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AGE, GROWTH, LENGTH–WEIGHT RELATION, AND REPRODUCTION OF SAND STEENBRAS, *LITHOGNATHUS MORMYRUS* (ACTINOPTERYGII: PERCIFORMES: SPARIDAE), IN THE KÖYCEĞIZ LAGOON, MEDITERRANEAN

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Reis İ., Ateş C. 2020. Age, growth, length–weight relation, and reproduction of sand steenbras, *Lithognathus mormyrus* (Actinopterygii: Perciformes: Sparidae), in the Köyceğiz Lagoon, Mediterranean. Acta Ichthyol. Piscat. 50 (4): 445–451.

Background. Sand steenbras, *Lithognathus mormyrus* (Linnaeus, 1758), has high commercial value and constitute an important catch for the coastal and lagoon fisheries in the Mediterranean. The information about the biology of this species in the lagoons of Turkey is very limited. This study provides updated data about age, growth, length–weight relation, and reproduction period for sand steenbras.

Materials and methods. A total of 319 samples were caught from the Köyceğiz Lagoon, Turkey, in monthly intervals, from January to December 2017, using a fish barrier, trammel net, beach seine, and cast-net. The fish age was determined from sagittal otoliths. Growth parameters were investigated by applying the von Bertalanffy growth function.

Results. The total length of females ranged from 12.5 to 24.1 cm, total length of males ranged from 11.7 to 23.4 cm, total length of intersexuals ranged from 15.5 to 22.3 cm, total length of immature ranged from 2.5 to 12.4 cm, and total length of all individuals ranged from 2.5 to 24.1 cm. The female ÷ male ratio was estimated at 1 ÷ 0.79. The age of the sand steenbras individuals ranged from 0 to 5 years for all individuals. The growth parameters of the von Bertalanffy equation were: L_∞ = 30.2 cm, K = 0.234 year^{-1}, and t_0 = –1.30 year for females, L_∞ = 29.7 cm, K = 0.238 year^{-1}, and t_0 = –1.28 year for males and L_∞ = 28.6 cm, K = 0.284 year^{-1}, and t_0 = –0.86 year for all individuals. The length–weight relations of females and males were $W = 0.0132L^{3.024}$ (r^2 = 0.947) and $W = 0.0169L^{2.941}$ (r^2 = 0.960), respectively. Reproduction period continued from late April (19.1°C) to early June (25.9°C) with the greatest intensity occurring in May (GSI = 5.879, 24.0 °C).

Conclusions. This study provides first information related to age, growth, reproduction period and length–weight relations of the sand steenbras from the Köyceğiz Lagoon. These results may be used in future studies on this fish and may contribute to a more effective fisheries management in the Köyceğiz Lagoon.

Keywords: Köyceğiz Lagoon, *Lithognathus mormyrus*, age, growth, reproduction

INTRODUCTION

Sparid species display a remarkable diversity of reproductive models (De Mitcheson and Liu 2008, Tsakogiannis et al. 2019). The sand steenbras is a protandric hermaphrodite, beginning its reproductive live as male, but reproducing as female later in life (Pajuelo et al. 2002, Kallianiotis et al. 2005, Monteiro et al. 2010).

Sand steenbras, *Lithognathus mormyrus* (Linnaeus, 1758), is a demersal fish species that inhabits sandy-muddy areas at depths of 0–80 m (Bauchot and Hureau 1986). The natural habitats of this species are the Atlantic and Indian oceans, Bay of Biscay, Canary Islands, Red Sea, and the Mediterranean (Kallianiotis et al. 2005).

Age, growth, and reproduction, of *L. mormyrus* have been studied in the Thracian Sea (Kallianiotis et al. 2005), south-western Mediterranean Sea (Boufersaoui et al. 2018), southwestern coast of Turkey (Sumer et al. 2014), east-central Atlantic (Pajuelo et al. 2002), and south coast of Portugal (Monteiro et al. 2010). The length–weight relations were also studied for the south-eastern Aegean Sea (Ceyhan et al. 2009), eastern Adriatic estuarine systems (Dulčić and Glamuzina 2006), and the central Mediterranean Sea (Giacalone et al. 2010).

