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Age, Growth and Mortality of Garfish, *Belone euxini* Günther, 1866 in the Central Black Sea, Turkey

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ABSTRACT

A total of 986 garfish were collected from commercial fisheries, using encircling nets between October 2016 and December 2017 in Sinop, Central Black Sea. The length and weight distribution of all garfish samples ranged from 28.8 to 51.6 cm TL and from 26.6 to 177.2 g, respectively. Female: male ratio was 0.3:1. The LWR parameters (*a, b*, r^2) were computed as 0.0009 ± 0.50, 3.040 ± 0.32 and 0.902 ±0.40, respectively. The age of garfish was between 1 and 4 years. The estimated von Bertalanffy growth parameters with standard errors were L_∞= 55.74 ±26.75 cm, K= 0.28 ±0.42, and t_0=-1.68 ±2.02. Natural, fishing and total mortality of the garfish were 0.47, 0.69 and 1.16, respectively. The current study revealed that about 68% of the fish caught were of size smaller than the first maturity length. In addition, exploitation rate was found to be higher than optimum. On the other words, there is a fishing pressure on the garfish stock in the Black Sea due to absence of minimum landing size (MLS) of the garfish. Apart from direct fishing control measures aiming to reduce fishing mortality, the establishment of a MLS of 38cm that coincides with the length at first maturity would be also beneficial for the stock. Our results suggest that the garfish stock undergoes high levels of fishing pressure and the adoption of management measures is necessary.

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Authors' Contribution
TC and OA designed and supervised the work. OS collected the samples and conducted the experimental work. OA helped in data analysis. TC wrote the manuscript.

Key words
Garfish, *Belone euxini*, Minimum landing size.

INTRODUCTION

The family Belonidae includes 32 species in all tropical and temperate seas, a few in freshwater, four species (*Belone belone, B. svetovidovi, Tylosurus acus imperialis* and *T. choram*) in the Mediterranean, all in the eastern basin (Golani *et al*., 2006). Three subspecies are recognized: *Belone belone belone* (Linnaeus, 1761), *B. belone euxini* Günther, 1866 and *B. belone acus* Risso, 1826 (Collette, 2015). *Belone euxini* is an endemic species for Black Sea, Sea of Azov and Sea of Marmara (Froese and Pauly, 2017).

This epipelagic species is found in surface waters, and it swims solitary or in small groups, and it feeds on small fishes, particularly clupeids and engraulids (Golani *et al*., 2006; Collette, 2015).

In the Black Sea, *B. euxini* females reached sexual maturity at age 2 and at 38.8 cm; and the spawning period begins in May with peaks in July to September (Samsun *et al*., 2006; Bilgin *et al*., 2014b). There were only a few biological studies on garfish in the Turkish Black Sea and they were growth characteristics and population biology and status of exploitation (Samsun, 1995; Samsun *et al*., 2006; Bilgin *et al*, 2014a), on the age determination, age-length and length-weight relationships (Polat *et al*., 2009), reproductive biology (Bilgin *et al*., 2014b) and feeding habits (Kaya and Sağlam, 2017).

Garfish fishing in the Black Sea is carried out mainly by encircling nets. Occasionally, the garfish is caught as by-catch from anchovy purse-seiners. The most garfish production in Turkey comes from the Black Sea (FAO, 2017). A total of 268 tons garfish were caught in Turkish waters in 2016, and more than 52% were from the Black Sea, especially the eastern part (TUIK, 2018). Between 2000 and 2015, 44% of the total production of garfish throughout the Mediterranean comes from Turkey, while 94% of catch of garfish from Black Sea countries (Bulgaria, Romania, Russia Federation and Ukraine and Turkey) belongs to Turkey (FAO, 2017). Therefore, Turkey is main garfish producer in the Mediterranean. However, total production tends to declining in the last six years (average: 278 tons). For instance, garfish production fluctuated from 661 tons in 2010 to 205 tons in 2013 (average for 2000-2016 is 396 tons). It seems that there is an intensive fishing on garfish stocks in the Black Sea. The stock status and level of fishing of the garfish in the Black Sea should be monitored to realize the fisheries management aimed to sustainable economic and social benefits from harvesting and conserving productivity of the fish stock. Thus, the current study analyses biological and fisheries data for garfish in the southern Black Sea, in order to estimate

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essential stock parameters and identify exploitation levels.

MATERIALS AND METHODS

A total of 986 garfish used in this study were collected from commercial fisheries, using encircling nets between October 2016 and December 2017 in Sinop, Central Black Sea. The encircling gillnet has 150 m length and 4 m depth. It has 11 mm stretched mesh size and it is used from sunset to night via phosphorescence by an observer.

