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Age and growth of iridescent toothcarp *Aphanius mento* (Heckel, 1843) (Cyprinodontidae) in Seyhan Reservoir (Southeastern Mediterranean, Turkey)

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Abstract

The population structure of *Aphanius mento* in the Seyhan Reservoir was studied on the basis of 834 fish specimens (516 males and 318 females) caught on a monthly basisbetween September 2013 and August 2014. Fish were collected using dip nets of tulle with a 1mm mesh size. The maximum age of fish was found to be 4 years for both sexes combined, the 1 year old age group comprised 62.20% of male samples. The overall sex ratio of females to males was 1:1.62. Von Bertalanffy growth parameters were L_∞=54.33 mm, K=0.399 year^{-1}, t_0 =-1.168 years for females, L_∞ =52.72 mm, K=0.397 year^{-1}, t_0=-1.137 years for males, and L_∞=56.50 mm, K=0.386 year^{-1}, t_0=-1.257 years for both sexes. The length (TL) - weight (W) relationship was W= 0.00051x$TL^{2.635}$, (r= 0.965) for males, W=0.00088x$TL^{2.464}$, (r= 0.987) for females and W=0.00066x$TL^{2.554}$, (r = 0.974) for both sexes. Condition factor ranged from 1.696 for males and 1.613 for females to 1.664 for both sexes. The mean condition factor (CF) was not significantly different between the sexes among all fish during different months (p>0.05). The present study represents the first comprehensive information on the population structure of *A. mento* in the Seyhan Reservoir. The results of this study will contribute to the population management and conservation of this species and be useful in increasing knowledge on its ecology and biology.

Keywords: *Aphanius mento*, Growth parameters, Condition, Southeastern Mediterranean

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Introduction

The genus *Aphanius* belonging to the Cyprinidontidae family currently includes about 20 species distributed along the ancient coast of the Tethys Sea (Kosswig, 1955; Villwock and Franz, 1972; Wildekamp *et al*., 1999) and many species that are local endemisms (Wildekamp *et al.,* 1999; Yogurtcuoğlu and Ekmekçi, 2013).

In Anatolia, the genus *Aphanius* is represented by 15 species: *Aphanius anatoliae, A. asquamatus*, *A. danfordii, A. fasciatus, A. fontinalis, A. icoii, A. irregularis, A. maeandricus***,** *A. marassantensis, A. meridionalis A. mento, A. saldae, A. splendens*, *A. sureyanus, A. transgradiens* and *A. villwocki* (Kuru, 2004; Fricke *et al.,* 2007; Parenti, 2002; Pfleiderer *et al.,* 2014, Çiçek *et al.,* 2015; Yogurtcuoğlu and Freyhof, 2018).

The genus *Aphanius* has no economic importance for human consumption. However, some species of this genus are aquacultured as ornamental fishes and scientifically used as material for some genetic studies (Güçlü, 2003; Sezen, 2011; Sezen and Olmez, 2012). Some species of the taxon are important because of their endemic character (Ergüden, 2015).

The iridescent toothcarp, *A. mento* (Heckel, 1843) is found in the Arabian Peninsula and is distributed throughout Iran, Iraq, Syria, Jordan, Israel, Lebanon and Turkey (Froese and Pauly, 2018). In Turkey, this species is found on the Tigris and Euphrates River drainages, Aksu River, Kırkgöz Stream, Orontes River and in the Seyhan and Ceyhan River drainages (Hrbek and Meyer, 2003; Fricke *et al.,* 2007; Güçlü and Küçük, 2008).

A few studies were carried out on *A. mento* focusing on its sytematic and growth features, nutrition, reproduction and determination of embryological and larval development stages and morphologic characters (Wildekamp *et al.,* 1999; Güçlü and Küçük 2008; Sezen, 2011; Güçlü and Küçük, 2011; Erguden, 2015).

A. mento is found in shallow waters among vegetation and it feeds on insect larvae, crustaceans, and algae (Krupp and Schneider, 1989). It tolerates a wide range of physico-chemical parameters, such as temperature (2-28.5°C), pH (7.5-8.5), salinity (1-3 g L^{-1}) and dissolved oxygen (5-8.4 mg L^{-1}) (Güçlü and Küçük, 2008; Sezen and Olmez, 2012).

The presence of this species was reported for the first time in the Seyhan Reservoir by Alagöz (2005) and Erguden and Göksu (2012) and the present study provides the first comprehensive information on the population structure of *A. mento* in the Seyhan Reservoir. The results of this study will contribute to the population management and conservation of this species and be useful in increasing knowledge on its ecology and biology.