Sand steenbras are commercially valuable and an important fish species for the coastal and lagoon fisheries in Turkey, with commercial landings reaching 181.7 t in 2018 (Anonymous 2020). In the coasts of Turkey, sand steenbras is mainly caught by trammel nets, gill nets, and longlines, while in Turkish lagoons they are caught by a fish barrier.

In the Köyceğiz Lagoon, *L. mormyrus* is economically important fish species. The species is caught mainly by

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fish barriers. Despite its economic importance, the sand steenbras has never been the object of a study in the Köyceğiz Lagoon. The aim of the presently reported study was to investigate the age, growth, reproduction period, and the length–weight relations, which may contribute to the management strategy for the species.

MATERIAL AND METHODS

A total of 319 individuals of sand steenbras were collected monthly, from January to December 2017, in the Köyceğiz Lagoon, Turkey using a fish barrier (40 mm mesh size), trammel net (32 mm mesh size), beach seine (10 mm mesh size), and cast-net (15 mm mesh size) (Fig. 1). The total length was measured to the nearest centimeter (0.1 cm), and the body weight was recorded with precision balance (0.01 g). The one-way analysis of variance (ANOVA) was used to compare the mean total lengths between each sex (Zar 2010). The sex of all specimens was recorded by macroscopic examination of the gonads as female, male, intersexual (possessing either ovarian or testicular tissue in their gonads), or immature (gonads are very thin and translucent). Then, each gonad was removed from fish and weighed to 0.01 g. The female ÷ male ratio of the sand steenbras was analyzed using Chi-square test (χ^2). Sagittal otoliths were removed, washed, dried, and stored in numbered Eppendorf® tubes for age determination. Age rings were examined under stereo-microscope considering 1 January as the nominal birth date. Annual growth increase was represented by one opaque and one translucent ring. The age of each fish was incorporated in an age class, taking into account the date of capture and nature of edge age rings (Morales-Nin 1987). Age determination of each fish was done 3 times by the researchers, and determination was accepted only when 2 researchers agreed.

Length at age was described by the von Bertalanffy growth model

$$L_t = L_\infty (1 - e^{-K(t - t0)})$$

where L_t is length at age t, L_∞ is asymptotic length, K is the growth coefficient, and t_0 is the hypothetical age at which length is equal to zero (von Bertalanffy 1938).

To describe the significance of differences in growth parameters of different regions or between sexes for the same species, the growth performance index ($Ø'$) was calculated (Microsoft Office Package Program 2016) by the equation of Pauly and Munro (1984)

$$Ø' = Log\ K + 2\ Log\ L_\infty$$

The length–weight relations (LWRs) were established using the equation;

$$W = aL^b$$

which is estimated through logarithmic transformation;

