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RESEARCH

Determination of Growth and Reproduction Characteristics of Garfish (*Belone Euxini* Günther, 1866) in the South Black Sea

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Abstract

In this study, it was aimed to determine some basic population parameters (age, length, sex composition, length-weight relationship, age-length relationship, growth parameters, condition factor, GSI) of garfish (*Belone euxini*, Günther, 1866) in the southern Black Sea region coasts. A total of 917 fish were sampled in the study, and their average length and weight were determined as 37.31 ± 0.147 cm, 58.74 ± 0.876 g. The ages were between 1 and 7 and 40.89% of fish consisted of 3 years old. Sex ratio (F:M) is determined as 1:1.81. Length-weight relationship equations $W = 0.0005*L^{3.196}$, $W = 0.0009*L^{3.040}$, $W = 0.0005*L^{3.196}$ for females and males and all, respectively. Asymptotic length (L_∞) and the growth coefficient (k) were estimated at 78.20 cm and 0.119 $year^{-1}$ for females, 69.82 cm and 0.120 $year^{-1}$ for males and 92.06 cm and 0.082 $year^{-1}$ for all indivuduals. Instantaneous total mortality, natural mortality and fishing mortality rates were calculated as $Z = 1.02$ $year^{-1}$, $M = 0.16$ $year^{-1}$, and $F = 0.86$ $year^{-1}$ for combined sexes. Exploitation rate was $E = 0.84$. The population of *Belone euxini* was affected by fishing during the study period, according to the estimated E values. According to the GSI values calculated for *Belone euxini*, it was determined that reproduction started in July and continued until October.

Keywords Garfish · *Belone Euxini* · Growth · age · Reproduction · Black Sea

Introduction

The garfish (*Belone belone*) is a pelagic and migratory fish species with economic value in the waters of our country and in other countries where it is distributed along coastal areas (Slastenenko, 1955–1956). *B. belone* has three subspecies, each of which is distributed in different regions. *B. belone belone* (Linnaeus, 1761) is distributed from the northern region of France to the northeastern Atlantic. *B. belone euxini* (Günther, 1866) is found in the Black Sea and the Sea of Azov. *B. belone gracilis* (Lowe, 1839) is distributed in the northwest Atlantic and the Mediterranean. The meristic characters that distinguish these subspecies are the number of vertebrae and the number of dorsal fin rays. Another species, *Belone svetovidovi* (Collette and Parin 1970), is found in the northeastern Atlantic and the Mediterranean (Collette and Parin 1986).

Turkey's total fisheries production amount in 2022 is 849,808 tons and 301,747 tons of this is provided by catch from the seas. On the other hand, 73.4% (221,507 tons) of the production (301,747 tons) obtained through catch provide from the Black Sea (TSI, 2013). 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 (Ceyhan et al. 2019). Between 2015 and 2022, 36.4% of the total garfish production in Türkiye was provided from the Marmara Sea and 43.8% from the Black Sea. The garfish, an economically significant species in small-scale fisheries, had 58.2% (108.5 tons) of its annual production of 186.2 tons in the year 2022 originating from the east Black Sea region (TSI, 2013). Some of the previous studies on garfish as follow; some biological parameters (Uçkun et al. 2004), age, growth and reproduction (Zorica and Kec 2013; Ceyhan et al. 2019; Châarii et al., 2022), growth characteristics (Samsun 1996) population dynamics (Bilgin et al. 2014), population biology and status exploitation (Samsun et al. 2006), age-length and length-weight relationships

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(Polat et al. 2009; Samsun et al. 2017; Çayır and Bostancı 2022), feeding habits (Kaya, 2018). Fish size, weight, age, and gender compositions can vary due to differences in the type of fishing gear used, fishing methods, sampling techniques, fishing time, and the location of the fishery grounds (Özdemir et al. 2006). Considering the overexploitation of many fish stocks in the Mediterranean and Black Sea, determining data related to the populations such as biological, fishing, and stock assessment is crucial for the sustainability and conservation of fisheries resources (Vasilakopoulos et al. 2014; Cardinale and Scarcella 2017). In this study, crucial parameters for fishery management of the garfish, including age, size, and gender composition, size-weight relationship, population growth equation, and GSI values, were determined. The obtained results were interpreted, and comparisons were made with the findings of previous studies. The study data may be useful in determining the level of exploitation of the species and ensuring the sustainability of its exploitation.

Materials and Methods

The research was conducted in the Southern Black Sea (between Samsun and Trabzon) in monthly intervals from January 2022 to February 2023 (Fig. 1). The examined samples were obtained through purchasing fish caught using fishing gear commonly used by coastal commercial vessels (such as garfish nets, gillnets, etc.).

In the study, the total length measurements of the collected samples were carried out using a millimeter-graded measuring board, while the weight measurements were conducted with an electronic scale with a precision of 0.01 g. In assessing important parameters like population structure, growth, and mortality rates of fish populations, age determination plays a crucial role. Fish age is often estimated using bony structures such as otoliths, scales, vertebrae, opercula, and fin rays. The otolith, used for fish age determination, is one of the three pairs of otoliths located in the inner ear, with the sagitta being the largest (Polat 2000). In this study, age determinations were attempted using otoliths. Otoliths, removed from the fish and cleaned, were stored in dry envelopes. Annuli of whole otoliths from each individual were determined under a binocular stereo microscope with x10 magnification and top illumination (Chilton and Beamish

