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Research Article

Population Dynamics, Current Trends and Future Prospects of the Black Goby (*Gobius niger*) in the Eastern Part of the Black Sea (Turkiye)

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ABSTRACT

With its adaptation to the Black Sea, the black goby *Gobius niger* (Linnaeus, 1758) has increased in biological and ecological importance in recent years. Despite previous studies, up-to-date information on population status in the Black Sea is still lacking. Specimens were collected monthly from April 2020 to March 2021 from different commercial fishing landings on the Turkish coast of the eastern Black Sea. The total length of sampled individuals (n=630) ranged from 7.20 to 14.0 cm. Males were dominant throughout all size classes and the overall sex ratio was significantly different from the expected ratio of 1:1. The length-weight relationship indicated isometric growth (b=3) for both sexes. Spawning occurred from March to June. The observed maximum age was 4 and both males and females were dominant in age group 3. The black goby appeared to have relatively low growth rates (Φ′=1.74) in the Black Sea, but longer asymptotic length (L_∞=16.94 cm) data were obtained in the study area. The total mortality rate (Z) estimated by means of the catch curve method was 1.43 yr^{-1} and the fishing mortality (F) was 0.88 yr^{-1}. The estimated exploitation rate (E) was 0.61 yr^{-1} which was higher than the optimum value of 0.5. Updated biological parameter estimates show that black goby populations in the Black Sea are now more exploited than previously thought. Additional studies are recommended to ensure sustainable management of black goby populations and national regulations to reduce bycatch.

Keywords: Sex ratio, age, growth, mortality, fisheries management, black goby

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INTRODUCTION

The Gobiidae (Perciformes) family comprises at least 2000 species (Nelson, 2006) and is well known for its successful adaptation to different environmental conditions. A few gobiid species are also fully adapted to marine and freshwater ecosystems (Freyhof, 2011). The goby species are distributed in various seas carried by ballast water (Skora & Storlarski, 1993). There are 74 known species of goby in the Black Sea and the Mediterranean (Engin & Bektaş, 2010; Sezgin, Bat, Ürkmez, Arıcı, & Öztürk, 2017; Aydın & Bodur, 2018; Aydın, 2021a; Karadurmuş & Aydın, 2021). The black goby *Gobius niger* (Linnaeus, 1758), a gobid species, has recently reached the Black Sea and has adapted to this area in a short time. It is distributed commonly in the Eastern Atlantic and the Mediterranean Sea and is common in the Black Sea, Baltic Sea, and the Red Sea (Miller, 1986; Whitehead, Bauchot, Hureau, Nielsen, & Tortonese, 1986). It prefers muddy and sandy bottoms up to 80 m in depth (Miller, 1986; Kara & Quignard, 2019) and frequently enters estuaries and lagoons (Whitehead et al., 1986). Rocky substrates, sea grasses, and mussel shells serve as spawning habitats and refuges to hide from predators (Malavasi et al., 2005). It mainly feeds on crustaceans, bivalves, gastropods, polychaetes, and small fishes (Miller, 1986; Filiz & Toğulga, 2009; Bengil & Aydın, 2020).

It is suitable as an indicator for monitoring marine pollution (Ramsak et al., 2007), and also occupies an essential position in the food chain (Rigal et al., 2008). It is classified as a discard in the coastal fisheries of the Black Sea. Recently, gobies have become a more abundant species in fishing operations, and they have started to be sold commercially in fish markets (Aydın, 2021b). There is no fishing regulation due to their non-commercial value in Turkiye. Because of its biological and ecological importance, this species has attracted the attention of many scientists over the years. Several studies on the distribution, genetics, ecology, behavior, and biology of this species have been carried out in different regions (Vaas, Vlasbom, & De Koeijer, 1975; Nash, 1984; Joyeux, Bouchereau, & Tomasini, 1991; Silva & Gordo, 1997; Immler, Mazzoldi, & Rasotto, 2004; Hajji, Ouannes-Ghorbel, Ghorbel, & Jarboui, 2013; Locatello, Mazzoldi, & Rasotto, 2021; Matern, Herrmann, & Temming, 2021). Limited studies focused on the population status (sex ratio, age, growth, mortalities) and biological aspects (reproduction, feeding) of the black goby on the coast of Turkiye (Özaydın, Taşkavak, & Akalın, 2007; Kınacıgil et al., 2008; Filiz & Toğulga, 2009; İlkyaz, Metin, & Kınacıgil, 2011; Kırdar & İşmen, 2018).

