http://www.egejfas.org
Ege J Fish Aqua Sci 31(2): 79-85 (2014)

Su Ürünleri Dergisi (2014)
DOI:10.12714/egejfas.2014.31.2.04

RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Age, growth and otolith morphometry of *Capoeta angorae* (Cyprinidae) collected from Menzelet Reservoir and Fırnız Stream (Turkey)

Menzelet Barajı ve Fırnız Çayı'ndan yakalanan *Capoeta angorae* (Cyprinidae)'nin yaş, büyüme ve otolit morfometrisi (Türkiye)

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How to cite this paper:
Emre, Y., Ayyıldız, H.,Özen, Ö.,Yağcı, A., 2014. Age, growth and otolith morphometry of *Capoeta angorae* (Cyprinidae) collected from Menzelet Reservoir and Fırnız Stream (Turkey). *Ege J Fish Aqua Sci* 31(2): 79-85. doi: 10.12714/egejfas.2014.31.2.04

Özet: Menzelet Barajı ve Fırnız Çayı'ndan Ağustos 2011 ve Kasım 2012 tarihleri arasında elektro-şoker ile yakalanan *Capoeta angorae* bireylerinin yaş, büyüme oranları ve otolit (asteriskus) morfometrik ölçümleri belirlenmiştir. Toplam boy (L) aralığı 7.5 ile 27.0 cm arasında olan *C. angorae* bireylerinden elde edilen toplam 175 adet otolit analizlerde kullanılmıştır. Toplam erkek : dişi oranı (E : D = 1.52 : 1.00) erkekler lehine eğimlidir. Student's t-test cinsiyetler arasında boy farklılığının istatistiksel olarak önemli olduğunu göstermektedir ($P < 0.05$). Boy – ağırlık ilişkisi dişiler için, $W= 0.0128L^{2.8703}$ ($R^2= 0.975$), erkekler için, $W = 0.0103L^{2.9462}$ ($R^2 = 0.969$) ve tüm bireyler için $W = 0.0097L^{2.9629}$ ($R^2 = 0.978$) olarak hesaplanmıştır. Otolit boyu (OL), eni (OW) ve yarıçapı (OR) sırasıyla 1.67 – 3.45 mm; 1.39 – 2.82 mm ve 0.89 – 1.70 mm olarak ölçülmüştür. Von Bertalanffy büyüme denklemi ise dişiler için, L_∞ = 27.55 cm (L), K = 0.465 ($yıl^{-1}$), t_0 = -0.539 (yıl), females; L_∞ = 22.84 cm (L), K = 0.772 ($yıl^{-1}$), t_0 = -0.71 (yıl) males; L_∞ = 42.25 cm (L), K = 0.102 ($yıl^{-1}$), t_0 = -2.84 (yıl) olarak hesaplanmıştır. Otolit morfometrik ölçümleri (OL, OW ve OR) ile toplam boy arasında kuvvetli doğrusal ilişki olduğu tespit edilmiştir. Gözlenen yaş ile otolit morfometrik ölçümleri sonucu tahmin edilen yaş arasında istatistiksel olarak önemli derecede fark bulunamamıştır (Mann-Whitney U test; $P > 0.05$).

Anahtar Kelimeler: Yaş, büyüme, asteriscus, otolit morfometrisi, *Capoeta angorae.*

Abstract: Age, growth rates and otolith morphometry of *Capoeta angorae*, collected by using electro shocker, were determined from the Fırnız Stream and Menzelet Reservoir between August 2011 and November 2012. A total of 175 otoliths were obtained from *C. angorae* that ranged between 7.5 and 27.0 cm L were used in the analysis. The overall male : female ratio (M : F = 1.52 : 1.00) was biased in favour of males. Student's t-test revealed significant differences between sexes, regarding total length ($P < 0.05$). The length–weight relationships were calculated as $W = 0.0128L^{2.8703}$ ($R^2= 0.975$) for females, $W = 0.0103L^{2.9462}$ ($R^2 = 0.969$) for males and $W = 0.0097L^{2.9629}$ ($R^2 = 0.978$) for all specimens. Otolith length (OL), width (OW) and radius (OR) were ranged between 1.67 – 3.45 mm, 1.39 – 2.82 mm and 0.89 – 1.70 mm, respectively. The von Bertalanffy growth models were L_∞ = 27.55 cm (L), K = 0.465 ($year^{-1}$), t_0 = -0.539 (year), females; L_∞ = 22.84 cm (L), K = 0.772 ($year^{-1}$), t_0 = -0.71 (year) males; L_∞ = 42.25 cm (L), K = 0.102 ($year^{-1}$), t_0 = -2.84 (year) for all specimens. The otolith morphometric measurements (OL, OW and OR) showed significant linear relationships with the total length. No significant differences were found between observed age and predicted ages of the *C. angorae* estimated from the OL, OW and OR (Mann-Whitney U test; $P > 0.05$).