$$log(W) = log\ (a) + b\ log\ (L)$$

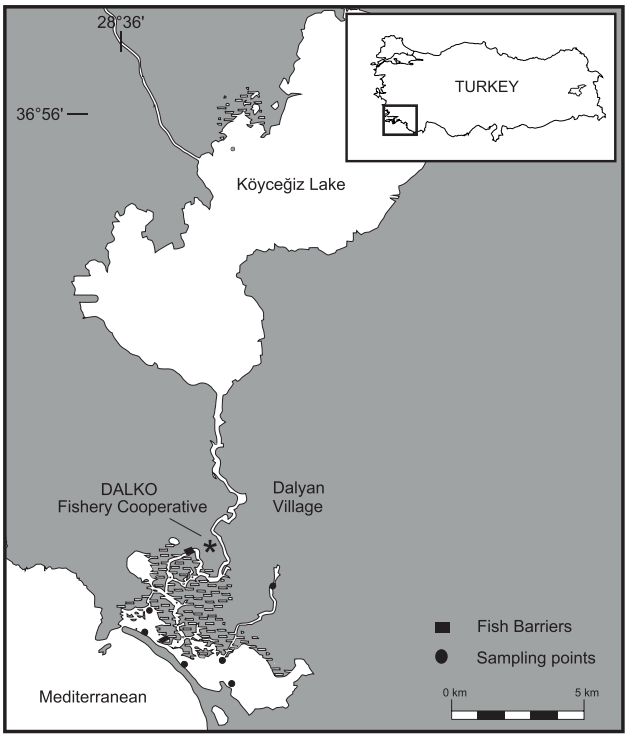

Fig. 1. Sampling points of Köyceğiz Lagoon, Muğla, Turkey

where W is weight [g], L is total length [cm], a is the intercept and b is the slope of the linear regressions. The significance of the b-values for each species was tested by Pauly's t-test to verify if it was significantly different from the predictions for isometric growth ($b = 3$) (Pauly 1984). Pauly's t-test was calculated as

$$t = (SD_{(logL)} / SD_{(logW)}) \times [|b - 3| / \sqrt{(1 - r^2)}] \times \sqrt{(n - 2)}$$

where SD_{logL} is the standard deviation of the log L values, SD_{logW} is the standard deviation of the log W values, n is the number of fish used in the computation. The value of b is different from 3 if t value is greater than the tabled t values for n–2 degrees of freedom (Pauly 1984).

The gonadosomatic index (GSI) value, commonly used to determine the reproductive period, was calculated monthly following the formula of King (2007)

$$GSI = 100 W_G \times W_T^{-1}$$

where W_G is the gonad weight and W_T is the total fish weight.

RESULTS

A total of 319 sand steenbras (117 females, 93 males, 96 immatures, 13 intersexuals) were examined. The female ÷ male ratio was estimated at 1 ÷ 0.79. The χ^2 test revealed that there was no significant difference between the number of females and males ($\chi^2 = 2.74$; df = 1; $P > 0.05$). The total length of females, males, intersexuals, immature, and all individuals ranged from 12.5 to 24.1 cm, 11.7 to 23.4 cm, 15.5 to 22.3 cm, 2.5 to 12.4 cm, and 2.5 to 24.1 cm, respectively.

Generally, females were found dominant compared to males in larger (13–24 cm) length groups (χ^2 = 6.89; df = 1; $P < 0.05$) (Fig. 2). The mean total length of females (18.1 cm) and males (17.0 cm) was significantly different from each other (*t*-test, $P < 0.05$). The total weight of sand steenbras ranged from 25.90 to 212.42 g for females, from 20.23 to 178.16 g for males, from 47.78 to 153.00 g for intersexuals, from 0.11 to 30.80 g for immature, and from 0.11 to 212.42 g for all individuals.

The parameters of length–weight regressions for female, male, immature, intersexual and all individuals are shown in Table 1. The *b* value of females, males and intersexuals was not significantly different from the theoretical value of 3 (*t*-test, $P > 0.05$). The *b* value was found significantly different from 3 (*t*-test, $P < 0.05$) and showed positive allometric growth for immature and all individuals. The curves of length–weight relations for female, male, immature and all individuals are given in Fig. 3.

The age of 319 sand steenbras was determined. Individuals of the sand steenbras were 0–5 years old and the highest age represented was 3 years (Table 2). Female ages ranged from 1 to 5 years and male ages ranged from 1 to 4 years. The estimated von Bertalanffy growth parameters for females, males and all individuals are given in Table 3. The calculated values of L_∞ were 30.2 cm, 29.7 cm, and 28.6 cm for female, male and all individuals, respectively. The estimated growth coefficients (*K*) in this study were 0.234 for females, 0.238 for males, and 0.284 for all individuals. The growth performance index ($Ø'$) was calculated as 2.33 for female, 2.32 for male, and 2.37 for all individuals.

The gonadosomatic index (GSI) value was calculated monthly for females and the highest GSI value was found in May with 5.88. The lowest GSI value was found in December with 0.21. Reproduction period continued from late April (19.1°C) to early June (25.9°C) with the greatest intensity occurring in May (24.0°C) (Fig. 4).