The status of black goby populations in the Black Sea was examined by different researchers between 2008 and 2013. Unlike this study, Kasapoğlu (2016) studied a lower number of samples, a study carried out by Bilgin & Onay (2020) included only the province of Rize, and the age determination was made according to the computer-based length frequency distribution analysis. Van & Gümüş (2021) studied in the same region as the current study and examined more samples, but more than ten years have passed since their study. Up-to-date information about the latest status of these populations is not available. The present paper aims to assess the current status of the black goby population in the Black Sea (Turkish coasts), by determining growth and mortality rates based on age readings from the otolith. Past and present data were evaluated in terms of fisheries management and inferences were made about the future status of the populations. In addition, the sex ratio, length-weight parameters, spawning season, and condition of the population were also evaluated separately by sex.

MATERIAL AND METHODS

The sampling studies were conducted along the Turkish coast of the eastern Black Sea (from 41°21′N–36°14′E to 40°55′N–38°31′E) (Figure 1) between April 2020 and March 2021. The black goby was caught by commercial fisheries using artisanal gillnets with different mesh sizes, at depths ranging from the shoreline to 50 m. After sampling, the samples were stored and transferred to the laboratory in a cooler for further analysis. For each sample, the total length (TL) was measured to the nearest 0.01 cm and the total weight (TW) was weighed to the nearest 0.01 g. The samples were sexed based on the macroscopic observation of the gonads – which are tubular with capillaries and a yellow-orange color in females, and soft-textured, flat, and white-cream in color in males (Guellard, Sokołowska, & Arciszewski, 2015).

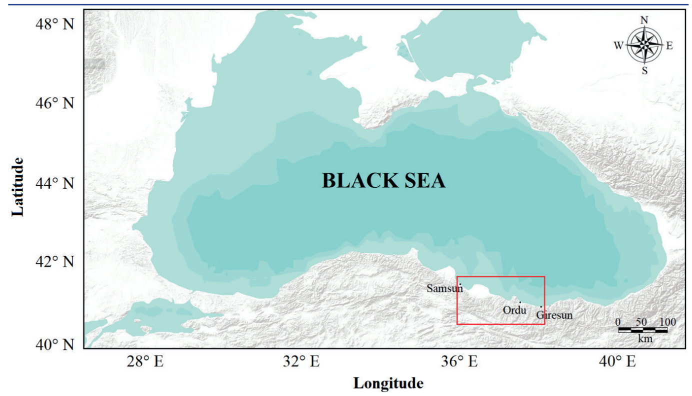

Figure 1. Location of sampling area in the eastern part of the Black Sea, Turkiye. The red line shows the limit of the study area.

The datasets of the total number of specimens by sex were used to calculate the sex ratio per month. In order to determine variations in the sex ratio, data were categorized into 1 cm TL size classes. Statistically, deviations from a theoretical sex ratio of 1:1 were determined by the Chi-square test (χ^2) (Zar, 1996).

The length-weight relationship (LWR) was estimated using the expression, $W=aL^b$ (Le Cren, 1951) where L is the total length (cm), W is the total weight (g), a is the intercept and b is the slope of regression. The regression coefficients (a and b) were computed using a least-square linear regression on log-transformed data (Froese, 2006). The growth type of the population was evaluated using the t-test to analyze whether the b slope was significantly different from the theoretical value of 3 (Sokal & Rohlf, 1969).

The spawning season was determined from the monthly variations of the gonadosomatic index (GSI) of the specimens and was calculated with the following formula GSI=GW×100/TW (Bagenal, 1978) where GW is the gonad weight (g) and TW is the total weight of specimen (g). Gonads were weighed to 0.001 g precision. Fulton's condition factor (Kn) was calculated with the formula $Kn=W/L^3\times100$ (Fulton, 1904), where L is the total length (cm) and W is the total weight (g).

Sagittal otoliths were removed, cleaned, and stored for further processing and readings (Chugunova, 1963). Otoliths were placed in alcohol and investigated under a stereo binocular microscope by 30× magnification and reflected light connected to a computer. The association of one opaque zone and one translucent zone was regarded as an annulus (Silva & Gordo, 1997; Florin et al., 2018). Only compatible otoliths were included in the reading's analysis. Age readings were performed by two independent readers. The error in the counting of the annuli between readers was evaluated by the coefficient of variation and percentage of agreement (Campana, 2001). Moreover, the index of average percent error was calculated according to Beamish & Fournier (1981). The length-at-age datasets were used to estimate von Bertalanffy (VBGF) parameters by sexes:

$$L_t = L_\infty (1 - e^{-K(t-t_0)})$$

where L_t is length at age t (yr), L_∞ is asymptotic length (cm), K is the intrinsic growth rate (yr^{-1}), and t_0=hypothetical age at which the length of the fish is zero (von Bertalanffy, 1938). Phi-prime growth index (Φ′) was calculated using the formula $\Phi' = \log K + 2\log L_\infty$ (Munro & Pauly, 1983).