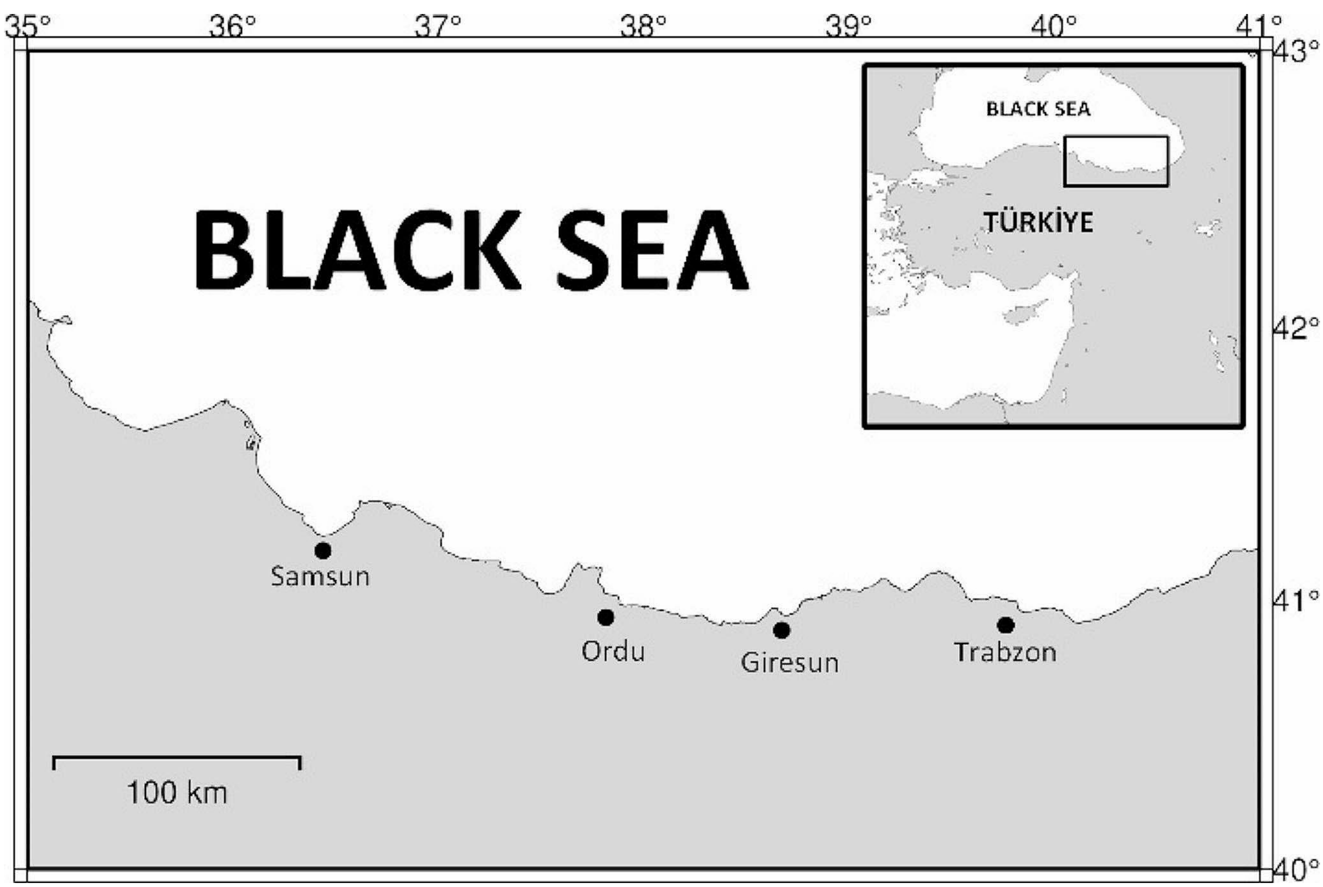

Fig. 1 Research area

1981). Age of indivuduals was assessed by two readers through otolith readings without referring to information. The individual age was estimated by counting growth increments, one opaque zone with one translucent zone was considered as annual growth (Wright et al. 2002) (Fig. 2).

In fish, there is an exponential relationship between size and weight, as indicated by the equation $W=a*L^b$ (Bagenal and Tesch 1978). In the size-weight relationship equation, W represents the fish weight in grams, a and b are the relationship constants, and L represents the fish length in centimeters. When $b=3$, the increase in weight is isometric. When the value of b is other than 3, weight increase is allometric (positive if $b>3$, negative if $b<3$) Significant difference of b values from 3, which represent isometric growth was determined by Student's t-test, ts=(b-3)/SE(b) (Sokal and Rohlf 1987). Where: ts is t-test value, b is a slope, and SE(b) is a standard error of the slope. The 95% confidence interval, CI of 'b' was computed using the equation, CI = b ± (1.96 x SE(b). Where SE is the standard error of 'b (Froese 2006).

Fulton's condition factor (K) was estimated using the formula $K = (W/L^3)*100$ (Ricker 1975; Froese 2006). In this equation, W represents the weight (g) of fish and L represents the total length (cm). The condition factor is a parameter used for comparing different stocks of the same species under different environmental conditions or time periods. It is also useful for determining the timing and duration of sexual maturity in stocks, as well as monitoring changes in feeding activities on a monthly and seasonal basis (Ricker 1975).

The von Bertalanffy growth equations were used to determine the age–length relationship of the population (Ricker 1975; Von Bertalanffy 1957). The equation is given as follows: $L_t= L_\infty*[1- e^{(-k(t - t_0))}]$. Where: t is the age (years), t_0 is the theoretical age at which the fish's length is considered to be zero (years), L_t is the length of the fish at age t (cm), k is the Brody coefficient, L_∞ is the asymptotic length (cm).