Keywords: Age, growth, asteriscus, otolith morphometry, *Capoeta angorae*

INTRODUCTION

The genus *Capoeta* Valenciennes, 1842 are widely distributed from Anatolia to the Levant, Transcaucasia, the Tigris and Euphrates basins, Iran, Turkmenistan, Northern Afghanistan, Southern China, Lake Aral and spreads the upper parts of the Amu-Darya and Syr-Darya drainages (Banarescu, 1999; Türkmen *et al.*, 2002). These fish inhabit gravel and stony zones of fast flowing rivers (Türkmen *et al.*, 2002), however, some species may also be found in lakes and springs (Turan *et al.*, 2008). Levin *et al.* (2012) have been reported three main groups of *Capoeta* genus. First; the Mesopotamian group, which includes three species from the Tigris–Euphrates system, second; the Anatolian– Iranian group, which has the most diversified structure and contains many species distributed throughout Anatolian and Iranian inland waters, and the last one; the Aralo-Caspian group, which consists of species distributed in basins of the Caspian

and Aral Seas, including many dead-end rivers in Central Asia and Northern Iran. In recent studies, 16 species (*C. tinca, C. umbla, C. antalyensis, C.erhani, C. ekmekciae, C. sieboldii, C. caelestis, C. mauricii, C. turani, C. bergamae, C. barroisi, C. banarescui, C. baliki, C. trutta, C. capoeta, C. angorae*) belonging to *Capoeta* genus have been reported in the inland waters of Turkey (Turan *et al.*, 2006a; 2006b; Özuluğ and Freyhof, 2008; Turan *et al.*, 2008; Elp and Şen, 2009; Kurutaş *et al.*, 2009; Küçük *et al.*, 2009; Özcan and Balık, 2009; Schoeter *et al.*, 2009; Turan and Özcan, 2009; Demirci and Özdilek, 2010; Yılmaz *et al.*, 2010; Aydoğdu *et al.*, 2011; Yıldırım *et al.*, 2011; Çoban *et al.*, 2013; Yüksel *et al.*, 2014).

Capoeta angorae Hankó, 1925 is the commercially valued fish around the Menzelet Reservoir and other regions of its distribution. Relatively few studies have been carried out on *Capoeta* genus and focused on the age, growth rates and reproduction (Türkmen *et al.*, 2002; Alp *et al.*, 2005; Kalkan, 2008). However, we have not enough information about age, growth rates and otolith morphometrics (OL, OW and OR) of *C. angorae*. Growth parameters are important data for use in fish stock assessments (Ofstad *et al.*, 2013). Although growth of *C. angorae* in the upper parts of the Ceyhan River, Turkey have been studied by using scales (Alp *et al.*, 2005), no study on the age and growth rates have been conducted by using otoliths. Otoliths are the most preferred structures by fisheries scientists owing to the precision of age estimates (Hammers and Miranda, 1991; Maceina and Sammons, 2006). Counting the opaque and translucent bands in otoliths for age determination is mostly time consuming procedure (Pilling *et al.*, 2003). Therefore, we also used the otolith morphometrics (OL, OW and OR) as an age predictor.

The aim of this study was to determine age, growth rate and otolith morphometrics (OL, OW and OR) for *C. angorae* in the Menzelet Reservoir and Fırnız Stream, Turkey. We also assessed the usage of the otolith morphometrics (Otolith length (OL), width (OW) and radius (OR)) as an age predictor of the investigated species.

MATERIALS AND METHODS

Samplings were carried out from Fırnız Stream located at 37°45'N, 36°39'E, a small tributary of the Ceyhan River and collected from Menzelet Reservoir located at 37°42'N, 36°52'E, between August 2011 and November 2012 (Figure 1).