The total mortality (Z, yr^{-1}) was estimated using a length-based converted catch curve analysis (Chapman & Robson, 1960). Natural mortality (M, yr^{-1}) was estimated using VBGF parameters and annual mean seawater temperature (16.4 °C; quoted from the Turkish State Meteorological Service) based on the equation of Pauly (1980). The fishing mortality (F, yr^{-1}) was obtained from the difference between Z and M. The exploitation rate was estimated using equation E=F/Z (Gulland, 1971).

Statistical analysis was performed at p = 0.05 using the statistical software SPSS v0.26. The normality of the data was checked using the Kolmogorov-Smirnov test, depending on the sample size (Sokal & Rohlf, 1969).

RESULTS

Sex ratio

The population consisted of 19.2% females and 80.8% males. The overall sex ratio (F:M) was 1:4.21 and was statistically significant departing from the expected ratio of 1:1 (X^2=238.96; n=630; df=1; p<0.001), indicating that males dominated the population. Although males predominated in all seasons, an almost equal sex ratio was observed in summer and autumn (Table 1). The sex ratio was balanced in the lower size interval (7 cm TL) and males significantly dominated in the upper size classes (8 cm TL) (Table 1).

Population status

The TL distribution range of black goby specimens was 7.20-14.0 cm (11.36±0.04), and the TW distribution range was 3.60-30.91 g (16.46±0.17) (Table 2). The majority of the samples (89.4%) were found in the size range of 10-13 cm. Males were abundant in longer length groups (Figure 2). The mean values of TL (U test; U=36695.0; Z=-2.280; p<0.05) indicated significant differences between males and females. No significant differences were identified for the mean TW between males and females (U test; U=29890.5; Z=-0.502; p>0.05). A significant difference was determined both in the mean TL (H test; H=77.205; df=11; p<0.001) and TW (H test; H=90.948; df=11; p<0.001) between sampling months.

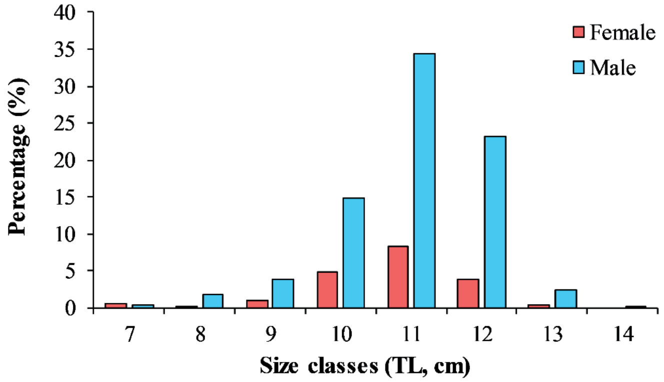

Figure 2. Length–frequency distribution of the studied *Gobius niger* population by sex.

Table 1. Sex ratios of *Gobius niger* according to months and size classes (TL, cm).

Key variables	Number of specimens		Sex ratio		
	Female	Male	Female:Male	χ^2	Significance
Months					
Apr 20′	17	134	1:7.88	90.66	***
May 20′	53	227	1:4.28	108.13	***
June 20	12	42	1:3.50	16.67	***
July 20	9	14	1:1.56	1.09	n/a
Aug 20′	8	12	1:1.50	0.80	n/a
Sep 20′	1	2	1:2.00	0.33	n/a
Oct 20′	2	5	1:2.50	1.29	n/a
Nov 20′	2	10	1:5.00	5.33	*
Dec 20′	4	17	1:4.25	8.05	**
Jan 21′	3	7	1:2.33	1.60	n/a
Feb 21′	4	18	1:4.50	8.91	**
Mar 21′	6	21	1:3.50	8.33	**
Size classes (cm)					
7	4	3	1:0.75	0.14	n/a
8	1	11	1:11.00	8.33	**
9	6	24	1:4.00	10.8	**
10	31	93	1:3.00	31.00	***
11	53	216	1:4.08	98.77	***
12	24	146	1:6.08	87.55	***
13	2	15	1:7.50	9.94	**
14	0	1	–	–	–
Total	121	509	1:4.21	238.96	***

Note: χ^2: Chi-square value, –: not calculated, n/a: not significant, *: p<0.05, **: p<0.01, ***: p < 0.001

Length-weight relationship (LWR)

The estimated LWR for the combined sexes was $TW=0.010TL^{3.019}$ (N=630; r^2=0.870) and the population exhibited isometric growth (t-test; t_{pauly}=0.411; p>0.05) (Table 2). Significant differences were determined between the predicted slopes (b) for male and female gobies (ANCOVA; F=19.973; p=0.031).