Materials and methods

Samplimg

The study was carried out in the Seyhan Reservoir (37°03′38″ N; 35°19′32″ E), that covers a total surface area of 67.82 km^2. The average height from the sea is 67 m (Fig. 1). The Seyhan Reservoir is

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classified as a mesotropic lake with a mean annual water temperature of 26.5 ºC and pH of 7.41. In addition to *A. mento*, thirteen other fish species occurr in the Seyhan Reservoir namely: *Oncorhynchus mykiss* (Walbaum, 1792), *Carassius carassius* (Linnaeus, 1758)*Carassius gibelio* (Bloch, 1783), *Acanthobrama* sp., *Alburnus orontis* (Sauvage, 1882), *Squalius kottelati* Turan, (Yilmaz and Kaya, 2009), *Luciobarbus pectoralis* (Heckel, 1843), *Capoeta angorae* (Hanko, 1925), *Capoeta erhani* (Turan, Kottelat and Ekmekçi, 2008), *Cobitis evreni* Erk'akan, (Özeren and Nalbant, 2008), *Aphanius fasciatus* (Valenciennes, 1821) *Garra rufa* (Heckel, 1843), and *Salaria fluviatilis* (Asso, 1801) (Erguden and Goksu 2009; Erguden, 2016).

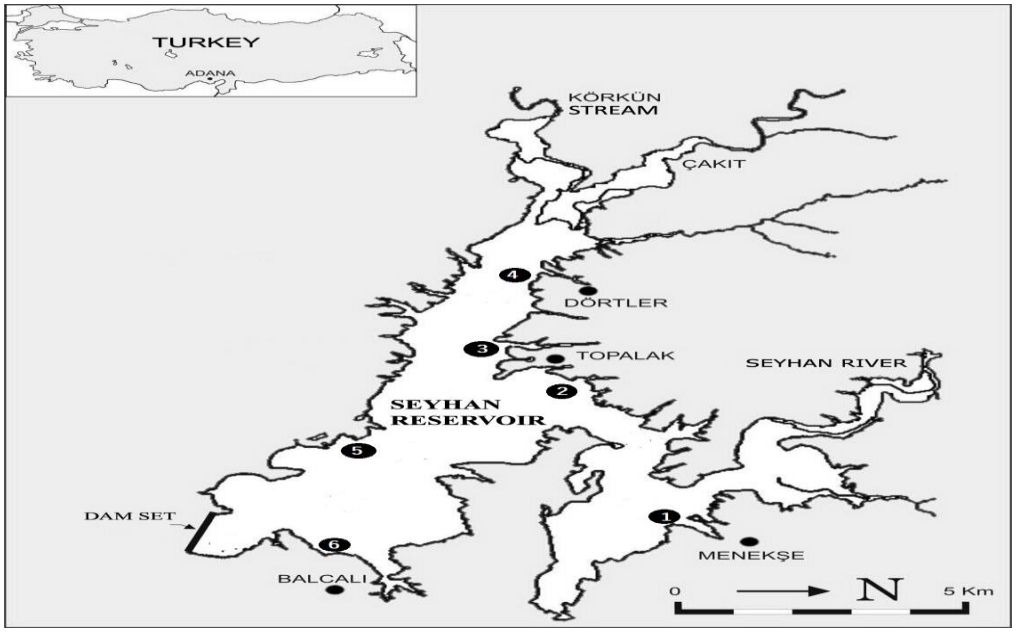


Figure 1: Map of the study area (Seyhan Reservoir).

Measurements and age determination

Fish were collected from September 2013 to August 2014 using dip nets of tulle with a 1mm mesh size. Samples were then preserved in 4% formalin. The age of the fish was determined from the scales taken from the left side of the body, between the end of the thoracic fin and the beginning of the dorsal fin. According to Lagler (1966) age was determined by taking 8-10 scales from each fish. Observations were made using a stereoscope with transmitted light. All readings for each scale preparation were undertaken twice by independent readers without prior knowledge about sex, length, or capture time. The total length (TL) of all preserved fish was measured to the nearest 0.01 mm. The total body weight (W) was recorded using an electronic balance to the nearest 0.001g.

Growth parameters and Condition factor

$W = a \times TL^b$,

where W is the weight in g, TL the total length in cm, a and b the parameters to be established (Ricker, 1975). The relationship between total length and

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weight was calculated separately for each gender.

The growth of the *A. mento* was calculated with the following Von Bertalanffy growth equations:

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

where L_t is the total length at age "t", L_∞ the average asymptotic length (mm). K is the body growth parameter, "t_0" the theoretical age and "a" and "b" constants (von Bertalanffy, 1938).

Condition factor of fish was estimated using Fulton's condition factor formula (Sparre and Venema, 1992):

$CF = W/TL^3 \times 100$.

where *W* is the total weight, TL is the total length, and *b* is the coefficient of allometric relation.