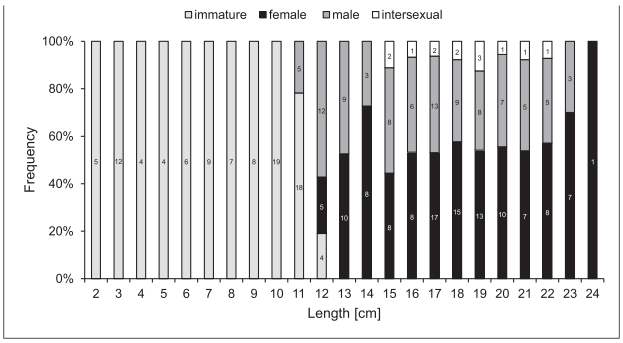

Fig. 2. Proportion of immature, female, male, and intersexual by length class for sand steenbras in the Köyceğiz Lagoon

DISCUSSION

Lorenzo et al. (2002) reported that small individuals of protandric species are usually males. In the presently reported study, it was determined that the mean total length of males was lower than the mean total length of females, and intersexuals ranged from 15 to 22 cm length classes. (Fig. 2). Kraljević et al. (1995, 1996) reported the dominance of males in lower length classes in the Adriatic Sea. Sumer et al. (2014) reported that in the Beymelek Lagoon, females ranged in size from 13.1 to 30.4 cm, males from 13.9 to 27.5 cm, and intersexuals from 18.6 to 22.6 cm. For the Thracian Sea, all individuals larger than 30.0 cm were females and intersexual individuals occurred from 18.1 to 30.0 cm (Kallianiotis et al. 2005), while Türkmen and Akyurt (2003) found that, in the İskenderun Bay, intersexual individuals ranged from 11.2 to 22.8 cm in length and all individuals larger than 22.8 cm were females. The occurrence of male individuals in the larger length and age class shows that the sex reversal may not be essential for all fish. This is contrary to the results of Lorenzo et al. (2002) for sand steenbras in the Canary Islands. This may be explained that sex reversal in the sparid species is an alternative reproductive style that varies geographically and with the population (de Mitcheson and Liu 2008).

The results of the length–weight relation of the immature sand steenbras (2.5 to 12.4 cm in total length) from the Köyceğiz Lagoon showed positive allometric growth (*t*-test, $P < 0.05$). This finding is similar with the results of Koutrakis and Tsikliras (2003) in the northern Aegean estuarine systems (samples from 2.1 to 14.3 cm TL), Gurkan et al. (2010) in shallow waters of the Gulf of Çandarlı (samples ranged from 1.0 and 4.2 cm TL) and

Table 1

Parameters of length-weight relation for female, male, immature, intersexual and all sand steenbras in Köyceğiz Lagoon

Sex	*n*	L_{min}–L_{max} [cm]	W_{min}–W_{max} [g]	Parameters of LWRs					
				a	*b*	SE(*b*)	95% CI(*b*)	r^2	Pauly's *t*-test
Female	117	12.5–24.1	25.90–212.42	0.0132	3.024	0.0553	2.913–3.179	0.947	$t = 0.36$; $P > 0.05$
Male	93	11.7–23.4	20.60–178.16	0.0169	2.941	0.0589	2.794–3.072	0.960	$t = –0.93$; $P > 0.05$
Immature	96	2.5–12.4	0.11–30.80	0.007	3.276	0.0747	3.206–3.356	0.988	$t = 7.44$; $P < 0.05$
Intersexual	13	15.5–22.3	47.78–153.00	0.0171	2.937	0.0729	2.021–3.853	0.819	$t = –0.15$; $P > 0.05$
All	319	2.5–24.1	0.11–212.42	0.0084	3.183	0.0654	3.145–3.213	0.991	$t = 10.73$; $P < 0.05$

n = number of fish sampled, *L* = total length, *W* = total weight, min = minimum, max = maximum, *a* = intercept, *b* = slope of the regression line, r^2 = coefficient of determination, SE(*b*) = standard deviation of *b*, CI(*b*) = confidence intervals of *b*.