Gonadosomatic index (GSI) and condition factor (Kn)

The reproductive period extends from March to June, and spawning takes place intensively in May (Figure 3). The GSI values increased markedly between winter and spring when the evolution of gonadal development in the ovaries began. The highest GSI values were observed for May with 12.73% for females and for April with 1.03% for males. The resting period starts in September with low GSI values for females (0.68%) and in July for males (0.10%). Temporal variation of GW presents significant changes among months (H test; H=132.53; df=11; p<0.001).

Table 2. Descriptive statistics and estimated parameters of the length-weight relationship of *Gobius niger.*

	TL (cm)	Regression parameters			Confidence intervals (CI)		Growth parameters		
	Mean±SE (Range)	a	b±SE	r^2	Cla	Clb	$t_{(pauly)}$	Sig.	Growth
Female	11.17±0.10 (7.40-13.10)	0.011	3.029±0.09	0.905	0.007-0.016	2.851-3.208	0.319	ns	I
Male	11.40±0.04 (7.20-14.00)	0.010	3.040±0.05	0.865	0.008-0.013	2.935-3.145	0.747	ns	I
Combined	11.36±0.04 (7.20-14.00)	0.010	3.019±0.05	0.870	0.08-0.013	2.927-3.110	0.411	ns	I

Note: TL: total length, a: regression intercept, b: regression slope, r^2: coefficient of determination, Cl: 95% confidence intervals, sig: significance, I: isometric growth

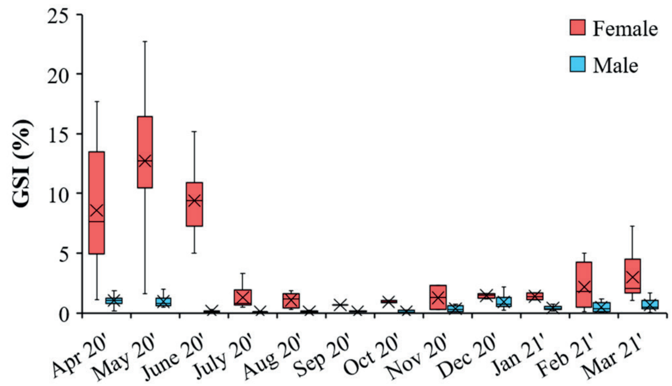

Figure 3. Box-plot of the gonadosomatic index (GSI%) for females and males of *Gobius niger.* Seawater temperatures along the study; Apr 20: 10.5 °C, May 20: 14.6 °C, June 20: 20.3 °C, July 20: 24.1 °C, Aug 20: 25.7 °C, Sep 20: 23.8 °C, Oct 20: 19.9 °C, Nov 20: 16.2 °C, Dec 20: 12.6 °C, Feb 21: 11.5 °C, Jan 21: 9.8 °C, Mar 21: 9.1 °C.

The mean Kn was calculated as 1.14±0.11, 1.09±0.01, and 1.10±0.01 for females, males, and combined sexes, respectively. The mean Kn was significantly different between females and males (t-test; t=20.286; df=1; $p<0.05$). The lowest Kn was observed in November for females (0.87) and in February and July for males (0.99) (Figure 4). The monthly variations of the Kn were not significantly different during all months (t-test; t=5.232; df=11; $p<0.05$).

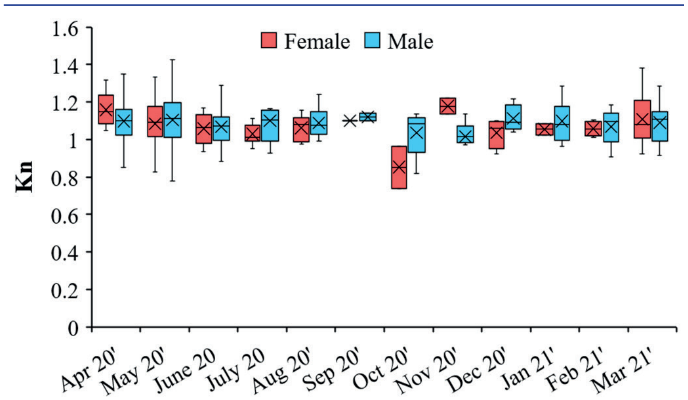

Figure 4. Box-plot of the condition factors (Kn) for females and males of *Gobius niger.*

Age and growth

The age of black goby specimens varied between 0 and 4 for both males and females. The otolith of a 13 cm long, four-year-old black goby is shown in Figure 5. Both females (42.1%) and males (55.4 %) were dominant in age group 3. The ratio of females (15.7%) and males (14.3%) at the maximum age (L_{max}) of 4 in the population was close together (Table 3).