Statistical analyses

A chisquare (X^2 (0.05)) test was used to detect differences between the overall ratio of males to females (Düzgüneş *et al*., 1995). The relationship of weight to total length was established by the exponential regression equation. The linearized form of the power function was used in a regression analysis to estimate the length-weight relationship parameters. Slopes of the regression lines and mean length for each sex was compared using a t test (Zar, 1999). Prior to the analyses, ln-ln plots of length and weight values were performed for visual inspection of outliers in accordance with Froese (2006). Growth was considered positively allometric if the estimate of b was approximately equal to or greater than 3 and negative if it was less than 3. All the statistical analyses were performed at 95% confidence limits using Excel 2017 and SPSS.20 computer software.

Results

A total of 834 fish (516 males and 318 females) were caught and examined during the study period. Age composition ranged from 1 to 4. Overall, the percentages of males and females in each age class were as follows: age 1, 38.50% and 18.95%; age 2, 19.30% and 15.59%; age 3, 2.99% and 2.63%; age 4, 1.08% and 0.96%. The maximum age was found to be 4 years for both sexes combined, the 1 year age group comprised 62.20% of males samples. Besides 1 and 2 year age groups were predominantly males (Table 1). The sex ratio of females to males was 1.00:1.62 and it was statistically significant according to X^2 analysis (X^2=12.731, p< 0.05).

Table 1: *Aphanius mento* Age-length structure in Seyhan Reservoir.

	Age Groups (in years)				
Length intervals (mm)	**1**	**2**	**3**	**4**	**Total**
13-16.9	62				62
17-20.9	199				199
20.9-24.9	216	132			348
25-28.9		91			91
29-32.9		68	25		93

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Table 1 continued:

33-36.9			18	2	20
37-40.9			5	11	16
41-44.9				5	5
Total	477	291	48	18	834
Mean TL ± SD	20.14±2.36	26.47±2.27	33.89±2.19	40.41±1.97	24.00±5.16
Mean TW ± SD	0.1486±0.040	0.2892±0.049	0.5262±0.096	0.8379±0.082	0.2329±0.140
Males (% n)	321 (38.50)	161 (19.30)	25 (2.99)	9 (1.08)	516 (61.87)
Females (% n)	158 (18.95)	130 (15.59)	22 (2.63)	8 (0.96)	318 (38.13)
F : M – (P)	1.00:2.03 (P < 0.05)	1.00:1.24 (P >0.05)	1.00:1.14 (P >0.05)	1.00:1.13 (P >0.05)	1.00:1.62 (P < 0.05)

The size of *Aphanius mento* in the population ranged from 13.6 to 44.0mm and weight varied from 0.05 to 1.10g. Female specimens were longer than males. There was no significant difference between sexes in overall total length and total weight (*t*-test, $p>0.05$) (Table 2). The length class interval 21-24.9 mm was the most aboundant for males and females. The length frequency is presented in Fig. 2. The length-weight relationships calculated for males, females and combined sexes of *A. mento* were as follows: W=-3.282 + 2.635*log L (r^2=0.965, n=516), for males, W=-3.292+2.464*log L (r^2=0.987, n=516) for female and W=-3.178+2.554*log L (r^2= 0.973, n=834) for combined sexes and the exponent of length-weight relationship, b, showed negative allometry (Figs. 3, 4, 5). The slopes (b values) of the total length-weight regressions were significantly different between sexes (t test, $p<0.05$). A geographic comparison concerning the length-weight relationship for the species was also made using the results reviewed from previous studies (Table 3).

The following von Bertalaffy growth equation was obtained for both sexes: $L_t = 56.50\ (1–e^{-0.386(t+1.257)})$ (Table 4). L_∞ values for males and females were 52.72 and 54.33mm (Lt) respectively, whereas observed maximum lengths were 41.5mm for males and 44.0mm (Lt) for females. The total lengths were statistically not significantly different in all age groups (*t* -test, $p>0.05$). Comparison of growth performance for the different *Aphanius* species is given in Table 5. Examining the Fulton's condition factor (CF) for *A. mento*, males had the best well-being with a mean condition factor of 1.696±0.47 whereas it was 1.613±0.22 for females and 1.664±0.21 for the total sample. The mean monthly condition factor ranged from 1.31 to 1.91 in males and from 1.40 to 1.86 in females (Fig. 6). The condition factor differences between males and females were not significant ($p>0.05$).

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Table 2: Descriptive statistics and length–weight relationships for *Aphanius mento*, Seyhan Reservoir.

