs from Gibraltar to Angola, the Mediterranean, the Bay of Biscay, Madeira, Cape Verde and the Canary Islands. It is a commercially important food and gamefish in aquariums. Spawning behavior is known to be gonochoric, while some cases are hermaphroditic protogynous (Bauchot & Hureau 1990). Additionally, Buxton & Garratt (1990) stated that rudimentary hermaphroditism may occur.

Although research on the population dynamics of marine fish has been carried out for many years, little information is still available about the biology of so many species. Researchers generally tend to investigate species based on the species composition of catches obtained by single common fishing tools such as trawls, gillnets, longlines, etc. However, some species, such as *O. melanura*, migrate throughout the year to different depths ranging from 0 to 50 m, making it difficult to sample with a single type of fishing gear. Due to their feeding strategy known to be omnivorous (Bauchot & Hureau 1990), it is difficult to catch such fish with meat baits during handline and longline fishing because of their preference for carbohydrates such as bread. In spring and summer, these fish can be caught with seines and gillnets, but after November, movement under the thermocline and distribution depending on rocky habitats have a negative effect on fishing with gillnets and seines.

For this reason, only two studies have been found on the age and growth of *O. melanura*, conducted in the eastern Adriatic (Pallaoro et al. 1998) and in Abu Qir Bay, Egypt (Mahmoud 2010). Several studies have provided estimates of the length–weight relationship (Can et al. 2002; Cengiz 2013; Karakulak et al. 2006; Crechriou et al. 2012; Bilge et al. 2014) and feeding habits (Pallaoro et al. 2003; Pallaoro et al. 2004) of *O. melanura*, but there are still insufficient data on age, growth, mortality, reproduction and fecundity of the species. In addition, except for the maximum length recorded in the Mediterranean (Akyol et al. 2014), no research has been found for the Eastern Mediterranean.

This study aimed to determine some population parameters such as age, growth, mortality, reproduction and fecundity of *O. melanura* around the North Aegean Sea, the Eastern Mediterranean.

## Materials and methods

A total of 373 individuals were obtained from

landings of commercial catches by fishermen around the Northern Aegean Sea, the Eastern Mediterranean Sea. Individuals were obtained monthly between November 2017 and October 2018. The total length (TL) was measured to the nearest millimeter using a measuring board, and the total weight, gonad weight and otolith weight were recorded to the nearest gram using precision scales. The length and width of otoliths were measured using the Q-Image digital imaging program. Sex and maturity stages were determined by macroscopic observation of male and female gonads. If ovarian and testicular tissues were observed in the same gonad, the fish was classified as hermaphrodite.

The length–weight relationship was estimated by the exponential regression  $W = a \times TL^b$ , where  $W$  is the total weight (g) and  $TL$  is the total length (cm) (Ricker 1975). Following the log transformation, the constants  $a$  and  $b$  were estimated by least-square linear regressions. The growth type was determined by the value “ $b$ ” that reflects allometry of the growth.

Both otoliths and scales were evaluated for age determination. It was observed that neither sectioning nor burning of otoliths is a suitable method of age determination. Otolith length–total length, otolith weight–body weight and otolith length–otolith width relationships were examined for linear and exponential relationships using best-fit equations. As in previous studies, the scales of *Oblada melanura* ( $N = 371$ ) were used for the determination of age. Five scales from the left part of the area below the pectoral fin were collected from each individual, washed, dried and kept in Eppendorf tubes. Readings were taken by three independent investigators. The scale reading was carried out using a binocular microscope. The hyaline zones were determined as annuli and counted. Growth parameters were estimated for the whole data set using the von Bertalanffy growth equation:

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

where  $L(t)$  is the total length at time  $t$ ,  $L_{\infty}$  is the asymptotic length (cm),  $K$  is the growth coefficient ( $t^{-1}$ ) and  $t_0$  is the hypothetical age when the size of fish is zero. FAO-ICLARM Stok Assessment Tools (FISAT II) were used to estimate growth parameters, which were calculated with the non-linear least-squares method. Pauly's (1984) age-converted catch curve method was used to determine the instantaneous total mortality ( $Z$ ). Natural mortality ( $M$ ) was determined using Pauly's (1980) empirical formula which contains von Bertalanffy growth parameters and mean annual seawater temperature (15.7°C; Türkoğlu 2010):

$$\log(M) = (-0.0066) - 0.279 \times \log(L) + 0.6543 \times \log(K) + 0.4634 \times \log(T)$$

Fishing mortality was calculated using the following formula:  $F = Z - M$  (Bingel 2002). The exploitation rate ( $E$ ) was obtained using Gulland's (1971) formula:  $E = F/Z$ .