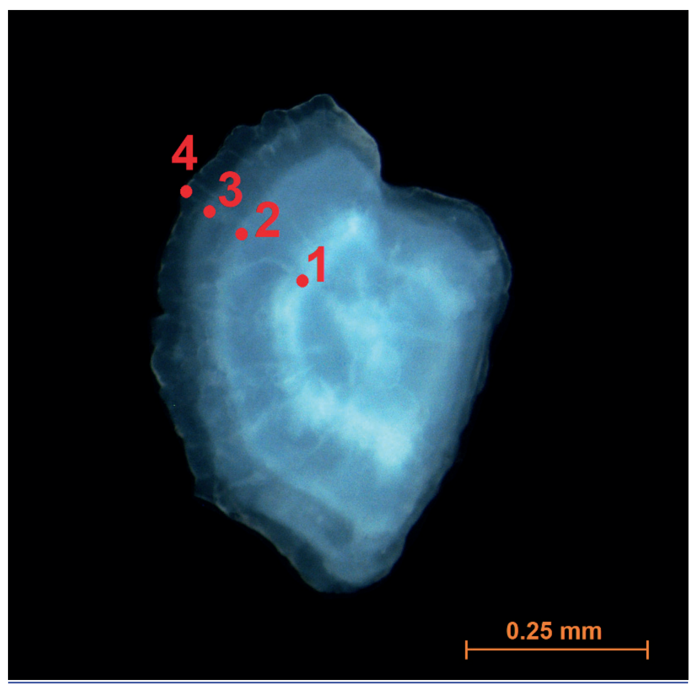

Figure 5. Sagittal otolith of a four-year-old black goby. Age rings are shown with red dots.

The VBGF equations were calculated as $L_t=14.55(1-e^{-0.29(t+2.45)})$, $L_t=18.05(1-e^{-0.16\ (t+3.23)})$, and $L_t=16.94(1-e^{-0.19(t+3.05)})$ for females, males and combined sexes, respectively. The predicted growth curve is illustrated in Figure 6. The Φ' was found to be 1.78, 1.73, and 1.74 for females, males, and combined sexes, respectively.

Mortality rates

The Z was estimated as 1.41yr^{1} and 1.46 yr^{1} for females and males, respectively. The other mortality estimates and exploitation rates are given in Figure 7. The E was calculated as higher than the optimum level (E~0.5) for the combined sexes (Patterson, 1992). The black goby stock in the study region appears highly exploited (E>50%, F/M>1).

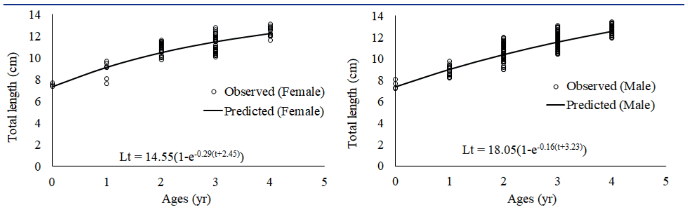

Figure 6. Estimated von Bertalanffy growth curves with observed (○) and predicted (–) length of *Gobius niger.*

DISCUSSION

The sex ratio may differ from the theoretical ratio of 1:1 by size class and gender in the same population, being influenced by reproductive behavior, the adaptation of the population, environmental conditions, and food availability (Clarke, 1983). In other studies of *Gobius niger* in the Black Sea, females were found to predominate males (Kasapoğlu, 2016; Bilgin & Onay, 2020; Van & Gümüş, 2021). However, in this study we report more males. The ratio obtained by the researchers in this study can be associated with the behavior of individuals during the reproduction period.

Table 3. Length-at-age key of *Gobius niger* for females and males based on otolith age readings.

Size classes (cm)	Age groups										Total	
	0		1		2		3		4			
	F	M	F	M	F	M	F	M	F	M	F	M
7	3	3	1								4	3
8		1	1	10							1	11
9			5	9	1	15					6	24
10					16	54	15	39			31	93
11					24	61	28	154	1	1	53	216
12						1	8	86	16	59	24	146
13								3	2	12	2	15
14										1		1
Total	3	4	7	19	41	131	51	282	19	73	121	509
TL_{avr} (cm)	7.53	7.58	8.91	8.90	10.97	10.74	10.79	11.62	12.36	12.61	11.17	11.40
±SE	0.09	0.21	0.29	0.10	0.07	0.05	0.04	0.03	0.10	0.04	0.10	0.04
TW_{avr} (g)	5.04	4.28	7.67	7.54	15.35	13.68	14.08	17.29	20.85	21.44	16.36	16.49
±SE	0.05	0.36	0.84	0.31	0.37	0.26	0.22	0.17	0.74	0.30	0.42	0.19

Note: F: female, M: male, TL_{avr}: average total length, TW_{avr}: average total weight, ±SE: standard error

Table 4. Parameter estimates of the von Bertalanffy and mortality rates of *Gobius niger* reported from various Turkish seas (modified and updated from Kasapoğlu, 2016; Kırdar & İşmen, 2018; Van & Gümüş, 2021).