				$W=aL^b$				
Sex	**n**	**$L_{min-max}$**	**$W_{min-max}$**	**A**	**b**	**95%CIof b**	**r2**	**Growth Type**
Male	516	13.6-41.5	0.05-1.00	0.000522	2.635	2.59-2.67	0.965	A (-)
Female	318	14.0-44.0	0.06-1.10	0.000881	2.464	2.43-2.49	0.987	A (-)
Combined	834	13.6-44.0	0.05-1.10	0.000663	2.554	2.52-2.58	0.974	A (-)

*n, sample size; L, length (mm); W, weight (g); SE, standard error; CI, confidence interval; a, intercept of the relationship; b, slope of the relationship; r^2, coefficient of determination.

Table 3: Comparison of growth parameters for *Aphanius* species in the different areas.

Reference	**Species**	**Locality/ Country**	**Sex**	**n**	**L_{min}-L_{max} (TL, mm)**	**a**	**b**	**r**
Güçlü (2012)	*A.anatoliae*	Lake Eğirdir, Isparta Turkey	M+F	522	16.7-50.2	0.0232	2.322	0.826
Güçlü and Küçük (2008)	*A. mento*	Kırkgöz Spring, Antalya, Turkey	M	312	4.0-87.0	0.0568	2.403	0.878
			F	342	6.0-75.0	0.0702	2.225	0.846
			M+F	654	4.0-87.0	0.0626	2.334	0.865
Karslı and Aral (2010)	*A. danfordii*	Sırakaraağaçlar Stream, Sinop, Turkey	M	219	18.0-48.0	0.0144	3.149	0.983
			F	233	19.0-50.0	0.0135	3.179	0.989
			M+F	452	18.0-50.0	0.0139	3.164	0.987
Yogurtcuoglu and Ekmekci (2013)	*A. danfordii*	Hirfanli Reservoir, Turkey	M	1010	-	0.00004	3.450	0.964
			F	1224	-	0.00003	3.460	0.978
			M+F	2252	12.9-68.6	-	-	0.977
Leonardos and Sinis (1999)	*A. fasciatus*	Mesolonghi Lagoon, Greece	M	185	-	0.00648	3.400	0.990
			F	276	-	0.00595	3.440	0.990
			M+F	461	31.2-64.6	0.00612	3.420	0.990
Leonardos and Sinis (1999)	*A. fasciatus*	Etolikon Lagoon, Greece	M	137	-	0.00758	3.260	0.980
			F	160	-	0.00826	3.220	0.970
			M+F	296	29.2-68.5	0.00753	3.270	0.990
Guezi *et al*. (2017)	*A. fasciatus*	Ayata Lake, Algeria	M	-	22.5-57.6	0.013	2.809	0.863
			F	-	16.7-60.2	0.013	2.848	0.861
			M+F	1868	16.7-60.2	0.013	2.866	0.869
Koutrakis and Tsikliras (2003)	*A. fasciatus*	Porto-Lagos, NE Aegean, Greece	-	16	29.0-52.0	0.00980	3.312	0.953
Tarkan *et al*. (2006)	*A. fasciatus*	Küçükçekmece Lagoon, Turkey	-	11	38.0-53.0	0.01820	2.940	0.909
Dulcic and Glamuzina (2006)	*A. fasciatus*	River Neretva estuary, Croatia	-	10	28.0-53.0	0.00990	3.312	0.944
Andreu-Soler *et al*. (2006)	*A. iberus**	Segura River basin, Spain	M+F	753	13.0-42.0	0.01610	3.020	0.987
Verdiell-Cubedo *et al*. (2006)	*A. iberus*	Mar Menor Lagoon	-	337	8.0-40.0	0.01670	2.981	0.984
Esmaeili and Ebrahimi (2006)	*A. vladykovi*	Modar Dokhtar Spring, Iran	M+F	319	18.0-56.0	0.01540	3.148	0.990
Alavi-Yeganeh *et al*. (2011)	*A. vladykovi*	Shalamzar Spring, Iran	M	41	25.0-38.0	0.01070	3.276	0.962
			F	78	15.0-46.0	0.00830	3.482	0.989
			M+F	148	15.0-61.0	0.00770	3.534	0.979

*Length type: FL; Fork Length

N, number; M male, F, female; TL, total length; a, intercept of the relationship; b, slope of the relationship; r, correlation coefficient.

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Table 4: Von Bertalanffy growth parameters and equation of *Aphanius mento*

	Growth parameters			Growth equations
Sex	L_∞ **(mm)**	***K***	t_0	$Lt=L_\infty[1-e^{-k(1-t_0)}]$
Male	52.72	0.397	-1.137	$Lt=52.72\ [1-e^{-0.397(1+1.137)}]$
Female	54.33	0.399	-1.168	$Lt=54.33\ [1-e^{-0.399(1+1.168)}]$
Combined	56.50	0.386	- 1.257	$Lt=56.50\ [1-e^{-0.386(1+1.257)}]$

Table 5: Growth performance comparisons of *Aphanius species* from different sampling area.