Sex of fish was determined by gonadal examination. Sagittal otoliths were removed, wiped clean, and stored dry in U-plates to read the ages. The age of 270 sagittal otoliths was determined by two readers, otoliths being placed in glycerol and examined under a binocular microscope (SOIF XSZ-7GX) equipped with a camera at 10× magnification under reflected light and against a dark background.

Specimens were measured to the centimetre (±0.1 cm) total length (TL) and live round weight (W) was also recorded in grams (±0.1 g). The length–weight relationship (LWR) was estimated based on power regression as $W = aL^b$. The logarithmic transformation was performed as $\log W = \log a + b \log L$; where, W is weight (g), L is length (cm), a is the intercept and b is the slope of the linear regressions.

Non-seasonal growth parameters (L_∞, K, and t_0) were estimated with the von Bertalanffy growth formula (VBGF) in the FAO–ICLARM Stock Assessment Tools (FISAT II) computer program (FAO, 2006-2008) using individual lengths-at-age. The von Bertalanffy growth equation for length, $L_t = L_\infty [1 - e^{-K(t-t0)}]$; where, L_∞ is the asymptotic length, K the growth curve parameter, and t_0 the theoretical age when fish length would have been zero, was applied. Overall growth performance was estimated by the index Φ' (phi-prime test) (Pauly and Munro, 1984), $\Phi' = lnL + 2lnL_\infty$.

Natural mortality of specimens was computed from Pauly (1984a) following multiple regression formula, $lnM = - 0.0152 - 0.2779\ ln(L_\infty) + 0.6543\ ln(K) + 0.463\ ln(T)$. The mean annual habitat temperature (according to World Sea Temperatures, 2018) is assumed as 13.5ºC.

The total mortality (Z) of the fish species was estimated using FiSAT II (FAO, 2006-2008) from linearized length-converted catch curve analysis of the length frequency data (Pauly, 1984b; King, 1995). A linearized length-converted catch curve was constructed using the following formula to estimate total mortality (Z): $ln (N_T / \Delta_t) = a + b_t$; where, N is the number of individuals of relative age (t) and Δ_t is the time needed for the fish to grow through a length class. The slope (b) of the curve with its sign changed gives Z.

The fishing mortality rate, F, was calculated as Z−M and exploitation ratio (E) found as E=F/Z (Sparre and Venema, 1992). The exploitation rate indicates whether the stock is lightly (E < 0.5) or strongly (E > 0.5) exploited, based on the assumption that the fish are optimally exploited when F = M or E= 0.5 (Gulland, 1971).

To test for normality and homoscedacity, data was evaluated using tests of: Kolmogorov–Smirnov (Zar, 1999) and statistical method of Skewness and Kurtosis (Tabachnick and Fidell, 2013). If the datasets passed the normality test, parametric procedures were employed; otherwise, data were transformed using an appropriate transformation process (*e.g.,* log) to meet the underlying assumptions of normality (Zar, 1999). The obtained coefficients of linear regressions of length-weight data were analysed with ANOVA (Zar, 1999). The degree of relationship between the variables was evaluated by the determination coefficient, r^2. The null hypothesis of isometric growth (H_0: b = 3) was tested by t-test, using the statistic: ts= (b-3)/Sb, where Sb is the standard error of the slope for α = 0.05 (Sokal and Rohlf, 1987). Female male (F:M) ratio in all age groups were tested by χ^2 of independence. The difference between the observed mean lengths and calculated mean lengths in all age groups were tested by Paired Sample t-test (Zar, 1999). The comparisons of growth performance indices were also performed by unpaired two-tailed t-tests. The significance level α for a given hypothesis in all statistical tests performed in this text is at 0.05. All of the means were given with standard error (±SE). All calculations were performed using the IBM SPSS Statistics Version 20 software package.

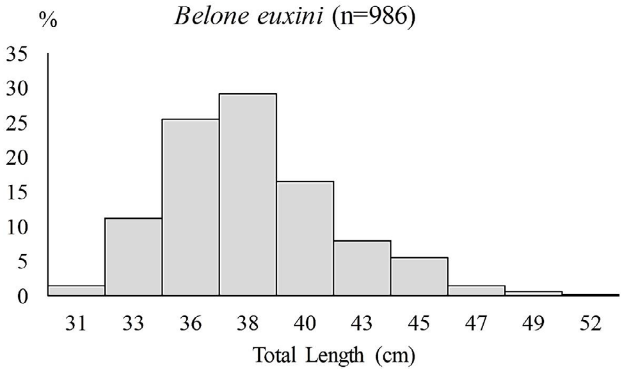

Fig. 1. Length-frequency distribution for *Belone euxini* in the Central Black Sea.