The growth performance index (Φ') was calculated as $\Phi'=\log(k)+2\log(L_\infty)$, where k and L_∞ are von Bertalanffy growth equation parameters. Munro's Phi Prime Test was used in order to compare the calculated equations with previous studies (Pauly and Munro 1984).

Gonadosomatic index (GSI) values are utilized for monitoring seasonal changes in gonads of fish and determining the breeding season. GSI is calculated as (gonad weight/total weight)*100 (Nikolsky 1969). GSI=(GW/W)*100. Where: GW: Gonad Weight (g), W: Fish Body Weight (g).

Total mortality (Z) was estimated from the mean size in the catch, developed by Beverton and Holt (1957). Z can be estimated from mean length in the catch from a given population by means of $Z=K*(L_\infty-L_{mean})/(L_{mean}-L_c)$. Where L_∞ and K are parameters of the von Bertalanffy growth equations; Erkoyuncu (1995) stated that if L_c is not available, L' can use in the formula instead of the L_c, i.e. L_c=L'. L_{mean} is the mean length computed from L' upward, the latter being a length not smaller than the smallest length of fish fully represented in catch samples (Pauly and Soriano

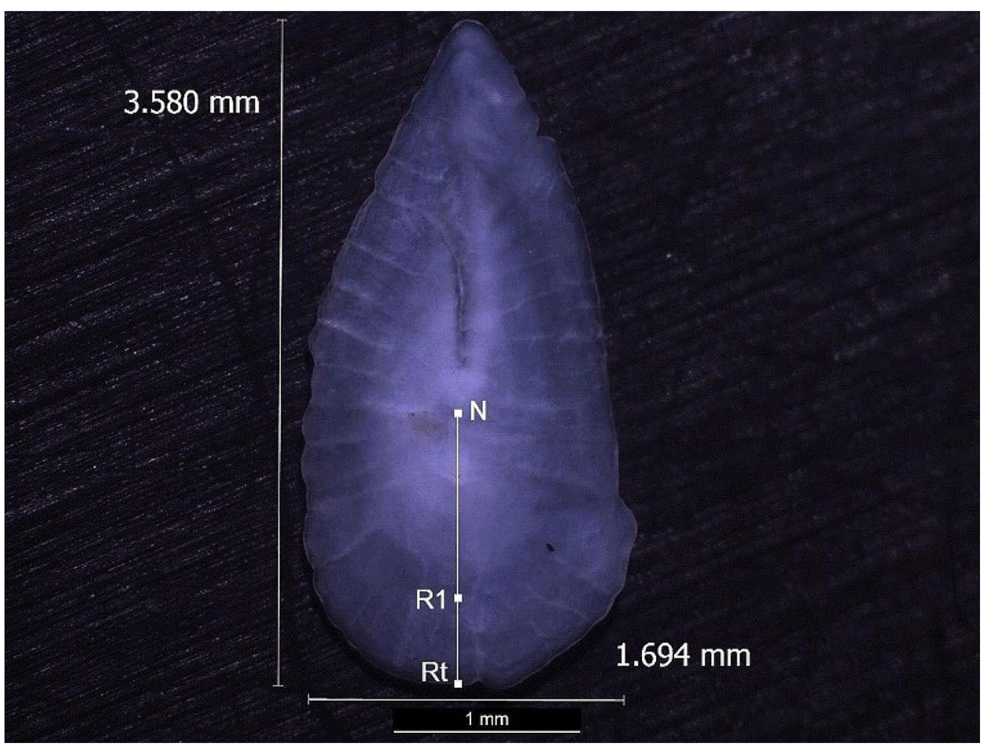

Fig. 2 Sagittal otolith of *B. euxini*. N: nucleus, Rt: total otolith Radius, R1: distance to the edge of transparent ring indicating first year

1986). Natural mortality of garfish was computed from Pauly (1980)'s following formula: M = 0.8*exp(-0.0152 -0.279*lnL_∞+0.6543*lnK + 0.463*lnT). Where M is natural mortality in a given stock, L_∞ is asymptotic length, K is growth coefficient and the value of T is the annual mean temperature (in ºC) of the sea water. The instantaneous rates of fishing mortality (F) were calculated by subtracting the estimates of M from Z: F = Z-M. The exploitation rate was calculated as follows: E = F/Z (Sparre & Venema, 1992).

The Chi square test was used to understand whether the sex-ratio was different from 1:1. The calculations of means and standard errors of the study data, as well as the graph plotting, were performed using the Microsoft Office Excel® computer program.

Results

The mean length and weight of the examined 917 individuals were determined as 37.31 ± 0.147 cm and 58.74 ± 0.876 g, respectively. In the present investigation, an analysis was conducted on the length distribution of 917 garfish. The findings revealed that a significant proportion of the sample, specifically 78.30% (718 individuals), fell within the length range of 32–40 cm. Furthermore, the largest subset, comprising 19.30% (177 individuals), was reported to have a length of 34 cm. Among females and males, the predominant length group was determined to be 36 cm, comprising 16.92% (100 individuals), and 34 cm, comprising 25.77% (84 individuals), respectively (Table 1; Fig. 3). During the study, the examined individuals consisted of 64.4% females (591 individuals) and 35.6% males (326 individuals). The female-male ratio was determined to be 1:1.81. The difference in sex ratios was found to be statistically significant ($P < 0.05$).