Study	Species	Sex	L_∞	k	t_0	Locality
Leonardos and Sinis (1999)	*A. fasciatus*	F	78.62	0.245	-1.200	Mesolonghi Lagoon
		M	75.68	0.246	-1.190	
		A	77.58	0.257	-1.020	
Leonardos and Sinis (1999)	*A. fasciatus*	F	108.16	0,115	-2.090	Etolikon Lagoon
		M	80.72	0,178	-1.550	
		A	97.78	0.145	-1.580	
Guezi *et al*. (2017)	*A. fasciatus*	F	80.00	0.172	-1.377	Ayata Lake
		M	77.58	0.138	-2.236	
		A	83.60	0.148	-1.620	
Güçlü (2012)	*A. anatoliae*	A	54.51	0.279	-1.345	Lake Eğirdir
Güçlü *et al*. (2007)	*A. anatoliae sureyanus*	F	94.44	0.160	1.580	Burdur Lake
		M	79.22	0.220	1.140	
Güçlü and Küçük (2008)	*A. mento*	A	23.51	0.041	-2.904	Kırkgöz Spring
Karslı and Aral (2010)	*A. danfordii*	A	51.49	5.945	-0.502	Sirakarağaçlar Stream
Yogurtcuoglu and Ekmekci (2013)	*A. danfordii*	F	126.63	0.090	-2.350	Kızılırmak Basin
		M	61.20	0.190	-2.760	

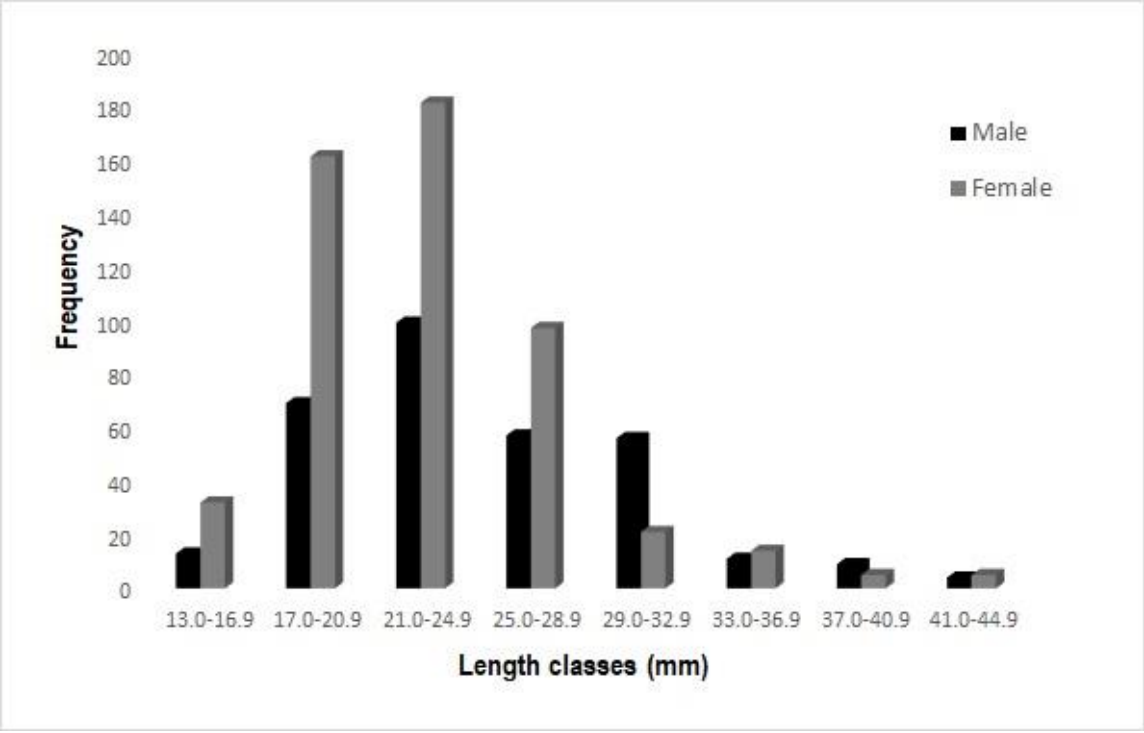


Figure 2: Length frequencies of *Aphanius mento* in the Seyhan Reservoir.