Sexual maturity stages were determined applying a five-staged maturity scale developed by Holden and Raitt (1974):

- stage I (immature) – gonads are very small and testis is whitish;
- stage II (maturing and recovering spent) – gonads are small, dully transparent and pinkish-whitish;
- stage III (ripening) – gonads are enlarged, ovary is pinkish-yellow with granular appearance and testis is whitish to creamy; no transparent ova;
- stage IV (ripe) – gonads are considerably enlarged, ovary is large and transparent, orange-pink with conspicuous superficial blood vessels; ripe ova are visible; testis is whitish-creamy, soft;
- stage V (spent) – gonads are shortened, walls loose, flabby, empty, dark red with traces of sperm or ova.

The spawning season of the species was estimated by assessing the sexual maturity stages and based on the Gonadosomatic Index Value ( $GSI$ ). The  $GSI$  was calculated using the formula developed by Gibson & Ezzi (1980):

$$GSI = (\text{Gonad weight} / (\text{Body weight} - \text{Gonad weight})) \times 100$$

The length at first maturity ( $L_{50}$ ) was estimated using the least-square method and the following formula (King 1995) for both sexes:

$$P = 1 / (1 + \exp[-rm(L - Lm_{50})])$$

where  $rm$  is the slope of the curve,  $Lm$  is the mean total length (cm) at sexual maturity,  $L$  is the mean total length (cm) and  $P$  is the probability of the presence of mature fish.

After microscopic examination, 38 out of 155 female mature gonads were selected for fecundity analysis. The gonads were dried on drying paper, their total weight was measured and 0.05 g subsamples from three parts (front, middle and back) were collected from each ovary. The gravimetric method according to Bagenal (1978) was used to calculate fecundity. Diameters of oocytes were measured using

the Q-Capture Pro image analysis tool. Ripening oocytes were determined according to the precursor of vitellogenesis (oocytes larger than 50  $\mu\text{m}$ ). Absolute fecundity was calculated using Bagenal's (1978) formula:

$$F = n \times (G/g)$$

where  $n$  is the mean number of eggs in each gonad,  $G$  is the total weight of gonad, and  $g$  is the weight of the female individual. The total length–fecundity and age–fecundity relationships were estimated for females using linear and exponential regression according to which the equations had the best fit.

## Results

In total, 373 individuals were assessed monthly between November 2017 and October 2018. The total length and weight of individuals varied from 13.8 to 29.6 cm  $TL$  ( $21.3 \pm 0.14$  cm) and 39 to 450 g ( $128.4 \pm 2.53$  g), respectively. The minimum mean weight was observed in July (72.7 g) after spawning, whereas the highest mean weight was observed in March immediately before spawning. The length–weight relationships were calculated separately for males, females and both sexes (Table 1). The  $b$  values did not differ significantly between the sexes (ANCOVA,  $p > 0.05$ ). The values of  $b$  for both sexes were significantly different from 3.0 (t-test,  $p < 0.05$ ).

The sex of individuals was determined as 187 females (50.1%), 139 males (37.3%) and 3 hermaphrodites (0.9%). The sex of the remaining 44 individuals was not determined due to immature gonads. The sex ratio was 1:1.34 in favor of females. When studying the temporal variation of sexes, we observed that males grew only during the spawning period.