LWR was estimated as $W = 0.0005*L^{3.196}$, $W = 0.0009*L^{3.040}$, $W = 0.0005*L^{3.196}$ for females and males and all, respectively (Fig. 4). The highest b value (3.169) was determined in winter season, while the lowest (2.955) was in summer season for females. The growth type was determined as positive allometric (A+) in winter, and other seasons represent isometric growth (I). For males, the lowest b value (2.719) was determined in summer, while the highest (3.719) was in spring. The low number of male individuals in the spring season sample and the difference in length and weight composition between the individuals in the sample caused the b value to be noteworthy high in this period. It was determined the growth type was isometric in all seasons.

Fulton's condition factor values for females and all indivuduals (0.13) reached the highest values in Summer. The GSI value, calculated to assess monthly gonad development,

Table 1 Range and mean values for total length (L) and total weight (W) and parameters for the, length-weight relationships and condition factors (K) of *B. euxini* for females from the south-eastern coast of Black Sea (n: number of specimens, GT: type of growth, SE: standard error, a: the intercept, b: the allometric coefficient)

		n	L_{min}	L_{max}	L_{mean}	SE of L	W_{min}	W_{max}	W_{mean}	SE of W	a	b	R^2	SE of b	CI of b	GT	K	GSI
Winter	♀	278	27.2	52.0	37.95	0.264	18.67	166.11	59.39	1.412	0.0006	3.169	0.927	0.055	3.062–3.277	A+	0.10	3.79
	♂	163	28.0	48.0	35.68	0.246	23.90	125.12	48.12	1.178	0.0007	3.114	0.900	0.088	2.939–3.289	I	0.10	1.63
	T	441	27.2	52.0	37.11	0.197	18.67	166.11	55.23	1.024	0.0006	3.149	0.927	0.045	3.062–3.237	A+	0.10	3.05
Spring	♀	41	35.4	55.0	41.90	0.720	50.50	230.35	90.50	5.916	0.001	3.049	0.898	0.199	2.646–3.451	I	0.12	14.18
	♂	7	32.5	39.5	36.54	1.281	32.24	69.67	53.30	6.713	0.00008	3.719	0.935	0.456	2.546–4.892	I	0.11	3.47
	T	48	32.5	55.0	41.11	0.695	32.24	230.35	85.07	5.472	0.0005	3.249	0.913	0.170	2.907–3.592	I	0.12	12.62
Summer	♀	24	36.2	53.5	45.86	1.068	52.50	190.34	130.98	8.373	0.0016	2.955	0.927	0.178	2.586–3.324	I	0.13	23.59
	♂	8	36.1	46.2	40.49	1.227	49,35	98.73	72.39	5.933	0.003	2.719	0.950	0.269	2.060–3.379	I	0.11	12,41
	T	32	36.1	53.5	44.52	0.946	49.35	190.34	116.62	7.863	0.0005	3.262	0.913	0.183	2.889–3.635	I	0.13	20.79
Autumn	♀	248	26.0	53.5	37.53	0.254	19.83	176.75	59.78	1.360	0.001	3.022	0.908	0.069	2.886–3.158	I	0.11	1.43
	♂	148	26.5	44.3	34.74	0.248	23.13	89.49	46.50	1.194	0.001	3.024	0.831	0.123	2.780–3.267	I	0.11	0.36
	T	396	26.0	53.5	36.49	0.196	19.83	176.75	54.82	1.014	0.001	3.035	0.902	0.057	2.923–3.148	I	0.11	0.96
Total	♀	591	26.0	55.0	38.37	0.192	18.67	230.35	64.62	1.209	0.0005	3.229	0.921	0.042	3.147–3.311	A+	0.11	5.23
	♂	326	26.5	48.0	35.39	0.179	23.13	125.12	48.06	0.851	0.0009	3.040	0.871	0.071	2.900–3.180	I	0.11	1.55
	T	917	26.0	55.0	37.31	0.147	18.67	230.35	58.74	0.876	0.0005	3.196	0.921	0.034	3.130–3.263	A+	0.11	3.93

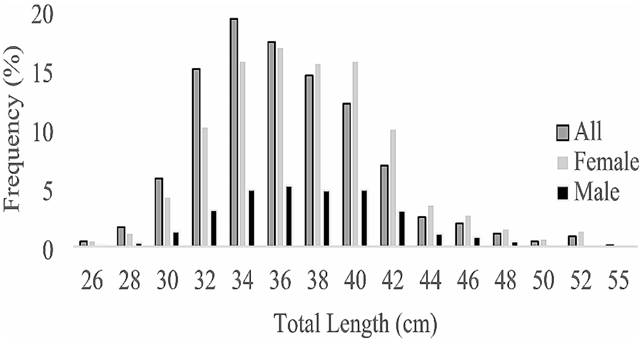

Fig. 3 Length-frequency distribution for female, male and all indivudualsof *B. euxini*

reached its peak at 27.63 in July. Examining the monthly gonadosomatic index (GSI) values, it was observed that the GSI value began to increase from March and reached its highest point in July. Based on this, it has been determined that the breeding season starts in July and continues until October (Fig. 5).

In the study, the age distribution of the sampled individuals ranges from 1 to 7 years, with the majority, at 40.89% (375), falling within the 3-year age group (Table 2). Among the 591 female individuals, the majority, at 41.79%, belong to the 3-year age group, while among the 326 male individuals, the majority, at 50.61%, belong to the 2-year age group.