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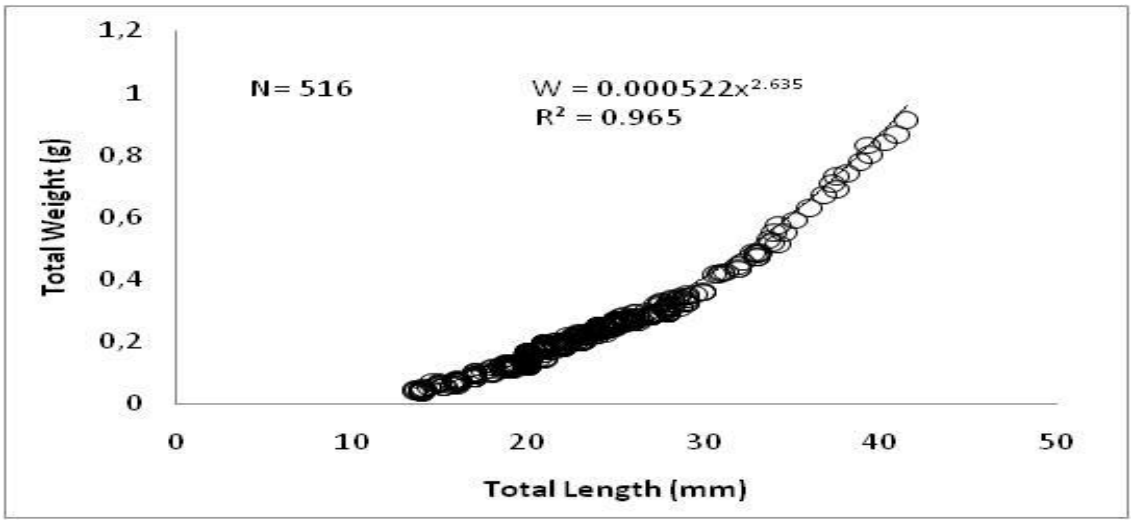


Figure 3: The length-weight relationships of *Aphanius mento* from the Seyhan Reservoir for males.

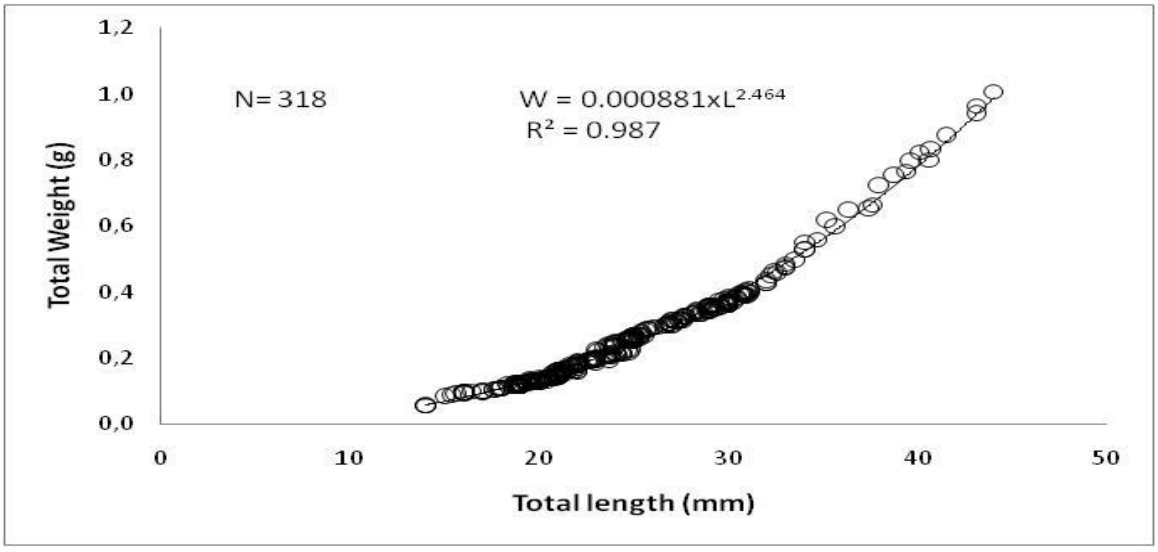


Figure 4: The length-weight relationships of *Aphanius mento* from the Seyhan Reservoir for females.