Region	Sampling year	L_{max} (cm)	t_{max} (cm)	L_∞ (cm)	K (yr^{-1})	t_0 (yr)	Φ′	Z (yr^{-1})	M (yr^{-1})	F (yr^{-1})	References
BS	2020-2021	14.0	4	16.94	0.19	-3.05	1.74	1.43	0.55	0.88	This study
BS[a] BS[b]	2010-2011	13.4	5	13.26 13.96	0.31 0.29	-1.43 -1.42	1.73 1.75	1.26[a] 1.01[b]	0.65[a] 0.66[b]	0.61[a] 0.35[b]	Van & Gümüş, 2021
BS	2012-2013	14.6	4	12.10	0.68	-0.54	2.00	-	-	-	Bilgin & Onay, 2020
BS	2008-2011	15.8	5	17.95	0.27	-1.50	-	0.68	0.54	0.14	Kasapoğlu, 2016
MS	2011-2014	14.2	4	15.31	0.36	-1.77	1.92	1.34	0.82	0.51	Kırdar & İşmen, 2018
AS	2004-2007	16.3	7	17.18	0.39	-0.13	-	-	-	-	İlkyaz et al., 2011
AS	2003-2004	15.2	5	17.6	0.26	-2.17	1.90	-	-	-	Filiz & Toğulga, 2009
AS	-	-	-	16.8	0.39	-0.04	2.04	0.81	0.72	0.09	Kınacıgil et al., 2008
AS	1995-1996	-	3	14.6	0.46	-1.54	1.99	-	-	-	Özaydın et al., 2007

Note: BS: Black Sea, MS: Sea of Marmara, AS: Aegean Sea, L_{max}: maximum length, t_{max}: maximum age, L_∞: asymptotic length, K: growth rate, t_0: hypothetic age at zero length, Φ′: growth performance index, Z: total mortality, M: natural mortality, F: fishing mortality, [a]: Kızılırmak-Yeşilırmak shelf area, [b]: Melet River shelf area.

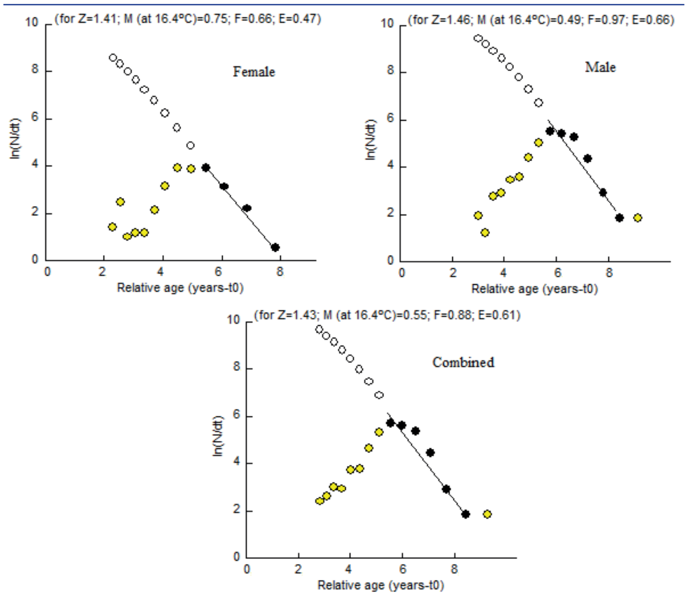

Figure 7. Parameter estimates of the mortality rates for the female, male, and combined *Gobius niger.* Derived from raw data based on a 0.5 cm size-class interval. Black dots represent the data used in the analysis.

The parental males of the black goby guard the nest until the eggs hatch (Mazzoldi, 1999). In this study, however, males were dominant during the reproduction period, and in other periods, sex ratios were almost equal (Table 1). Researchers in previous studies (Kasapoğlu, 2016; Bilgin & Onay, 2020; Van & Gümüş, 2021) used bottom trawls for sampling and this indicates non-selective sampling and a sampling site away from the shore. In this study, gill nets were used and sampling was made in a narrow depth range. In order to clarify this contradiction, it is recommended to examine the seasonal and reproductive migration behaviors of male and female black gobies. Males may have an advanced survival chance than females, especially in excessive environmental conditions, which explains the increasing male dominance with increasing size (Table 1). The studies reported that males become dominant during the spawning period (Hajji et al., 2013; Van & Gümüş, 2021). Males undertake burrow construction and egg maintenance (Filiz & Toğulga, 2009), and therefore the ratio of males caught during the spawning season is expected to decrease as they are not more easily caught (Miller, 1984). A male-biased sex ratio during the spawning season (May to June) does not mean that there is no burrow or egg maintenance. One of the reasons is probably the sampling method using gill nets. Since this study was mostly carried out with gillnets in areas close to the shore, males who took care of the nests may have been caught more.