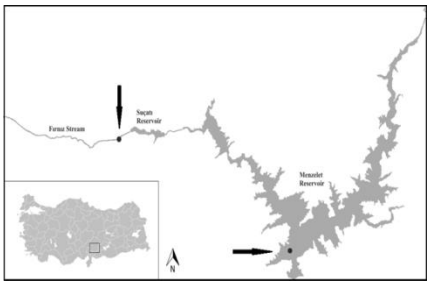

Figure 1. Map of the Menzelet Reservoir and Fırnız Stream indicating locations where samples of *Capoeta angorae* were collected (●).

Menzelet Reservoir was constructed on the Ceyhan River in the East Mediterranean region of Turkey. It has a surface area of 42 km^2 at 700 m altitude and the maximum depth is nearly 100 m with total water volume is about 12 x 10^9 m^3 (Alp *et al.*, 2004). The samples were caught using an electro shocker.

Laboratory procedures and data analysis

A total of 178 *C. angorae,* ranging from 7.5 to 27 cm in total length (L) were sampled during the study period (Figure 2). Total length was measured with a measuring board to the nearest 0.1 mm, and weighed with an electric balance to the nearest 0.01 g. Sex was determined by gonad examination according to its shape and structure. The sex-ratio (number of males to each female; *M : F*) of the samples were analysed. Student's t-test was applied to test the existence of significant differences between sexes according to the total length.

This study examined the relationships between L and W for each sex separately by geometric mean functional regression (Ricker, 1975) in exponential form;

$$W = aL^b$$

where "b" is the regression coefficient and "a" is the regression constant. Additionally, the Student's t-test (Zar, 1984) was used to test for difference of the parameter "b" from the theoretical value of 3.

The lagenar otolith (asteriscus) pairs were removed and stored in plastic vials. One otolith was randomly selected and immersed in plastic vial with glycerine solution for a while.

Annular ring counts were made blind-read by two readers; the information about fish length and date of capture was withheld from the readers. All otoliths were read twice and final age estimates achieved when the same results were obtained from the two readers. A third reading was performed if the first two readings differed from each other. If the contradiction persisted, the otolith was discarded. A light microscope with objective lenses with nominal magnifications of 0.5 – 5.6 X were used for the counts.

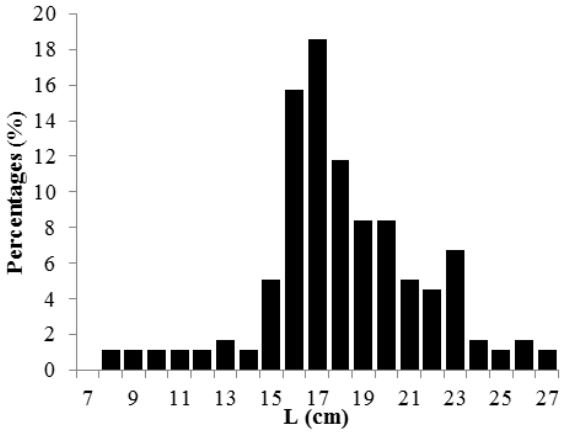

Figure 2. Length–frequency distribution of *Capoeta angorae* specimens

Otolith morphometrics Otolith length (OL), width (OW), and radius (OR) measured to the nearest 0.001 mm using Q Capture Imaging Software. OL was defined as the longest axis between the anterior and posterior otolith edge and OW as a distance from the dorsal to the ventral edge. OR was measured as the longest axis between the nucleus and posterior edge (Figure 3). Differences between left and right otoliths were tested by paired t-test. The relation between the fish growth and the otolith growth was investigated by linear regression. Relationships between observed age and otolith morphometrics were calculated using the power model. Differences between observed age and predicted age were compared by the Mann-Whitney U test.

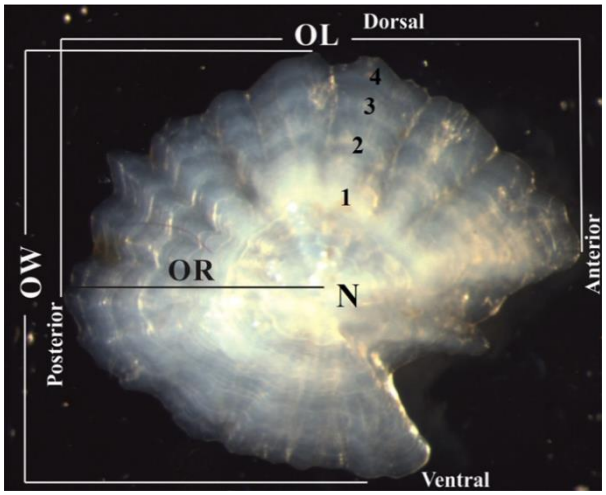

Figure 3. Morphometric measurements of *Capoeta angorae* asteriscus otolith (W = 99.4 g, L = 23.3 cm, age 4+, 16 August 2012). N = nucleus.