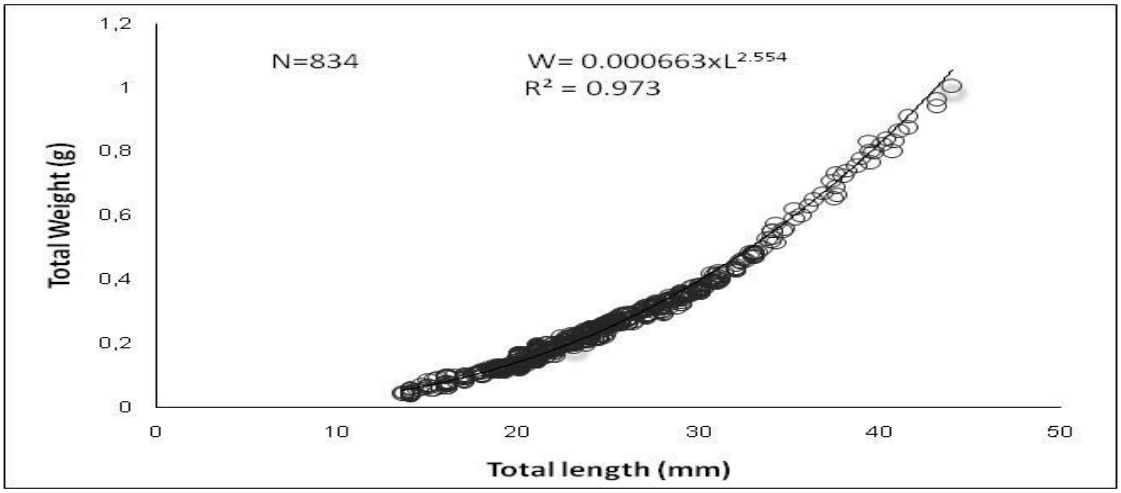


Figure 5: The total length-weight relationships of *Aphanius mento* from the Seyhan Reservoir for combined sexes.

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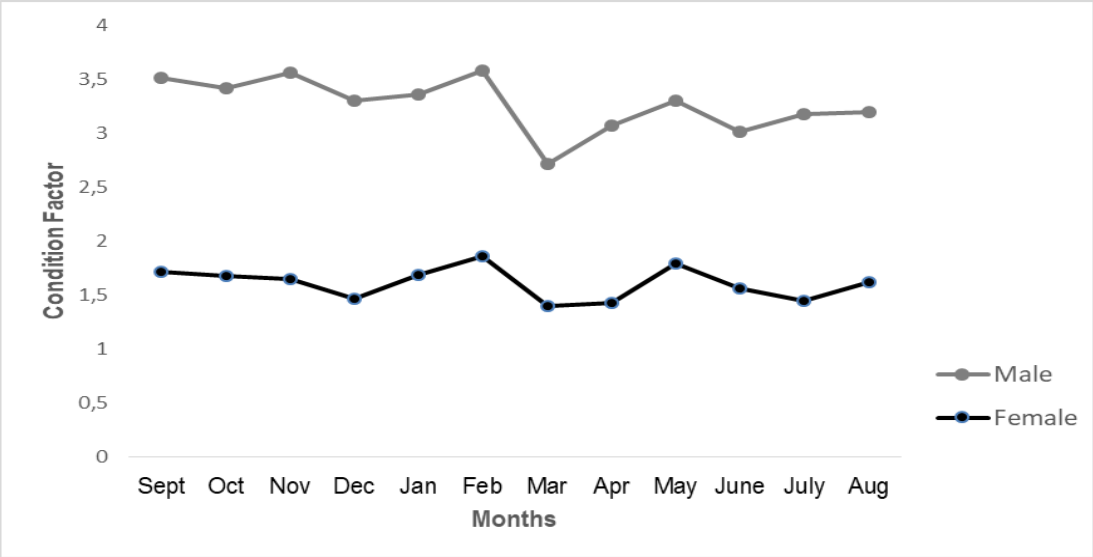


Figure 6: Mean condition factor for males and females of *Aphanius mento* during September 2013 to August 2014.

Discussion

In this study, the males to female sex ratio for *A. mento* from the Seyhan Reservoir was found to be 1.62:1.00. This ratio was similar to those reported for *A. mento* (1.10:1.00) in Kırkgöz Spring (Güçlü and Küçük, 2008), *A. anatoliae* (1.07:1.00) in Eğirdir Lake (Güçlü, 2012), (2.10:1.00) and *A. fasciatus* in Mariut Lake (Penaz and Zaki, 1985), but differs from *A. fasciatus* (1:2.44) in Mesolongi and Etolikon Lagoons (Leonardos and Sinis, 1999), *A. sureyanus* (0.64:1.00) in Burdur Lake (Güçlü *et al.*, 2007) and *A. danfordii* (1:1.21) in Hirfanlı.

Rezervoir. This differences may be due to fishing equipment, sample size and genetic structures of the examined populations.

The analysis of size and age showed that *A. mento* is a small-sized fish with populations mainly made of young individuals. Population length structure of *A. mento* in the Seyhan Reservoir ranged from 13.6-44.0 mm. However it was different in the results reported by Güçlü and Küçük (2008) for *A. mento* in Kırkgöz Spring (24.6-87.8mm). This difference may be caused by differences in the habitats and sampling methods. Total length and body weight of *A. mento* indicated that the females of each age class and each season were longer (Table 2) and heavier than the males. Leonardas and Sinis (1999) reported similar results for *A. fasciatus* in the Mesolongi and Etolikon lagoons.