The average TL of females was significantly lower, due to the predominance of males in the higher length classes (Figure 2). In contrast, different populations have been described where there is no difference in TL between males and females of black goby (Kasapoğlu, 2016; Kırdar & İşmen, 2018; Bilgin & Onay, 2020). The L_{max} of the black goby in the study area is close to that in previous studies in the Black Sea (Table 4). Differences in mean sizes between intra-specific populations may be due to several factors such as the relative abundance of the species, the selectivity of the fishing gears, sampling methods, or environmental variations (Baganel & Tesch, 1978; Edgar & Shaw, 1995; Gonçalves et al., 1997; Basilone et al., 2006).

The estimated *a* value for black goby was in accordance with the expected range of 0.001-0.05 for the natural fish populations (Froese, 2006). The b value of LWR is generally expected to be in the range of 2.5-3.5 for fish in general (Carlander, 1969) and the estimated b values of black goby were within expected ranges (Table 2). The black goby displayed an isometric growth (b=3) which may be concerned with the environmental factors of its natural habitat or its typical phenotype (Tsoumani, Liasko, Moutsaki, Kagalou, & Leonardos, 2006). This means that the length and weight of the individuals increase at the same rate. The LWR results in the Turkish coasts of the Black Sea show that the calculated b values were changed between 2.86 (Kasapoğlu, 2016) and 3.54 (Bilgin & Onay, 2020). LWR parameters may differ significantly due to environmental or biological factors, and temporal, geographical, and sampling factors (Bagenal & Tesch, 1978; Froese, 2006). Therefore, it is usual to obtain different results from different studies and regions.

Spawning of black gobies was observed in spring and at the beginning of summer in the study area (from March to June). This period coincided with the range where the seawater temperature was above 10°C and below 20°C. Partially similar spawning seasons are observed in the Black Sea (Bilgin & Onay, 2020), the Sea of Marmara (Kırdar & İşmen, 2018), the Aegean Sea (Özaydın et al., 2007; Kınacıgil et al., 2008) and in different countries (Arruda, Azevedo, & Neto, 1993; Immler et al., 2004; Hajji et al., 2013). Filiz & Toğulga (2009) reported a long spawning season from March to October in the Aegean Sea. Bilgin and Onay (2020) suggested that the extent of the black goby spawning period was mainly determined by daylight length and water temperature. Kara and Quignard (2019) linked the spawning cycle of the land goby with feeding. Due to the errors that are prone in macroscopic observations of gonads (West, 1990), it is usual for the spawning season to differ between regions. GSI values were lower in males than in females. The lower GSI value for males is a general characteristic of most gobies (Miller, 1984) including the black goby (Hajji et al., 2013). Females commonly invest more in reproduction than males. The testes are lighter than the gonads and constitute a lower ratio of the total fish weight (Wootton, 1990).

High conditions estimated for the black goby (Kn>1) may be signs of favorable environmental conditions and good nutrition (Le Cren, 1951). There was no significant difference between mean Kn and monthly seawater temperature (t-test; p>0.05) for these fish species (Figure 4). Fish feeding activities are reduced during spawning, they use up their lipid reserves, and their condition is significantly reduced (Lloret, Demestre, & Sánchez-Pardo, 2007). On the contrary, as the spawning season of the black goby begins in the cold season, the sudden increase in Kn observed in the spring can be explained by the increase in gonadal mass. The Kn of females was significantly higher than males only in spring, while males had higher Kn in other seasons (Figure 4). Males undertake critical tasks such as burrow construction, egg maintenance, and intraspecific competition

(Clark, Stoll, Alburn, & Petzold, 2000; Dinh, Qin, Dittmann, & Tran, 2014). During this time, females have more feeding opportunities because they need more energy to prepare for reproduction. These behaviors are thought to be the main factor in the low Kn values of males.

Males were more dominant in all age groups and females revealed a younger age profile (Table 3). The maximal life span was determined as 4 years in this study. Similar age groups (Kırdar & İşmen, 2018; Bilgin & Onay, 2020) and older individuals were reported from the Turkish coasts (Filiz & Toğulga, 2009; Kasapoğlu, 2016; Van & Gümüş, 2021). The longest lifespan of the black goby reported so far was 7 years in İzmir Bay, in the Aegean Sea (İlkyaz et al., 2011).