The VBGE parameters and mortality rates for garfish for both female and male individuals are given in Table 3. L_∞ value of females (78.2) was found higher than that of males (69.82). The instantaneous rates of total, natural, fishing mortalities and exploitation rate were 1.02, 0.16, 0.86 and 0.84 for combined sexes. The E value for female (0.81), male (0.78) and all indivuduals (0.84) was calculated above the maximum acceptable 0.50. For mean lengths of individuals estimated via Von Bertalanffy growth equation for each age group was shown in Fig. 6.

Growth performance index (Φ’) was calculated as 2.86, 2.77 and 2.84 for females, males and combined sexes, respectively.

Discussion

The study sampled 917 individuals of *B. euxini* at monthly intervals, obtaining data on various population parameters. The size and weight distributions for females and males were as follows: 26.0–55.0 cm (average of 38.37 ± 0.192 cm) and 18.67-230.35 g (average of 64.62 ± 1.209 g) for females, and 26.5–48.0 cm (average of 35.39 ± 0.179 cm) and 23.13-125.12 g (average of 48.06 ± 0.851 g) for males. The size and weight distribution of the garfsh have been reported respectively as, In the Mediterranean, Châarii et

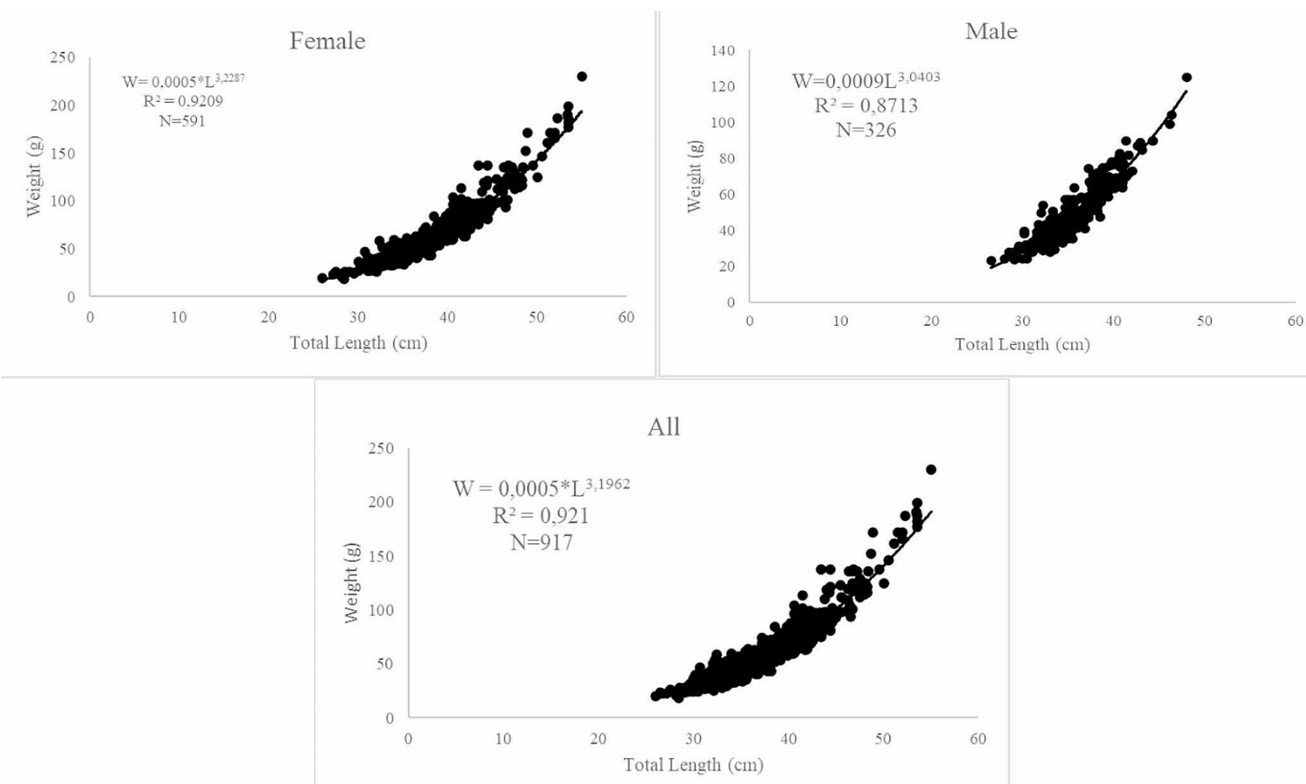

Fig. 4 Length-weight relationship of *B. euxini*

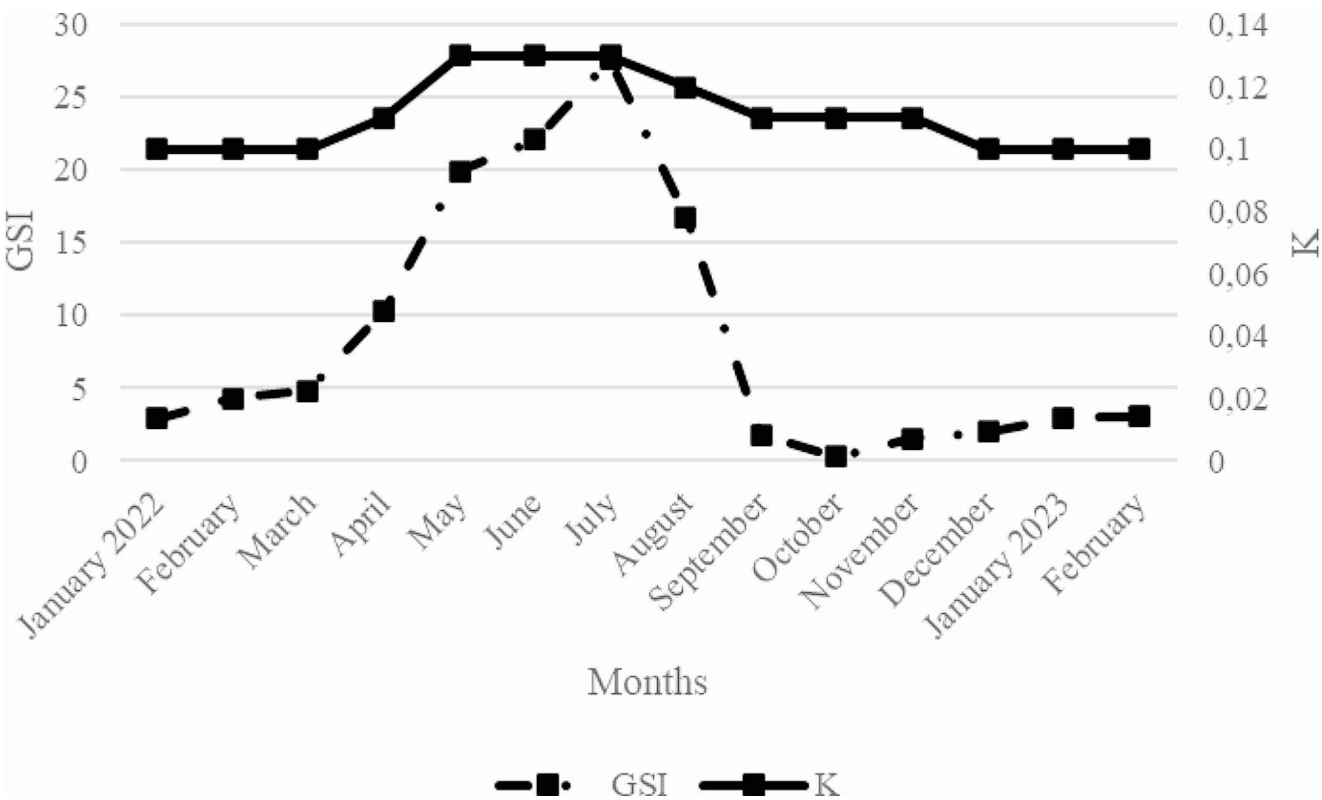

Fig. 5 Monthly variations of gonadosomatic index and condition factor for all indivuduals of *B. euxini*

al., (2022) reported a range of 24.2–55 cm (with an average of 40.2 ± 5.9 cm) for females and 25.8–52.5 cm (with an average of 40.0 ± 4.5 cm) for males. In the Black Sea, Çayır and Bostancı (2022) reported a range of 30.4–44.5 cm and 32.6–92.0 g, and in the Marmara Sea, a range of 27.9–51.6 cm and 15.4–91.6 g. In the Black Bilgin et al. (2014) reported a range of 24.7–65.1 cm (with an average of 39.10 ± 0.248 cm) for females and 22.2–55.3 cm (with an average of 35.2 ± 0.209 cm) for males.