### Age, growth and mortality

The scales showed clear opaque and hyaline rings that enabled easy determination of annual rings. Two

**Table 1**  
Length–weight regression parameters for males, females and both sexes for *Oblada melanura*

	N	a	b	r <sup>2</sup>	s	Growth Type
Female	187	0.0098	3.086	0.949	$p > 0.05$	A(+)
Male	139	0.0086	3.128	0.949	$p > 0.05$	A(+)
Both sexes	373	0.0091	3.108	0.954	$p > 0.05$	A(+)

\*A(+): Positive allometric

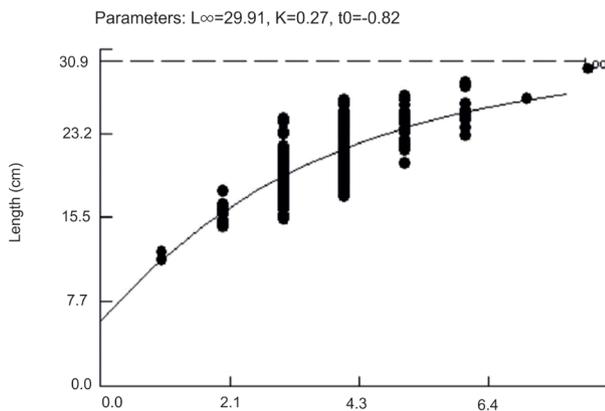
of the 373 individuals were removed from the age analysis due to damage to scales caused by gillnets. A total of 371 individuals were between 1 and 8 years old. Due to the fact that individuals came from landings of commercial catches made by fishermen, the 0 age group was not observed and the 1 age group was represented by only 2 individuals. The maximum age group observed was 4, representing 60% of the total. The majority of individuals (91%) were in age groups 3, 4 and 5 (Table 2). According to the non-linear least-squares method applied to the whole data set, von Bertalanffy growth parameters were calculated as  $L_{\infty} = 29.91$  cm,  $K = 0.27$  per year and  $t_0 = -0.82$  year (Fig. 1). The calculated theoretical maximum length is nearly the same as the size of the largest individual (29.2 cm TL).

According to the age-converted catch curve (Fig. 2), the descending point of the slope ( $1.36 \text{ t}^{-1}$ ) is regarded as total mortality ( $Z$ ). Based on Pauly's (1980) empirical formula which contains von Bertalanffy growth parameters and mean annual seawater temperature ( $15.7^{\circ}\text{C}$ ; Türkoğlu 2010), the natural mortality ( $M$ ) was estimated at  $0.58 \text{ t}^{-1}$ . Using Bingel's (2002) formula, fishing mortality was calculated as  $0.78 \text{ t}^{-1}$ . The exploitation rate was determined as  $0.57 \text{ t}^{-1}$ .

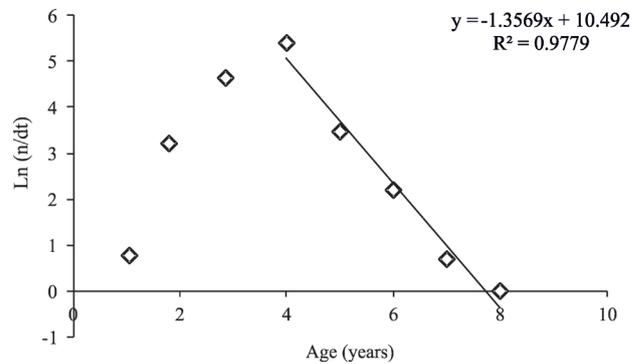
### Sexual maturity, reproductive biology and fecundity

The length at first maturity ( $L_{50}$ ) was estimated using the least-square method and showed a logistic curve for both sexes in Figure 3. The size at first maturity was 18.97 cm TL for males and 18.83 cm TL for females.

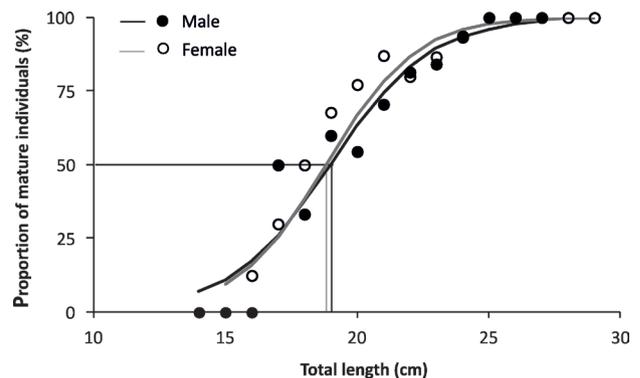
The condition factor ( $K$ ) of individuals varied between 0.81 and 1.58 with a mean of  $1.27 \pm 0.0.2$ .