Age and growth

Ages were determined by counting the number of opaque and translucent rings from the nucleus to the outer edge of the otolith (Figure 3). The von Bertalanffy growth curve was fitted to the length at age data using non-linear least squares parameter estimation (von Bertalanffy, 1938); $L = L_\infty\left[1 - e^{-K(t-t_0)}\right]$

where: L is the fish length at age t (year), L_∞ the theoretical asymptotic length, K the growth rate coefficient, and t_0 the theoretical age when fish length is zero. Separate analyses were carried out for males, females and all specimens.

RESULTS

A total of 178 otoliths (104 males, 68 females and 6 specimens were undetermined sex) were processed for age counts, however, 3 pairs of otoliths could not be read due to the age inconsistency between two readers, these otoliths were excluded from further analysis. Thus, 175 otoliths obtained from *Capoeta angorae* that ranged between 7.5 and 27 cm L were used in the analyses (Figure 2). Student's t-test revealed significant differences between sexes, regarding L ($P < 0.05$). The overall male:female ratio ($M : F$ = 1.52 : 1.00) was biased in favour of males and it was not significantly different from a balanced ratio (1:1) ($P > 0.05$).

The length–weight relationships were calculated as $W = 0.0128L^{2.8703}$ ($R^2 = 0.975$) for females, $W = 0.0103L^{2.9462}$ ($R^2 = 0.969$) for males and $W = 0.0097L^{2.9629}$ ($R^2 = 0.978$) for all specimens. Our data suggested that *Capoeta angorae* showed negative allometric growth. The parameter "b" of length–weight relationships was significantly different from 3 ($P < 0.05$).

Otolith morphometrics

Otolith length, width and radius were ranged between 1.67 – 3.45 mm, 1.39 – 2.82 mm and 0.89 – 1.70 mm, respectively (Table 1). No significant differences in otolith morphometrics were found between left and right otoliths (paired t test, $P > 0.05$). The different otolith measurements (OL, OW and OR) showed significant linear relationships with the L (Table 2).

Table 1. Otolith length (OL), width (OW) and radius (OR) measurements according to the age of *Capoeta angorae* from Menzelet Reservoir and Fırnız Stream.

Age Class	Sex	N	Otolith Length (mm)				Otolith Width (mm)				Otolith Radius (mm)			
			Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
0+	Female	2	1.735	1.735	1.735	0.000	1.445	1.445	1.445	0.000	0.912	0.912	0.912	0.000
	Male	3	1.849	2.041	1.956	0.098	1.534	1.684	1.618	0.077	0.959	1.038	1.003	0.041
	Undetermined	3	1.674	2.058	1.818	0.163	1.397	1.698	1.550	0.149	0.887	1.046	0.943	0.068
	All	**8**	**1.674**	**2.058**	**1.843**	**0.145**	**1.397**	**1.698**	**1.549**	**0.123**	**0.887**	**1.046**	**0.955**	**0.061**
1+	Female	1	2.216	2.216	2.216	...	1.821	1.821	1.821	...	1.111	1.111	1.111	
	Male	5	2.111	2.360	2.219	0.095	1.739	1.850	1.803	0.047	1.040	1.121	1.085	0.033
	Undetermined	3	1.920	1.920	1.920	0.093	1.780	1.780	1.780	0.069	0.950	0.950	0.950	0
	All	**9**	**1.920**	**2.360**	**2.176**	**0.137**	**1.739**	**1.850**	**1.802**	**0.040**	**0.950**	**1.121**	**1.069**	**0.060**
2+	Female	20	2.100	2.750	2.388	0.140	1.720	2.140	1.964	0.106	1.040	1.370	1.191	0.064
	Male	40	2.090	2.790	2.436	0.149	1.720	2.340	2.005	0.117	1.010	1.370	1.203	0.078
	All	**60**	**2.090**	**2.790**	**2.420**	**0.147**	**1.720**	**2.340**	**1.992**	**0.114**	**1.010**	**1.370**	**1.199**	**0.074**
3+	Female	20	2.350	3.180	2.659	0.170	1.770	2.340	2.144	0.109	1.130	1.490	1.301	0.074
	Male	33	2.250	2.870	2.591	0.140	1.900	2.450	2.131	0.134	0.968	1.531	1.266	0.109
	All	**53**	**2.250**	**3.180**	**2.617**	**0.154**	**1.770**	**2.450**	**2.136**	**0.124**	**0.968**	**1.531**	**1.280**	**0.098**
4+	Female	14	2.723	3.291	2.904	0.171	2.100	2.664	2.320	0.139	1.250	1.555	1.367	0.092
	Male	11	2.610	3.240	2.796	0.174	2.080	2.420	2.244	0.102	1.310	1.570	1.371	0.079
	All	**25**	**2.610**	**3.291**	**2.859**	**0.177**	**2.080**	**2.664**	**2.288**	**0.128**	**1.250**	**1.570**	**1.369**	**0.085**
5+	Female	11	2.924	3.390	3.148	0.194	2.290	2.820	2.545	0.185	1.270	1.680	1.495	0.120
	Male	9	2.900	3.450	3.016	0.167	2.190	2.620	2.404	0.114	1.350	1.700	1.451	0.098
	All	**20**	**2.900**	**3.450**	**3.089**	**0.190**	**2.190**	**2.820**	**2.481**	**0.169**	**1.270**	**1.700**	**1.475**	**0.110**