The age of *A. mento* from the Seyhan Reservoir ranged from 1 to 4. According to Nikolsky (1980) a wide range in age distribution in a population can be an indication of enough food in the water system. The age range for *Aphanius* species was similar to that of *A. anatoliae* from the Eğirdir Lake ranging from 1 to 4 (Güçlü, 2012) and to that of *A. sureyanus* from Burdur Lake ranging from 0 to 4 (Güçlü *et al.*, 2007). However, the age range of this study was different from those reported in other studies: *Aphanius mento* from

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Kırkgöz Spring had a wider age range (0-7) (Güçlü and Küçük, 2008), *A. fasciatus* in Mesolongi and Etolikon Lagoon (Greece) ranged from 0-6 (Leonardos and Sinis, 1999) and from 1-6 in Ayata Lake (Algerian), *Aphanius vladykovi* in Modar Dokhtar Spring (Middle Zone of Iran) ranged from 0-2 (Keivany and Soofiani, 2004), *A. dandfordii* from Sırakaraağaçlar Stream (Turkey) ranged from 0-2 (Karslı and Aral, 2010), and from 0-5 in Kızılırmak (Yogurtcuoglu and Ekmekci,, 2013). According to Güçlü (2012) these differences may be due to the genetic structure of the populations.

In this study, b values within the length-weight relationships of *A. mento* were determined as 2.554for combined sexes. The allometry coefficient of the length-weight relationship indicate a negative allometric growth for males (b=2.635) and females (b=2.464) in the Seyhan Reservoir. In Kırkgöz Spring (Turkey) Güçlü and Küçük (2008) found negative allometric growth in males (2.403) and in females (2.256) for *A. mento* and similarly in Ayata Lake, Guezi *et al.* (2017) calculated negative allometric growth in males (2.809) and in females (2.848) for *A. fasciatus*. Hovewer, in Mariut Lake, Penaz and Zaki (1985) reported positive allometric growth in females (3.619) and negative growth in males (2.740) for *A. fasciatus*. In addition, Leonardos and Sinis (1999) found positive allometry for males and females for *A. fasciatus* and *A. vladykovi* in Mesolongi and Etolikon lagoons and Alavi-Yeganeh *et al.* (2011) in Shalamzar Spring (Iran) (Table 3). The origins of these differences probably are biotic and environmental factors. According to Bagenal and Tesch (1978), length-weight relationships may be influenced by sex, maturity, geographical location and environmental conditions.

The correlation coefficient (r) of the length - weight relationship of *A. mento* was 0.974 for combined sexes. The value is similar to *A. dandfordii* (Yogurtcuoglu and Ekmekci, 2013; Karslı and Aral, 2010), *A. iberus* (Andreu-Soler *et al.,* 2006) and *A. sureyanus* (Güçlü *et al.* 2007), but different from *A. anatoliae* (Güçlü, 2012), *A. mento* (Güçlü and Küçük, 2008), *A. fasciatus* (Guezi *et al.*, 2017) and *A. vladykovi* (Keivany and Soofiani, 2004). These situations may be caused by the habitats and also by morphological differences.

The average asymptotic total length (L_∞) values showed that females of this population had a higher length growth rate than males and L_∞ value was calculated as 54.33 mm for females and 52.72 mm for males. Similarly, Güçlü (2012) determined L_∞ value of 54.51 mm for females for *A. anatoliae* in Lake Eğirdir, Isparta (Turkey). However, different values were reported for the total sample of *A. mento* (L_∞ value 23.51mm) in Kırkgoz Spring (Güçlü and Küçük, 2008) and for *A. fasciatus* from Mesolongi and Etolikon lagoons, with (L_∞ values of 94.44 mm and 79.22 mm for females and males, respectively) (Leonardos and Sinis, 1999). Different values of L_∞ can be explained by environmental conditions such as salinity and temperature.

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Condition factor values ranged from 1.61 to 1.69 with a mean of 1.66 for the total sample of *A. mento*. The highest condition factor for males and females was in February. Average condition factor for the same species was found to be 2.55 in Kırkgöz Spring by Güçlü and Küçük (2008), and 1.72 in Hirfanlı Reservoir for *A. danfordii* by Kırankaya *et al.* (2014). Guezi *et al.* (2017) also reported values similar to those found in the present study: 1.41 in females and 1.20 in males for *A. fasciatus* in Ayata Lake (Algeria). The condition factor may vary by sex, age, feeding condition, season, reproduction cycle (Alavi Yeganeh *et al.*, 2011; Kiani *et al.*, 2016).

Since no information currently exists on the growth parameters of *A. mento* in the Seyhan River Basin (Adana, Turkey), this paper is an important contribution to the science and fisheries management applications for this species.

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