L_∞ calculated in this study is higher than noticed in previous studies on the Black Sea coasts (Table 4). The differences may be due to the selectivity of gill nets that can select especially smaller individuals of black goby (Wootton, 1990). However, high L_∞ values indicate that black gobies in the study area have a longer chance of living. Van and Gümüş (2021) reported a younger age profile for the black goby in the Black Sea related to high fishing pressure due to bottom trawls. The sexes have different growth rates, as is similarly recorded in different studies (Silva & Gordo, 1997; Filiz & Toğulga, 2009; Van & Gümüş, 2021). The Φ′ value was estimated lower than in other regions, but similar to studies carried out in the Black Sea (Table 4). The results indicated that the growth performance of the black goby is relatively low in the Black Sea. Geographical differences in the growth parameters of fishes may be based upon various factors such as environmental conditions, fishing pressure, sampling methodology (Blanchard et al., 2005; Mouine-Oueslati, Ahlem, Ines, Ktari, & Chakroun-Marzouk, 2015), the physicochemical contents of the water, environmental factors (Özeren, 2009), and genetics and social interactions (Helfman, Collette, & Facey, 1997).

In this study, the E are mostly higher than in previous studies performed on the Turkish coasts (Kınacıgil et al., 2008; Kasapoğlu, 2016; Kırdar & İşmen, 2018; Van & Gümüş, 2021) (Table 4). The black goby does not have commercial value but is captured together with target species, and it is categorized as 'discard' prey in gill nets (Aydın, Karadurmuş, & Kontaş, 2015) and trawling (Bilgin & Onay, 2020). Small-scale fishing in the Black Sea is an important source of livelihood and gillnets are frequently used in coastal areas (Aydın et al., 2015). In addition, rapa whelk fishing with beam trawl is carried out intensively in areas close to the coast of the Black Sea (Aydın, Düzgüneş, & Karadurmuş, 2016). It is inevitable that the black goby distributed in the shallower area where small-scale fishing and beam trawling are densely carried out is subject to death due to fishing activities. This unreported mortality rate explains the high fishing mortality in the Black Sea (Table 4). For the sustainable management of black goby populations, it is recommended to investigate the exploitation effect of different fishing gear. The higher mortalities in males ($Z=1.46\ yr^{-1}$) than in females ($Z=1.41\ yr^{-1}$) may be due to their sociobiological and ecological behaviors. Males prepare nests in a seagrass area in shallow coastal territory. Females lay their eggs in the nest and the males guard them until hatching (Poli et al., 2021). Black goby can compete with native fish for nesting spots during the guarding period (Janssen & Jude, 2001). This competition makes males more sensitive to survival.

CONCLUSION

The broad adaptive abilities and the successful reproductive strategy of the black goby are expected to result in further colonization and competition with other species in the Black Sea. Even though the population status of black gobies (in terms of size distribution, Kn, L_{max}, L_∞ , and Φ′) has not fluctuated much over the years in the Black Sea, this should not be considered a sign of potential resilience. It can be concluded that the black goby exhibited a high degree of tolerance in the Black Sea ecosystem, but there was an adverse effect of the fishing pressure based on discard on its population. There are no known species-specific protection programs for the black goby in the Black Sea. The living areas are open for commercial fisheries, including trawling, in the Black Sea. The response of the population to intense fishing pressure may depend on additional factors, such as vulnerability to capture, selectivity of fishing gear, and the survival of species in their natural environment. Further studies on catch per unit effort will provide more concrete data on prey pressure and species behavior. Bilgin and Onay (2020) reported the size at sexual maturity of the black goby as 8.9 cm for combined sexes in the Black Sea. Approximately 97% of the individuals in the population had reproductive potential (>9 cm). To make the sustainability of this population possible, a more restrictive arrangement is suggested, where only adult individuals are caught. Such an arrangement would allow successful spawning activities and recruitment in the subsequent season. Recently, goby species have started to be sold commercially in fish markets (Aydın, 2021b). The black goby may potentially become a commercial fish for coastal fisheries on the Black Sea coast of Turkiye and become an important source of income for fishermen. Although the black goby is not yet consumed as primary human food, its sustainable management is required because it forms the food of other commercial species such as turbot and whiting. In this case, long-term monitoring studies (stock and biomass estimation, spawning, and recruitment) and good management strategies (locational and seasonal prohibitions, catch quota, and regulation of selective fishing gears) will be needed to maintain stocks in the Black Sea. Updated parameter estimates and results serve as important indicators of fisheries management, and should be documented and monitored for changing trends.

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