Table 2. Parameters of the otolith measurements (otolith length, OL; otolith width, OW; otolith radius, OR) linear relationships with the fish length (L) of *Capoeta angorae* from Menzelet Reservoir and Fırnız Stream.

Otolith Measurements	N	a	b	R^2	*P*
OL	178	0.087	1.018	0.897	<0.01
OW	178	0.068	0.883	0.892	<0.01
OR	178	0.036	0.616	0.799	<0.01

N is the number of speciemens, "a" is the slope of the regression line, "b" is *y*-intercept and R^2 is the coefficient of determination.

The relationships between otolith morphometrics and age were described in Figure 4. A power model explained between 67.5% and 77.8% of the variation in age. No significant differences were found between ages estimated from otoliths and ages predicted from OL, OW and OR (Mann- Whitney U test; $P > 0.05$).

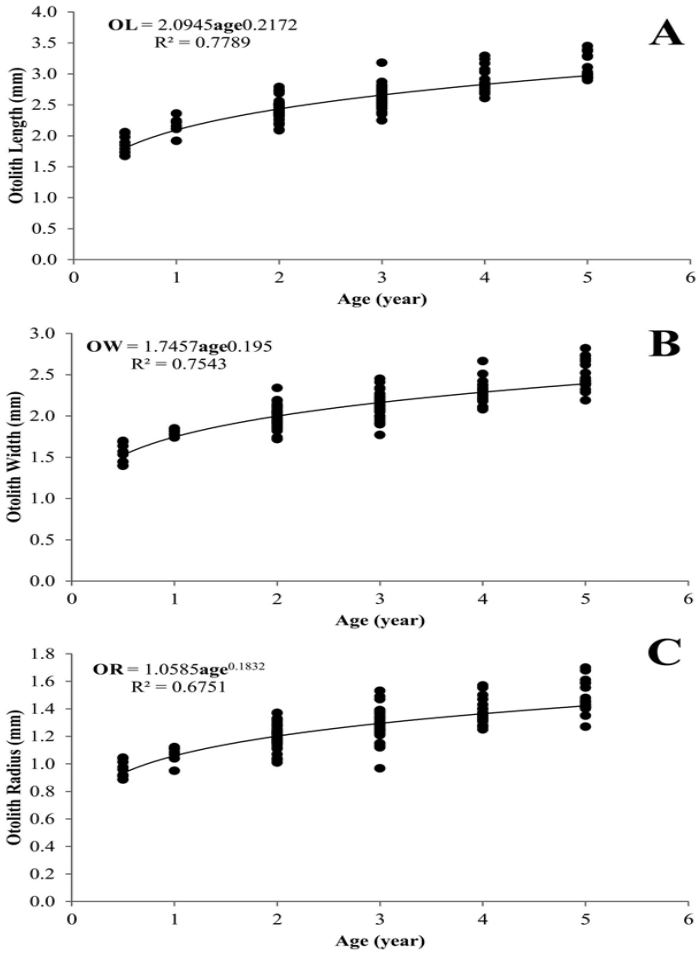

Figure 4. The relationships between otolith morphometrics and age for *Capoeta angorae*. A) Otolith Length B) Otolith Width C) Otolith Radius.