The average size and weight values of all the fish examined in the study align with those reported in previous research. The female-to-male ratio in this study is determined to be 1:1.81, contrasting with Châarii et al., (2022) reporting 1:2.86, Bilgin et al. (2014) reporting 1:1.04, and Kaya (2018) reporting 1:1.5. The presence of an exponential relationship between fish length and weight signifies the extent to which weight increases relative to the growth in length, consequently influencing changes in body shape. Parameters of the length-weight relationship exhibit variability not only across different species but also within the same species across diverse factors such as years, populations in distinct habitats, genders, seasons, and life stages (Çetinkaya 1989). The length-weight relationship parameters from the present study, along with those from various other studies, are summarized in Table 4.

The condition factor, calculated using the variables of length and weight of fish, can vary depending on age, gender, habitat, and seasons (Erkoyuncu 1995). The variations observed in the condition factor primarily reflect the sexual maturity status and the level of nutrition, as a parameter indicating the well-being or relative fatness of a fish (Le Cren 1951; Williams 2000). Samsun (1996) reported an average condition factor of 0.1053 for garfish. Uçkun et al. (2004) reported a range of 0.118–0.126 for females and 0.112–0.134 for males. Samsun and Erdoğan Sağlam (2021) reported a value of 0.11. In this study, the condition factor for all individuals ranged from 0.077 to 0.171, with an average of 0.107. Changes in the condition factor can occur due to various factors such as the ecological conditions of habitats, sampling methods, timing, sample size, the size and weight distribution of samples, and the type of length measurement used. However, values obtained from different studies tend to show similarities. According to research results, it is observed that GSI and condition factor curves follow a similar course. When other conditions in the environment are the same, it can be said that the habitat with the highest condition factor has the most favorable feeding conditions. Water temperature can affect nutrient abundance and quality and nutrient uptake. While the average sea water temperature in the Black Sea was 14.8 °C between 1980 and 1990, it was measured as 16.5 °C between 2013 and