RESULTS

The length and weight distribution of all garfish samples ranged from 28.8 to 51.6 cm (average: 36.97±0.11 cm) and from 26.6 to 177.2 g (average: 56.90±0.60 g), respectively (Table I). The length distribution of all fish is indicated in Figure 1; the 38 cm length range had the highest rate that is approximately 30%. Female: male ratio was 0.3:1 and males dominated all age groups. There is a significant difference between female/ male ratios in all age groups ($p<0.05$).

Table I.- Range, mean with standard error (SE), median and mode of length (TL, cm), and weight (W, g) for garfish in the Central Black Sea.

n=986	Length (cm)	Weight (g)
Range	28.8-51.6	26.6-177.2
Mean±SE	36.97 ±0.11	56.90 ±0.60
Median	36.4	52.1
Mode	36.5	42.5

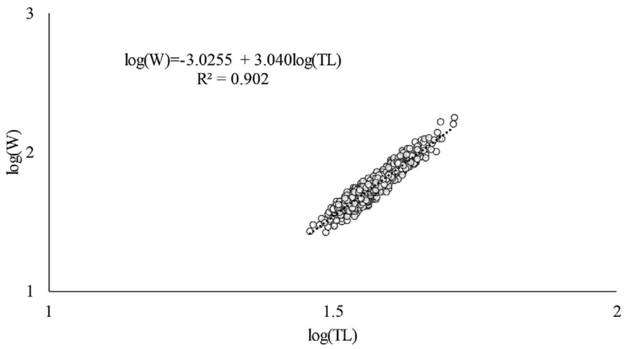

Fig. 2. Log transformed length-weight relationship for *Belone euxini* in the Central Black Sea.

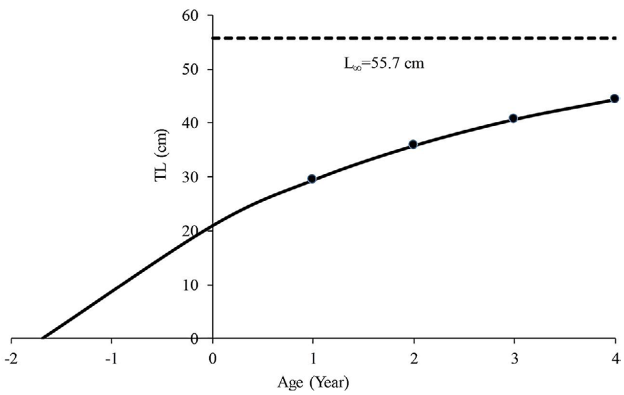

Fig. 3. Von Bertalanffy growth curve fitted by length-at-age for garfish, *Belone euxini* in the Central Black Sea.

The length–weight relationship is shown in Figure 2. The LWR parameters (*a*, *b*, r^2) were computed as 0.0009±0.50, 3.040±0.32 and 0.902±0.40, respectively. The *b* value indicates an allometric growth ($p<0.05$).

The age of garfish was between I and IV. Thus, the estimated von Bertalanffy growth parameters with standard errors were L_∞= 55.74±26.75 cm, K = 0.28±0.42, and t_0=-1.68± 2.02. The von Bertalanffy growth equation for length was $L_t = 55.74[1 - e^{-0.28(t+1.68)}]$. The observed lengths of garfish assigned to each age group were used to fit the VBGF (Fig. 3). There were statistical differences between the observed (obs) and calculated (calc) mean lengths in all age groups ($p<0.05$) except age III ($p>0.05$; Table II). Growth performance was estimated as 2.939 by the index Φ`.

The natural and fishing mortalities of *Belone euxini* are demonstrated in Table III. Exploitation rate was also calculated as 0.59.

Table II.- Observed and calculated mean lengths (TL, cm) of garfish of each age group.

Length parameter	Value per age group (year)			
	1	2	3	4
L_{obs}	31.6	35.5	41.0	47.9
L_{calc}	29.4	35.8	40.7	44.4

Table III.- Mortalities (M, F, Z) and exploitation rate (E) of garfish in the Central Black Sea.

Natural mortality M $year^{-1}$	Fishing mortality F $year^{-1}$	Total mortality Z $year^{-1}$	Exploitation rate E $year^{-1}$
0.47	0.69	1.16	0.59

DISCUSSION

In the Black Sea, *Belone euxini* is a commercially important fish for fresh consumption. It's price range is 8 - 25 TL/kg (2 - 6.5 $/kg). It is usually caught by small boats (5-10 m LOA) at a depth of 2-50 m on rocky and/or gravel bottom during autumn and winter.

In this study, length frequency distribution of the sampled fish was comprised between 33 and 40 cm TL. Samsun *et al*. (2006) reported that females reached 50% sexual maturity at age 2 and 38.8 cm length. Thus, about 68% of fish is under first maturity length. However, there is no minimum landing size (MLS) regulation in the Turkish Fisheries Regulation Circular (TFRC).