Age and growth

The total length of aged specimens ranged from 7.5 to 27.0 cm (Table 3). The age-classes in the otolith sample ranged from 0+ to 5+ years, while the samples were dominated by the 2+ and 3+ age-classes (34.3% and 30.3%, respectively). There were no difference between the age distributions of males and females, as most of the females were 2+ (27.9%) and 3+ (32.4%) years old, while males were mostly the same 2+ (40.6%) and 3+ (32.7%) years old (Figure

5). From this data we can see that most of the females were 3+ years old while the males were 2+ years old. The von Bertalanffy growth curves fitted to the length at age data. The estimated parameters of the equation were: L_∞ = 27.55 cm (L), K = 0.465 (year^{-1}), t_0 = -0.539 (year), females; L_∞ = 22.84 cm (L), K = 0.772 (year^{-1}), t_0 = -0.71 (year) males; L_∞ = 42.25 cm (L), K = 0.102 (year^{-1}), t_0 = -2.84 (year) overall.

Table 3. Age–length key for *Capoeta angorae* with mean total length (L) and weight (W). SE = Standart error

Total length (cm)	Age Classes					
	0+	1+	2+	3+	4+	5+
7.5 - 9.4	5					
9.5 - 11.4	3	2				
11.5 - 13.4		3				
13.5 - 15.4		4	12	1		
15.5 - 17.4			41	23		
17.5 - 19.4			6	24	2	
19.5 - 21.4			1	2	16	1
21.5 - 23.4				2	5	13
23.5 - 25.4				1	1	2
25.5 - 27.0					1	4
N	8	9	60	53	25	20
%	4.6	5.1	34.3	30.3	14.3	11.4
L_{mean} ±SE	9.1 ± 0.5	13.7 ± 0.3	16.4 ± 0.1	17.9 ± 0.2	20.9 ± 0.3	23.2 ± 0.4
W_{mean} ± SE	7.16 ± 1.1	24.63 ± 2.6	39.66 ± 1.3	51.56 ± 2.3	79.59 ± 5.5	113.63 ± 7

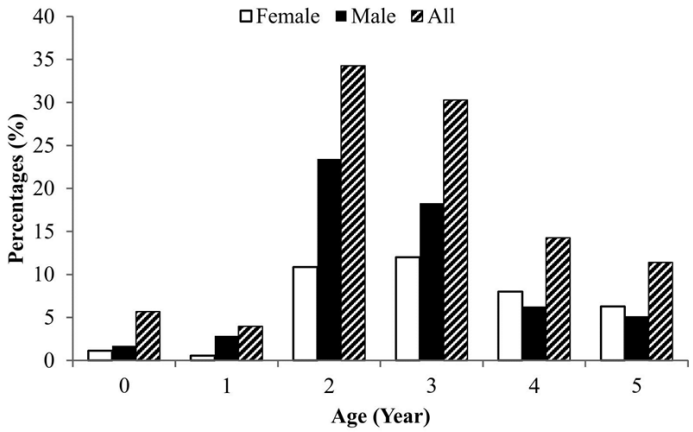

Figure 5. Age structure of *Capoeta angorae* from Menzelet Reservoir and Fırnız Stream.

DISCUSSION

The asteriscus otoliths of the *C. angorae* showed identifiable opaque and translucent bands. We determined that whole otoliths are suitable for age and growth studies for this species. In addition, whole otoliths can be more easily obtained and do not involve time consuming analysis processes. The results of the present study showed that *C. angorae* otoliths have relatively larger bands of at least first growth increments (Figure 3). In point of fact, it is known that growth rate drops after the first year which related to sexual maturity, leading to shorter growth increments in the forthcoming years (Wootton, 1992).

In the present study only 1.68% of otoliths could not be read, but also 14% of otoliths were read very difficult. The analysis of the other 175 otoliths revealed that age-class 2+ was dominant (34.3%). Males were dominant until age 3, but after then females were became dominant in the population (Figure 5). Maximum age and length was estimated as 5+ years and 27 cm L for females, and 5+ years and 23 cm L for males. These results are similar to those reported for the same species from upper parts of the Ceyhan River, Turkey (5+ years and 25.6 cm FL, for females; 5+ years and 25.0 cm FL, for males in Alp *et al.*, (2005).