Table 2 Age-length key of both female and male of *B. euxini*

Length (cm)	Age													
	Female							Male						
	I	II	III	IV	V	VI	VII	I	II	III	IV	V	VI	All
26	1							1						2
27	2													2
28	4							2						6
29	3							5	1					9
30	4	4						7	2					17
31	1	16						8	11					36
32		24							29					53
33		36							49					85
34		43	2						36	2				83
35		40	8						19	27				94
36		16	31						10	24				81
37		5	48						4	21				78
38		2	50						4	23				79
39			40							14				54
40			48							9				57
41			10	35						8	1			54
42			5	28							3			36
43			3	23							1			27
44			2	14							2			18
45				4	1									5
46				8	4							2		14
47				2	2									4
48				2	6								1	9
49					1									1
50					2									2
51					1	1								2
52						3								3
53						3	2							5
54														
55							1							1

Table 3 VBGE parameters and growth equation of *B. euxini*

	Female	Male	Female + Male
L_∞	78.20	69.82	92.06
K	0.1185	0.1201	0.0824
t_0	-2.7429	-3.5213	-3.5496
Z	1.10	1.02	1.02
M	0.21	0.22	0.16
F	0.89	0.80	0.86
E	0.81	0.78	0.84

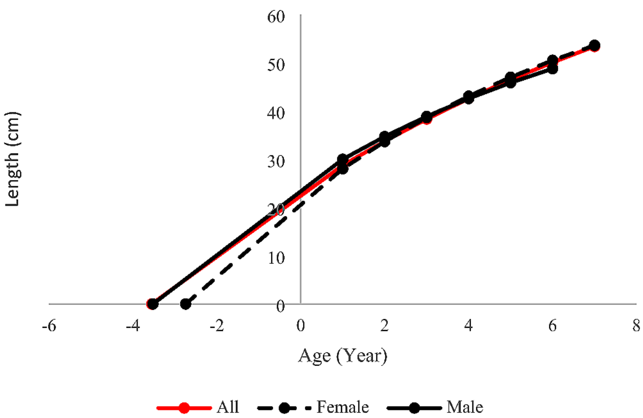

Fig. 6 Estimated lengths for different ages for female, male and all indivuduals of *B. euxini*

2023 (GDM 2023). The periods of intensive breeding in 2022–2023, which covers the research period, are the periods when the average seawater temperature in the region is high. Therefore, it can be concluded that the beginning of the reproductive period coincides with the periods when the average seawater temperature in the study area is high, which may cause the condition factor and GSI to show a similar course.

Châarii et al., (2022) reported that in the Mediterranean, the 2-year age group was dominant with 56%, with females ranging from 1 to 4 years and males ranging from 1 to 5 years. Uçkun et al. (2004) reported that in the Aegean Sea, the 2-year age group was dominant with 47.26%, with females ranging from 1 to 5 years and males ranging from 1 to 4 years. In studies done in the Black Sea, Samsun (1996) found that within the 1–6 age group, the 1-year age group was dominant at 66.87%. Samsun et al. (2006) reported that, the 2-year age group was dominant (54.57%) with females ranging from 1 to 6 years and males ranging from 1 to 4 years. Bilgin et al. (2014) observed that within the 1–7 age group, the 3-year age group was dominant among females (17.5%), while among males, the 2-year age group (20.2%) was dominant. Kaya (2018) noted that within the 1–4 age group, the majority (48.45%) consisted of individuals from the 3-year age group. In this study, age groups were delineated as 1–7 for females and 1–6 for males, revealing that the 3-year age group prevailed among females at 41.79%, while among males, the 2-year age group dominated with 50.61%.

The parameters of the Von Bertalanffy Growth Equation, the extensively used growth equation in fisheries biology studies, are detailed in Table 5 for comparative analysis with different studies. The Φ' values for females were slightly higher than for males, attributed to females attaining a larger asymptotic total length at age compared to males. In order

Table 4 Comparision of length-weight relationship parameters from different localities of garfish

Reference	N	Sex	L_{min}	L_{max}	L_{mean}	a	b	r^2	Growth type	Study period	Study area
Samsun 1996	643	All	31.2	52.2	37.55 ± 0.17	0.00055	3.1778	0.97	-	1995–1996	Black Sea
Uçkun et al. 2004	240	F	26.0*	54.5*	-	0.0002	3.46	0.981	-	1997	Aegean Sea
	107	M	27.5*	47.7*	-	0.0009	3.07	0.941	-		
	347	All	26.0*	54.5*	-	0.0003	3.40	0.974	-		
Samsun et al. 2006	609	F	-	-	39.13 ± 0.16	0.00061	3.153	0.9357	A+	2000–2001	Black Sea
	322	M	-	-	36.08 ± 0.16	0.00280	2.998	0.8981	I		
	931	All	29.0	58.0	-	0.00076	3.137	0.9363	A+		
Polat et al. 2009	278	All	23.7*	60.3*	36.07 ± 4.78*	0.0005	3.245	0.97	A+	2003–2004	Black Sea
Bilgin et al. 2014	618	F	24.7	65.1	39.1 ± 0.25	0.0005	3.180	0.9208	A+	2011–2013	Black Sea
	593	M	22.2	55.3	35.2 ± 0.21	0.0007	3.090	0.8967	A+		
	1211	All	22.2	65.1	37.2 ± 0.17	-	3.138	-	-		
Samsun et al. 2017	647	All	28.8	51.6	-	0.008	3.10	0.87	-	2016–2017	Black Sea
Çayır and Bostancı 2022	108 BS		30.4	44.5	35.331 ± 2.835	0.0006	3.171	0.91	A+	2018	Black Sea, Marmara
	113 M		27.9	51.6	36.841 ± 4.289	0.0007	3.115	0.96	A+		
Châarii et al., 2022	284	F	24.2	55.0	40.2 5.9	0.0003	3.419	0.91	A+	2004–2009	Mediterranean
	120	M	25.8	52.5	40.0 ± 4.5	0.0002	3.530	0.90	A+		
This study	591	F	26.0	55.0	38.37 ± 0.192	0.0005	3.229	0.921	A+	2022–2023	Black Sea
	326	M	26.5	48.0	35.39 ± 0.179	0.0009	3.040	0.871	I		
	917	All	26.0	55.0	37.31 ± 0.147	0.0005	3.196	0.921	A+		

*Fork length

BS: Black Sea, M: Marmara

to Munro's Phi Prime Test was performed and a difference was not observed between the growth invariants of von Bertalanffy obtained in other studies and the values found in this study.