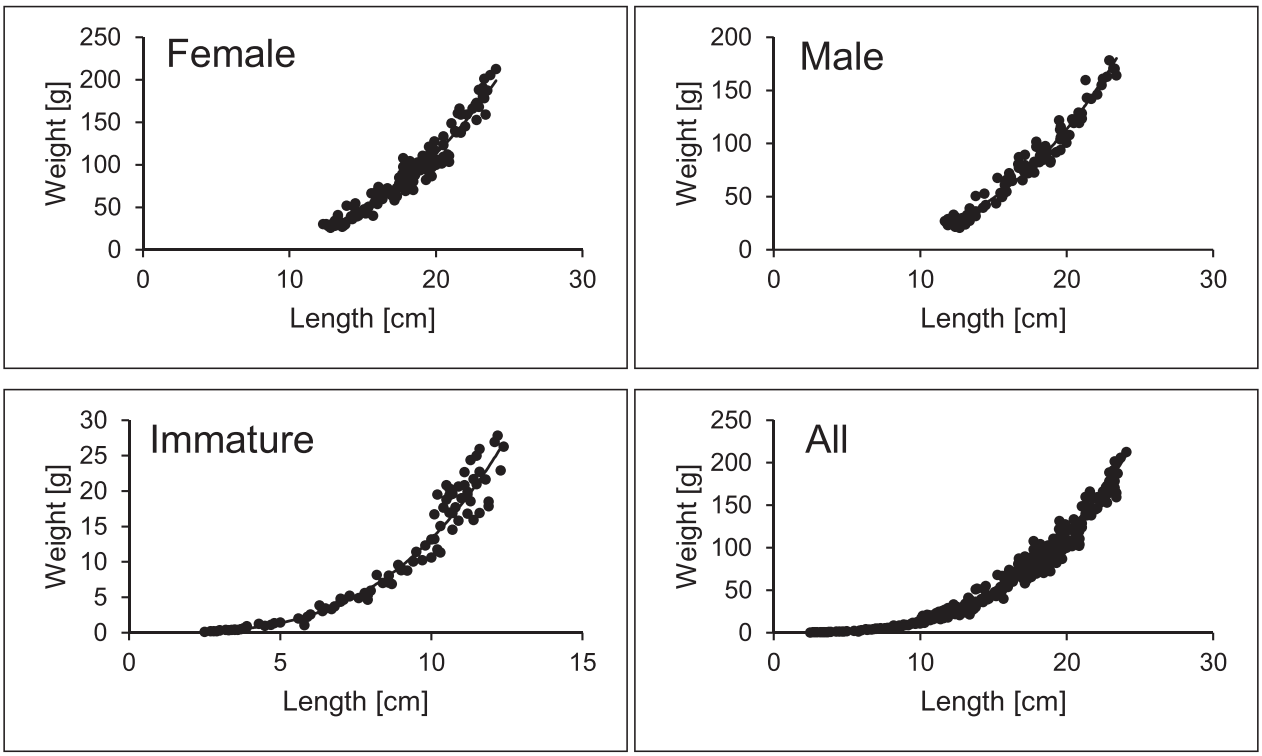

Fig. 3. Length-weight relations of female, male, immature and all sand steenbras from Köyceğiz Lagoon

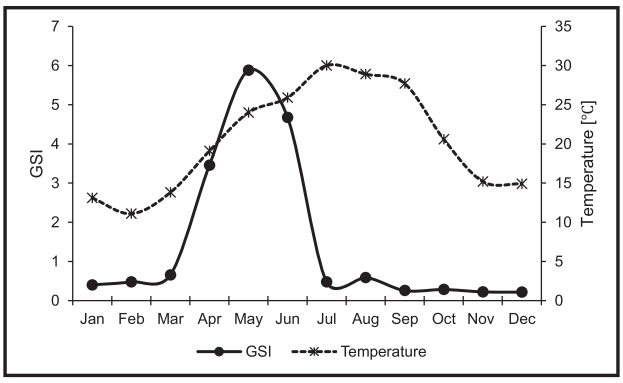

Fig. 4. Monthly variation of the gonadosomatic index (GSI) for female sand steenbras and water temperature in Köyceğiz Lagoon

Kallianiotis et al. (2005) in the coastal water of the Thracian Sea (samples ranged from 4.2 and 24.3 cm TL).