**Figure 1**  
Von Bertalanffy growth curve of *Oblada melanura* for the whole data set



**Figure 2**  
Age-converted catch curve for estimating the total mortality ( $Z$ ) of *Oblada melanura*



**Figure 3**  
Logistic curve for estimating the size at first maturity ( $L_{50}$ ) for both sexes

The lowest condition was determined in July, whereas the highest one in October for females and November for males. No significant difference in  $K$  ( $p > 0.05$ ) was found between the two sexes. The gonadosomatic index ( $GSI$ ) ranged from 0.04 to 6.84 (mean:  $0.94 \pm 0.40$ ). The minimum values were observed in October and the maximum ones in June for both sexes. It was observed that the mean  $GSI$  values of *Oblada melanura* were generally low throughout the year, started to increase in May and peaked in June. The  $GSI$  values decreased immediately in July (Fig. 4).

Individuals with ripe gonads (stage 4) were observed between April and June for both sexes. The developing stages (stage 2 and 3) of females were observed earlier than in males (Fig. 5). Rapid and sudden development was observed for male gonads, when the peak time for spawning occurred in June. In June, whole female gonads were observed as ripe.

When sexual maturity,  $K$  and  $GSI$  values are assessed together, the spawning period of *O. melanura* was determined between May and June and its peak in June.

Table 2

Age and length key for *Oblada melanura* occurring in the north Aegean Sea

Length Class (TL; cm)	Age								Total
	1	2	3	4	5	6	7	8	
11	1								1
12	1								1
14		3							3
15		6	3						9
16		8	4						12
17		2	9	4					15
18			15	9					24
19			19	23					42
20			12	37	1				50
21			14	40	1				55
22			9	48	4				61
23				32	5	2			39
24				20	10	3			33
25				6	8	2			16
26				2	3	1	1		7
27						1	1		2
29								1	1
Total	2	19	85	221	32	9	2	1	371
Mean length (cm)	12	15.9	20	22	24	25	27	29.2	
Proportional growth (%)	33	23	11	11	5	5	10		

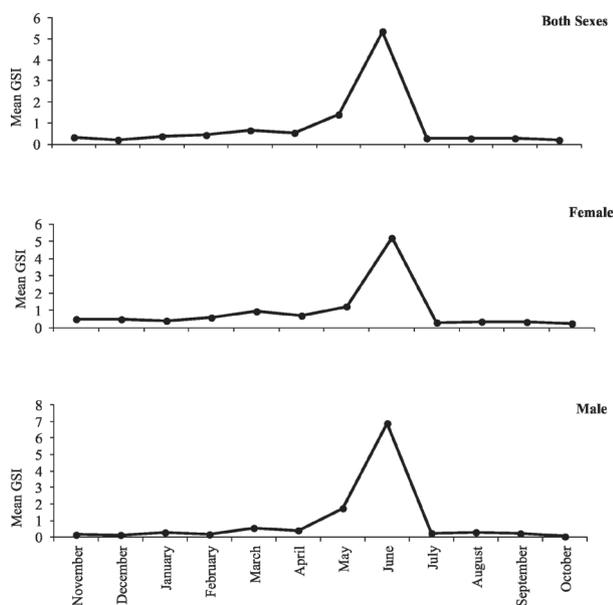


Figure 4 Temporal changes in the gonadosomatic index values (GSI) for *Oblada melanura*

For fecundity, ovaries of 38 individuals were microscopically examined. Out of them, 23 ovaries containing eggs with a diameter larger than 50  $\mu\text{m}$  were selected. Total fecundity estimates came from individuals with a total length ranging from 17.7 to 27.9 cm TL, aged from 3 to 8 years. No significant