The von Bertalanffy growth function provided an accurate description of *C. angorae*'s somatic growth. The von Bertalanffy growth functions that were calculated for male and female *C. angorae* in this study showed that, female theoretical maximal length value (L_∞ = 27.55 cm) were higher than the males (L_∞ = 22.84 cm). Growth parameters (L_∞, K and t_0) from the present study and previously published studies of *Capoeta* genus in Turkey are given in Table 4. The differences in the theoretical maximal length value between regions can be attributed to the difference in the size of the largest individual sampled in each area. The values of growth constant (K) determines how fast is the fish reaching L_∞ length (Sparre and Venema, 1992). The values of growth constant (K) obtained from this study were close to the values of

estimated for the *C. erhani* from Menzelet Reservoir (Ayyıldız *et al.*, 2014). However, these results differ from other studies (Erdoğan, 1988; Türkmen *et al.*, 2002; Alp *et al.*, 2005). A possible explanation for these results may be due to the samples collected in both lentic and lotic habitats. But in the other studies, samples were collected only in lotic habitats.

Table 4. Von Bertalanffy growth parameters of the different *Capoeta* species from different regions in Turkey.

Author	Study area	Species	Sex	Age	L_∞	K	t_0
Türkmen *et al.* (2002)	Karasu River	*C. c. umbla*	M	1 – 10	42.30	0.146	– 0.98
			F	1 – 12	45.70	0.139	– 0.83
Erdoğan (1988)	Aras River	*C. c. capoeta*	M	1 – 11	44.30	0.116	– 1.21
			F	1 – 11	48.40	0.111	– 0.79
			M+F	1 – 11	47.50	0.112	– 1.02
Alp *et al.* (2005)	Ceyhan River	*C. c. angorae*	M	1 – 7	47.25	0.133	– 0.76
			F	1 – 10	62.25	0.101	– 0.59
Ayyıldız *et al.* (2014)	Menzelet Reservoir	*C. erhani*	M	0 – 6	32.02	0.843	– 0.57
			F	0 – 6	33.83	0.964	– 0.56
			M+F	0 – 6	33.85	0.821	– 0.48
Present Study	Menzelet Reservoir and Fırnız Stream	*C. angorae*	M	0 – 5	22.84	0.772	– 0.53
			F	0 – 5	27.55	0.465	– 0.71
			M+F	0 – 5	42.25	0.102	– 2.62

Otolith size - fish size relationships were significantly linear, demonstrating that otolith growth was proportional to the somatic growth for *C. angorae* from Turkey. This result showed that fish size can be estimated by using the otolith size. Bostancı (2009) reported that, it is possible to determine fish length from otolith length or vice versa by using the relationship between fish and otolith length. Otolith morphometry informations are very useful to estimate size and species of prey fishes which are found in digestive stomach contents (Aydın *et al.*, 2004). Some authors have been studied the relationships between otolith morphometry and fish size for different species, however, only otolith length was used in the analysis (Aydın *et al.*, 2004; Uçkun *et al.*, 2006). In the current study, additional information has been reported given by the otolith length (OL), width (OW) and radius (OR). It is more appropriate to determine more than one equation (OL-L, OW-L or OR-L), because the otolith may be damaged in stomach.

The average otolith length, width and radius increased with the age of *C. angorae*. All models provided precise estimates, and otolith length was the best predictor of fish age for *C. angorae*, accounting for 78% of the variability in age followed by otolith width then otolith radius. Skeljo *et al.* (2012) reported that if a stereomicroscope with digital camera are available, measuring otolith length may be the best choice due to the quick procedure and provides better precision than the otolith width. Even though otolith morphometrics contain some ageing errors, they could make a better estimation of age structure than counting otolith annuli rings (Matic-Skoko *et al.*, 2011). However, in order to determine the utility of otolith morphometrics for age estimations, it is necessary to compare observed ages with the predicted ages (Pilling *et al.*, 2003; Steward *et al.*, 2009; Matic-Skoko *et al.*, 2011; Skeljo *et al.*, 2012). In the present results, no significant difference was found between the age predicted from the OL, OW and OR and counting otolith rings.

The present study provides the first information on otolith morphometrics, age and growth of *C. angorae*. The results derived in this study provide essential information needed for stock assessment and management. However, this study is missing monthly data. Further studies of *C. angorae* are needed to examine ageing and growth by using otoliths as well as samplings should be done on a monthly basis.

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