B. euxini exhibited positive allometric growth (*b*=3.040±0.32). The previous data about length-weight realtionships (LWRs) in the Black Sea are presented in Table IV. During the present study, the *b* values were generally in agreement with all former results.

Table IV.- Substantial LWR records of *Belone euxini* in the Black Sea.

Authors	n	L_{min}-L_{max}	W_{min}-W_{max}	a	b	r^2
Samsun (1995)	643	34.1-50.9	39.8-156.6	0.0006	3.18	0.94
Samsun et. al. (1995)	682	31.9-56.9	32.0-208.4	0.0047	3.22	0.94
Samsun *et al*. (2006)	931	29.0-58.0	23.5-258.4	0.0008	3.14	0.94
Polat *et al*. (2009)	278	23.7-60.3*	12.0-277.0	0.0005	3.25	0.94
Bilgin *et al*. (2014a)	1211	22.2-65.1	-	0.0005	3.14	0.92
This study	986	28.8-51.6	26.6-177.2	0.0009	3.04	0.90

*as FL.

Table V.- The natural, fishing, total mortality and exploitation rates of *Belone euxini* derived from different studies.

Authors	Natural mortality M $year^{-1}$	Fishing mortality F $year^{-1}$	Total mortality Z $year^{-1}$	Exploitation rate E $year^{-1}$
Samsun *et al*. (1995).	0.360	0.710	1.070	0.664
Samsun (1996)	0.520	0.640	1.160	0.552
Samsun (2006)	0.230	1.010	1.240	0.815
Bilgin *et al*. (2014a)	0.39♂ 0.34♀	0.85♂ 0.7♀	1.24♂ 1.04♀	0.69♂ 0.67♀
This study	0.47	0.69	1.16	0.59

Several researchers reported the growth parameters for garfish in Central Black Sea between 56.1 and 79.05, 0.125 and 0.198; -1.42 and -2.25 for L_∞, K and t_0, respectively (Samsun, 1995; Samsun *et al*., 1995, 2006; Polat *et al*, 2009). Bilgin *et al*. (2014a) estimated L_∞=81.6, K=0.125 and t_0=-2.25 for garfish population in South eastern Black Sea. In this study, estimated von Bertalanffy growth parameters were 55.74, 0.28, -1.68 for L_∞, K and t_0, respectively. Although, L_∞ in this study is on the small side, our results are consistent with the estimated parameters above. The small maximum recorded length of the garfish sampled in this research could explain relatively the difference. Charnov and Berrigan (1991) argued a negative relationship between the Brody growth coefficient (K) and the maximum asymptotic length. Therefore, comparisons of estimated growth parameters are problematical due to the negative relationship between them. Φ' indicates the growth performance and the parameter that corresponds to growth rate is suitable for comparisons because of its statistical robustness (Gallucci and Quinn, 2011). The growth performance index values are 2.881, 3.03, 2.86, 3.092 and 2.92 for Samsun (1995), Samsun *et al*. (1995), (2006), Polat *et al*. (2009) and Bilgin *et al*. (2014a), respectively. There is no significantly difference between them and present value of 2.939 ($p>0.05$).

Mortality rates are important to determine abundance of fish population. The estimated values of mortality and exploitation rates of *B.euxini* derived from previous researches are shown in Table V. All natural mortality values seem high in Table V. Natural mortality is an outcome of behavioural and life history strategies. It can be affected by environmental changes, food availability and mortality at the spawning grounds. Natural mortality could also rise in some heavily harvested stocks (Jørgensen and Holt, 2013). In the previous studies all of the explotation rates were higher than 0.5 (*i.e.* over exploited stock). The current findings are in line with past studies indicating that most Mediterranean and Black Sea stocks are over-exploited as the other fish populations in many parts of the world (Vasilakopoulos *et al*., 2014; Cardinale and Scarcella, 2017; Muhammad *et al*. 2017).

The current study revealed that about 68% of the fish caught were of size smaller than the first maturity length. In addition, exploitation rate was found to be higher than optimum. Although our findings should be considered as preliminary due to the short time series of data, they suggest that the garfish stock undergoes high levels of fishing pressure and the adoption of management measures is necessary. Apart from direct fishing control measures aiming to reduce fishing mortality, the establishment of a MLS of 38cm that coincides with the length at first maturity (Samsun *et al*., 2006) would be also beneficial for the stock.

CONCLUSION

Based on the above discussion, we conclude that the garfish stock undergoes high levels of fishing pressure and the adoption of management measures is necessary. Therefore, we recommend to reduce fishing mortality and the establishment of a MLS for sustainable economic and social benefits from harvesting and conserving productivity of the fish stock.

Statement of conflict of interest

Authors have declared no conflict of interest.

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