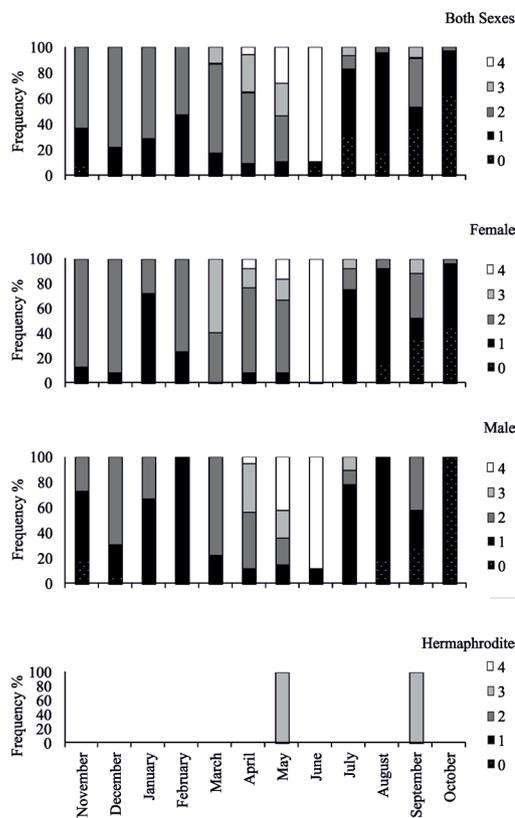
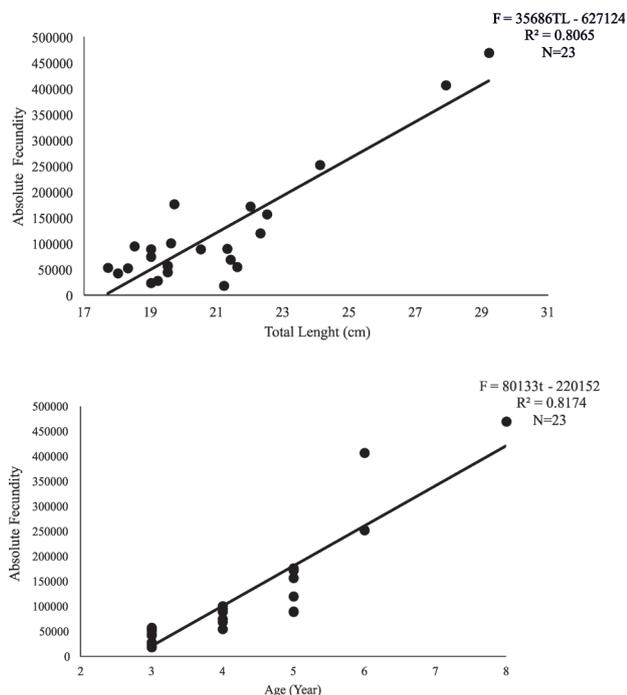


Figure 5 Sexual maturity stages of *Oblada melanura*. Stage 0-1: inactive, Stage 2-3: developing, Stage 4: ripe

differences were observed between ovarian lobes and different parts of the same ovary. Absolute fecundity varied from 19 130 (21.2 cm, age 5) to 470 132 (29.2 cm, age 8) eggs, with a mean of  $117\,075 \pm 23\,243$  eggs. Females used for fecundity analyses were sampled between May and July. The highest mean fecundity was observed in June with 134 804 eggs. A linear relationship was found between absolute fecundity and total length ( $F = 35\,686 \times TL - 627\,124$ ;  $R^2 = 0.81$ ) and fecundity age ( $F = 80\,133 \times t - 220\,152$ ;  $R^2 = 0.82$ ; Fig. 6).



**Figure 6**  
Relationship between mean absolute fecundity–total length and fecundity and age

## Discussion

The results of this study provide the first information on the dynamics of the population of common but poorly studied *Oblada melanura* in the Eastern Mediterranean. Several studies related to the length–weight relationships (Table 3) and feeding habits have been conducted. However, only few comparative growth studies are available worldwide (Table 4). Furthermore, the fecundity data in this study constitute the first information in the literature.