In addition, length–weight relation parameters for females, males, and intersexuals showed an isometric growth and no differences in the relative growth rate between sexes in the presently reported study (*t*-test, $P > 0.05$). For the sand steenbras, similar results were reported by Türkmen and Akyurt (2003) from the Gulf of İskenderun, Kallianiotis et al. (2005) from the coastal water of the Thracian Sea, Sumer et al. (2014) from the Beymelek Lagoon, Boufersaoui et al. (2018) from the central coast of Algeria for fish ranging between 9.1 and 34.1 cm in total length. In contrast, Kraljević et al. (1995), Lorenzo et al. (2002), and Osman (2005) reported negative allometric growth for different study areas. In the presently reported study, positive allometric growth was determined for all individuals of the sand steenbras in Köyceğiz Lagoon (*t*-test, $P < 0.05$). This is in agreement with the results of Kallianiotis et al. (2005) from the coastal water of the Thracian Sea, for fish ranging between 4.2 and 34.1 cm in total length. As disagreement with presently reported results, a negative allometric growth was found by Giacalone et al. (2010) in the coast of northern Sicily and Bilge et al. (2014) from the southern Aegean sea for fish ranging between 13.0 and 25.0 cm in total length. The LWRs could be affected by season, habitat, temperature, salinity, gonad maturity, sex, diet, prey–predator relations, food availability, and length range (Bagenal and Tesch 1978, Froese 2006).

About 41% of the sand steenbras were at the age of 0 and 1 in Köyceğiz Lagoon. The maximum age was found as 4 years for males and 5 years for females. Emre et al. (2010) reported that the maximum age was 3 years for male and 4 years for female in Beymelek Lagoon. The maximum age of sand steenbras was reported as 12 years in the northern Adriatic (Kraljević et al. 1996), 10 years in the Canary Islands (Lorenzo et al. 2002), 7 years from the Gulf of İskenderun (Türkmen and Akyurt 2003), 11 years in the coastal waters of the Thracian Sea (Kallianiotis et al. 2005) and 7 years from the central coast of Algeria, Mediterranean Sea Boufersaoui et al. (2018). It can be assumed that differences were due to the otolith reading method, the age attribution method, the size range and the characteristics of the study areas. Generally, it is known that lagoons are preferred especially by young individuals of many fish species (Emre et al. 2010).

The asymptotic length (L_∞ = 28.6 cm) was found smaller than those estimated by Türkmen and Akyurt

Table 2

Age-length-keys of sand steenbras from the Köyceğiz Lagoon

Length class [cm]	Age [years]						Total
	0	1	2	3	4	5	
0–2.5	1						1
2.6–3.5	10						10
3.6–4.5	8						8
4.6–5.5	4						4
5.6–6.5	6						6
6.6–7.5	7						7
7.6–8.5	7						7
8.6–9.5	9						9
9.6–10.5	6	7					13
10.6–11.5		21					21
11.6–12.5		24					24
12.6–13.5		16	4				20
13.6–14.5		5	10				15
14.6–15.5			11				11
15.6–16.5			19	2			21
16.6–17.5			17	3			20
17.6–18.5			3	27			30
18.6–19.5				25			25
19.6–20.5				21			21
20.6–21.5				10	7		17
21.6–22.5					10	1	11
22.6–23.5					6	10	16
23.6–24.5						2	2
Age	0	1	2	3	4	5	Total
n	58	73	64	88	23	13	319
%	18.18	22.88	20.06	27.59	7.21	4.08	
L mean ± SD	6.3 ± 2.48	11.9 ± 1.05	15.8 ± 1.26	19.1 ± 1.16	22.0 ± 0.75	23.2 ± 0.43	

The total length values are mean ± standard deviation; *n* = the number of fish sampled.

Table 3

Parameters ($L\infty$, K, and t_0) of the von Bertalanffy growth curve and growth performance indexes ($Ø'$) for male, female, and all sand steenbras in the Köyceğiz Lagoon

Sex	L_∞ [cm]	K [year^{-1}]	t_0 [year]	$Ø'$
Female	30.2	0.234	–1.30	2.329
Male	29.7	0.238	–1.28	2.322
All	28.6	0.284	–0.86	2.366

L_∞ = asymptotic length, K = growth coefficient, t_0 = hypothetical age, $Ø'$ = growth performance index.