Mortality rates are estimated to understand how fishing mortality and natural mortality affect fish populations. Fishing mortality of females was higher than for males. The total mortality rate (Z) of garfish for both sexes combined was estimated at 1.02 per year, a lower value compared to previous studies. The fishing mortality rate is higher than the natural mortality rate of garfish. The exploitation rates of *B. euxini* for both sexes obtained showed that garfish stock was overexploited in study period ($E > 0.5$). The exploitation rate for garfish has been reported between 0.513 and 0.815 in previous studies (Table 5). As seen in Table 5, especially in the same region, when compared with the results of the study by Bilgin et al. (2014), it is seen that there is a decrease in the asymptotic length of garfish and an increase in the exploitation rate. This indicates that the fishing pressure on the species has increased even more.

The gonadosomatic index value used to determine the breeding time in fish is generally at its minimum level in the days following spawning. It gradually increases in the ongoing process and reaches its maximum level in the period closest to ovulation. Subsequently, the GSI begins to decline, and the month when it reaches its minimum level is indicative of the spawning month, signifying that spawning has occurred. These changes in GSI values help determine the season in which sexually mature individuals in a population reproduce under the prevailing conditions (Nikolsky 1969; Erkoyuncu 1995). Various studies have reported different findings regarding the breeding season of garfish. Châarii et al., (2022) noted that the Gonadosomatic Index (GSI) reached its highest value in March, with breeding occurring between March and May. Uçkun et al. (2004) reported that GSI reached its maximum value in spring, and breeding occured in spring. Samsun et al. (2006) observed that GSI reached its maximum value in July, and breeding continued from May to mid-September. However, in this current study, it was determined that the GSI value reached its maximum in July, and breeding continued until October.

The changes observed in the growth and life cycle of a species, as well as the differences that emerge over the years, are crucial for evaluating and determining fishing trends. This is particularly important for maintaining the balance of fish stocks and, consequently, implementing sustainable fisheries management measures. Parameters such as size, weight, age composition, and sexual maturity status obtained from fisheries biology and population analysis studies are utilized in efforts to achieve sustainable fisheries and ensure the preservation of ecological balance. (Bellido et al. 2000). The implementation of bans and restrictions

Table 5 Comparison of growth equation parameters, growth performances, mortality rates and exploitation rates obtained for garfish populations in different studies

Sex	Age	L_∞ (cm)	K ($year^{-1}$)	t_0 (year)	Φ'	Z	M	F	E	Study period	Study area	Reference
All	1–6	56.01	0.3249	-1.8641	-	1.16	0.52	0.064	0.55	1995–1996	Black Sea	Samsun 1996
F	1–5	62.24	0.249	-1.422	2.990	-	-	-	-	1997	Aegean Sea	Uçkun et al. 2004
M	1–4	54.32	0.336	-1.252	2.996	-	-	-	-			
All	1–5	62.71	0.237	-1.566	2.970	-	-	-	-			
All	1–6	74.64	0.13	-3.67	2.86	1.240	0.230	1.010	0.815	2000–2001	Black Sea	Samsun et al. 2006
All	1–5	79.05*	0.198	-1.42	3.09	-	-	-	-	2003–2004		Polat et al. 2009
All	1–8	90.3	0.158	-0.109	-	0.880	0.429	0.451	0.513	2003–2008	Adriatic Sea	Zorica and Kec 2013
F	1–7	81.6	0.1248	-2.245	2.92	1.04	0.25	-	0.76	2011–2013	Black Sea	Bilgin et al. 2014
M	1–7	71.9	0.1507	-2.127	2.89	1.24	0.29	-	0.77			
F	1–4	48.48	0.57	-1	3.12	-	-	-	-	2004–2009	Mediterranean	Châarii et al., 2022
M	1–5	44.70	0.67	-1	3.12	-	-	-	-			
F	1–7	78.2	0.1185	-2.7429	2.86	1.10	0.21	0.89	0.81	2022–2023	Black Sea	This study
M	1–6	69.82	0.1201	-3.5213	2.77	1.02	0.22	0.80	0.78			
All	1–7	91.86	0.0828	-3.5358	2.84	1.02	0.16	0.86	0.84			

should be based on scientific research to ensure the conservation of fish stocks and their optimal utilization. In our country, essential scientific data serving as the basis for fishing bans can be obtained through long-term and comprehensive research efforts (Genç et al. 1999). The conclusion of this study provides information related to biological aspects that can be used as a basis for making garfish fisheries management policies in the coasts of southern Black Sea. In order to reduce the fishing pressure of the garfish stock in the Black Sea It is necessary to accept effective management measures. Thus It will be possible to reduce fishing mortality and evaluate the garfish stock in more detail.

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Data Availability All the data for the work are present in the manuscript.

Declarations

Ethical Approval All the specimens were caught by professional fishermen. For this, 'Ethical Approval' is not applicable.

Competing Interests The authors declare no competing interests.

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