Table 3 summarizes the studies on the length–weight relationship. It was found that both similar and different results were obtained in different geographical regions. In nearby geographical areas,

Karakulak et al. (2006) found positive allometry, whereas Cengiz (2003) reported negative allometry. Cavallaro et al. (1985), Goncalves et al. (1997) and Pallaro et al. (1998) found positive allometry in the Messina Strait, the south-western Mediterranean and the Eastern Adriatic, respectively. Pallaro et al. (1998) published their results based on a large sample size of 5987 individuals, which included a great variety of length classes. It is known that a larger sample size and a wide size class increase the accuracy of length–weight relationships. In addition, the growth type and rate may vary at different stages of development. Although the lack of young individuals collected during the year in our study was due to sampling, our results were consistent with those of Pallaro et al. (1998). In general, it is observed that the species shows negative allometry as the age increases. Akyol et al. (2014) recorded the maximum size of the saddled seabream in the Mediterranean as 35.7 cm TL. The maximum length in this study was 29.6 cm TL. If larger-sized individuals were included in the data, the growth type could shift toward isometry.

The sex ratio in this study was determined as 1:1.34 in favor of females. For comparison, a single study by Pallaro et al. (1998) reported the sex ratio as 1:1.20 in favor of females. Pallaro et al. (1998) stated that the prevalence of sex varied depending on length. They found that males were more dominant in lower length classes. On the other hand, Pallaro (1996) found that females were abundant up to 19 cm, males were abundant up to 22 cm and after this length females were again abundant (Pallaro et al. 1998). In this study, the results coincide with the findings of Pallaro (1996). In addition, males were most dominant in the length class of 22.0–25.0 cm TL. We observed that the spawning period was a more significant factor when it comes to length. Females dominated throughout the year, except for the spawning season. The number of males increased as the spawning season approached. We predicted that the sex change occurs based on the spawning pattern, which takes place in different ways throughout the life cycle, depending on the sex balance of the stock.

A relatively short and suddenly peak spawning season of *O. melanura* was observed. Spawning began in May, reached its peak and ended in June. Bauchot & Hureau (1986) reported spawning of *O. melanura* in the Mediterranean between April and June, whereas Cetinic et al. (2002) – in the eastern Adriatic in June and July. Similar results were obtained in this study and it is believed that the small differences may be caused by regional sea-water temperature differences. The sea surface temperature varied in the study area between 17 and 20°C (Turkoglu 2010) during the spawning

**Table 3**

Comparison of length–weight relationship of *Oblada melanura* with previous studies

Authors	Region	Sex	N	Length Interval	a	b	GT
This study	North Aegean Sea, Eastern Mediterranean	F	187	11.6–29.2 TL	0.0098	3.086	A(+)
		M	139	14.6–27.6 TL	0.0086	3.128	A(+)
		Both	373	11.6–29.2 TL	0.0091	3.108	A(+)
Karakulak et al. 2006	Gökçeada Island North Aegean Sea	F	112	12.5–19.8 TL	0.0052	3.310	A(+)
		M	145	12.1–19.8 TL	0.0047	3.347	A(+)
		Both	316	9.1–19.8 TL	0.0034	3.463	A(+)
Can et al. 2002	Iskenderun Bay Eastern Mediterranean	Both	22	15.6–27.0 TL	0.0322	2.697	A(-)
Gonçalves et al. 1997	South Portugal Western Mediterranean	Both	23	22.0–24.0 TL	0.00000127	3.404	A(+)
Crechriou et al. 2012	French Catalan Coast	Both	74	17.0–36.6 TL	0.127	2.89	A(-)
Bilge et al. 2014	South Aegean Sea	Both	157	11.6–25.8 TL	0.0174	2.857	A(-)
Karachle and Stergiou 2008	North Aegean Sea, Eastern Mediterranean	Both	56	12.6–22.7 TL	0.0124	3.0220	I
Borges et al. 2003	Algarve Southern Portugal	Both	49	20.5–28.2 TL	0.0161	2.906	A(-)
Cengiz 2013	Gallipoli Peninsula and Dardanelles	Both	97	12.7–26.1 TL	0.0180	2.89	A(-)
Mahmoud 2010	Abu Qir Bay Egypt	Both	477	12.0–29.2 TL	0.017	2.934	A(-)
Pallaoro et al. 1998	Eastern Adriatic	F	2911	2.0–33.4 TL	0.0088	3.132	A(+)
		M	2430		0.0113	3.017	I
		Both	5987		0.0099	3.081	A(+)
Cavallaro et al. 1985	Eastern Sicily Messina Strait	Both	353	1.0–14.0 SL	0.0157	3.246	A(+)
Cetinic et al. 2002	Eastern Adriatic	Both		11.3–33.1 TL	0.0091	3.081	I