(2003), Monteiro et al. (2010), Sumer et al. (2014), and Boufersaoui et al. (2018). The asymptotic length (L_∞), the estimated growth rate (K) and growth performance index ($Ø'$) obtained in the presently reported study are compared by different researches in other locations and some differences were determined (Table 4). Differences in growth parameters are related to environmental conditions, such as temperature, salinity and food ability, changing from one location to another (Kraljević and Dulčić 1997). Ma et al. (2010) noted that different age compositions may be causes of differences in the estimated growth parameters in different study areas.

In this study, reproduction period of sand steenbras was found earlier (from April to June; 19.1 and 25.9 ℃, respectively) in the Köyceğiz Lagoon than in the coastal waters of the Thracian Sea (from June to August) (Kallianiotis et al. 2005). Bauchot and Hureau (1986) reported that the reproduction period of sand steenbras was during spring and summer in the Mediterranean and the Atlantic. Türkmen and Akyurt (2003) observed the same situation from the Gulf of İskenderun. Monteiro et al. (2010) reported that spawning for this species was between June and August in the south coast of Portugal. Sumer et al. (2014) noted two possible spawning periods with the first spawning occurring between March and June (21.8℃) and second spawning was between June and September (29.3℃) in the Beymelek Lagoon. These differences may be explained by environmental factors especially temperature (Wooton 1998, Lorenzo et al. 2002). This is because temperature condition was affected by shallow waters in the lagoon system (Sumer et al. 2014). Sagi and Abraham (1984) reported that the water temperature and salinity effect reproduction periods.

Growth parameters provide some indication of resource utilization and the effectiveness of management strategies. When age and growth were evaluated in

Table 4
Comparison of von Bertalanffy growth parameters (L_∞, K, t_0) and growth performance index (Ø′) for *Lithognathus mormyrus* with other studies

Location	*n*	Method of age determination	Length range [cm]	Age range [year]	L_∞ [cm]	K [year^{-1}]	t_0 [year]	Ø′	Reference
Eastern Spain	2452	Scales	21.0–29.0	1–6	33.3	0.275	–0.057	2.48	Suau 1970
Northern Adriatic Sea	202	Scales	19.4–37.6	3–12	40.1	0.196	–0.945	2.50	Kraljević et al. 1996
Canary Islands	452	Otoliths	11.3–35.0	0–8	42.7	0.190	–1.460	2.54	Pajuelo et al. 2002
Gulf of İskenderun, Turkey	3336	Otoliths	9.1–27.7	1–7	30.22	0.157	–2.12	2.16	Türkmen and Akyurt 2003
Thracian Sea, Greece	721	Otoliths	5.1–34.1	0–11	30.9	0.210	–0.996	2.30	Kallianiotis et al. 2005
Waters off Alexandria, Egypt	891	Scales	9.0–25.0	1–7	37.1	0.127	–1.49	2.24	Osman 2005
Southern coast of Portugal (Algarve)	530	Otoliths	6.7–42.7	0–13	35.3	0.264	–0.809	2.52	Monteiro et al. 2010
Beymelek Lagoon, Turkey	338	Scales	12.6–30.4	0–7	31.7	0.267	–2.728	5.591	Sumer et al. 2014
South-western Mediterranean Sea	449	Otoliths	11.3–34.5	1–7	34.85	0.28	–1.12	2.54	Boufersaoui et al. 2018
Köyceğiz Lagoon, Turkey	319	Otoliths	2.5–24.1	0–5	28.6	0.284	–0.86	2.366	Presently reported study

n = the number of fish sampled, L_∞ = asymptotic length, K = growth coefficient, t_0 = hypothetical age, Ø′ = growth performance index.

combination, it may be easier to understand the relation between population size and biomass. This understanding is the basis of modern fisheries resource allocation and management. Fisheries management should be designed on biological data to understand the status and to manage fish stocks. This study provides first information related to age, growth, reproduction period, and length–weight relations of the sand steenbras from the Köyceğiz Lagoon and will hopefully contribute to a better local fisheries management.

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