**Table 4**

Comparison of Von Bertalanffy growth parameters for *Oblada melanura* with previous studies

Authors	Region	Sex	Length (TL)	$L_{\infty}$ (cm)	K	$t_0$	Z	M	E	Age
This study	North Aegean Sea, Eastern Mediterranean	F	11.6–29.2	29.91	0.27	0.82	1.36	0.58	0.78	1–8
		M								
		Both								
Mahmoud 2010	Abu Qir Bay Egypt	Both	12.0–29.2	33.83	0.242	0.669	0.96	0.56	0.41	1–8
Pallaoro et al. 1998	Eastern Adriatic	F	2.0–33.4	34.13	0.201	0.75	1.08	0.47	0.56	1–11
		M								
		Both								
Cetinic et al. 2002	Eastern Adriatic	F M	11.3–33.1							
Cavallaro et al. 1985*	Eastern Sicily Messina Strait									1–8
Cefali et al. 1987*	Eastern Sicily Messina Strait				0.309					1–3

\*These data come from the study by Pallaoro et al. (1998) due to the unavailability of the main sources.

period of *O. melanura*. The observed short spawning period of *O. melanura* in the Mediterranean and the Adriatic may result from its opportunistic nature in relation to water temperature.

Eight age classes were identified in this study. The 0 age group was not observed due to the fact that samples were obtained from commercial catches of fishermen, which in turn was related to the selectivity of their nets. The maximum age was estimated at 8 years. In comparison with previous studies, these values were similar to the results obtained from Abu

Qir Bay by Mahmoud (2010) and the Messina Strait by Cavallaro et al. (1985), but were lower compared to the results obtained by Pallaoro et al. (1997) in the eastern Adriatic (11 years). The lower maximum age and asymptotic length ( $L_{\infty}$ ) in this study may result from fewer outsize individuals. The estimated higher exploration rate in this study may affect the availability of outsize individuals. Although the growth parameters coincide with the results of the study conducted in Abu Qir Bay (Mahmoud 2010), the growth coefficient was higher and  $L_{\infty}$  was lower in this study.

This may be explained by the higher fishing mortality in the presented study.

Also the food availability and varied physicochemical conditions of study areas may cause differences. The growth at an early age of individuals was relatively faster than at any later age. Although the higher growth rate at an early age is a known situation, we presume that the habitat selection, settlement behavior and schooling contributed to it. *O. melanura* settles in rocky areas and remains immobile in a school (Harmelin-Vivien et al. 1995). This behavior may reduce early life mortality and improve the health of recruited individuals through lower energy consumption and protection against predators. Pallaoro et al. (2004) indicated that the stomach of juveniles contained Copepoda and Cladocera crustaceans and that the feeding intensity was very high. The feeding behavior is nearly constant up to 22 cm TL, then *O. melanura* included fish eggs and larvae in the diet. In addition, the feeding intensity did not vary depending on length (Pallaoro et al. 2003). Taking all this into account, a decrease in the growth rate at a later age may result from the gonadal development and sexual pattern.

All individuals were used according to sex to calculate the size at first maturity, which varied from 13.8 to 29.6 cm TL. The size at first maturity was estimated at 18.83 and 18.97 for females and males, respectively. Genetic, environmental and fishing factors (Olsen et al. 2004) may affect the sexual maturity length. Cetinic et al. (2002) determined the first maturity size of *O. melanura* from individuals ranging in length between 11.3 and 33.1 as 17.5 and 16.4 cm TL for females and males, respectively. These results differ from Cetinic's (2002) estimate of the first maturity length. The differences can be explained in part by geographical differences given the deficiency of fishing pressure in that study. In addition, smaller individuals in terms of length in that study may cause the difference. Subakan et al. (2017) studied the selectivity of *O. melanura* with gillnets around the North Aegean Sea. Optimum catch lengths for 20, 22, 23 and 25 mm mesh size were calculated as 15.3, 16.83, 17.59 and 19.12 cm for *O. melanura*. When comparing the size at first maturity obtained from our data set with the optimum catch lengths, only nets with a nominal mesh size of 25 mm are suitable for the selectivity of the species in the study area.

The  $L_{50}/L_{\infty}$  ratio showing changes in the growth rate over the life cycle has been used in many studies to compare decreasing growth rates through length (Cushing 1981). The  $L_{50}/L_{\infty}$  ratio was calculated in this study as 0.63 for *O. melanura*. Stergiou (2000) determined the  $L_{50}/L_{\infty}$  ratio for 24 species as 0.33–0.74 in the Hellenic Seas. *O. melanura* was not included

among 24 species covered by Stergiou's (2000) study. The calculated ratio for *O. melanura* was within the range of the 24 species from the Hellenic Seas. As the  $L_{50}/L_{\infty}$  ratio is close to the upper limit, it can be assumed that the relative length at maturity of *O. melanura* is higher.

The absolute fecundity varied between 19 130 and 470 132 eggs, with a mean of  $117\ 075 \pm 23\ 243$  eggs for *O. melanura*. In addition, only one study was found to consider the fecundity of the species (Rafalah & El-Mor 2018). The authors found that the absolute fecundity varied between 22 278 and 366 780 eggs for fish with an average total length ranging from 16.5 to 32.4 cm. Almost similar values were observed in this study. In addition, the fecundity of *O. melanura* showed a linear relationship with length and age. The same relationship was found by Rafalah & El-Mor (2018). Due to the limited number of previous studies, the fecundity results were compared with those dealing with other Sparidae members.

Dulcic et al. (1998) and Guerra et al. (1993) studied the total fecundity of *Spondyliosoma cantharus* in the Adriatic. The mean annual total fecundity was calculated by Dulcic et al. (1998) as ranging from 31 670 to 554 070 eggs per female, whereas Guerra et al. (1993) reported 36 926 to 143 900 (average 65 659) eggs in the same area. Taieb et al. (2012) determined that the total fecundity of *Diplodus vulgaris* ranged from 8400 to 30 800 oocytes in the southern Tunisian waters. Gordo et al. (1996) reported that the total fecundity of *Boops boops* ranged from 11 550 to 357 800 eggs per female from the Portuguese coast, whereas Taylan & Bayhan (2015) found between 33 072 and 66 123 oocytes. The fecundity values were found to vary greatly between areas and species, although the estimated fecundity for *O. melanura* was within the range of family members.

Buxton & Garratt (1990) reviewed alternative reproductive styles in seabreams. In this study, the reproductive style of *O. melanura* was reported as gonochoristic (Zei & Zupanovio 1961) and rudimentary hermaphroditic (D'Ancona 1949b; Reinboth 1962). Buxton & Garratt (1990) identified the rudimentary hermaphrodites as both male and female immature gametes in a single gonad at any development stage, once after showing a single stable sex per individual. Three of 373 individuals (0.9%) were observed in this study as hermaphrodites. The length of hermaphrodite individuals varied between 19.0 and 22.0 cm TL, and both were 4 years old. Rudimentary hermaphrodites have some special life history characteristics such as schooling, migration and the equal size of the sexes (Buxton & Garratt 1990). Our results and observations regarding *O. melanura* coincide with the findings

of Buxton & Garratt (1990) and we think that the reproductive style of *O. melanura* is rudimentary hermaphroditic.

It is known that *O. melanura* is caught in the study area mainly by gillnets. It was observed that the optimum catch length values calculated for gillnets in the study area were smaller than the first maturity length of this species. It can therefore be suggested that the nominal bar lengths of gillnets that should be used to fish *O. melanura* could be increased to ensure the sustainability of the species.

There are no technical regulations (minimum catch length or weight) imposed on *O. melanura* fisheries in Turkey. High fishing pressure, a short spawning period and insufficient knowledge about stock and biomass cause many doubts about the sustainability of stocks in the North Aegean Sea. The presented findings imply that the first sexual maturity length, spawning season, fishing mortality and fecundity should be taken into account when legislative regulations are prepared by the fisheries management authority. More information on the biological parameters of *O. melanura* would help fisheries managers to establish a greater degree of accuracy in this regard.

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