RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Age and some growth parameters of *Squalius cephalus* (Linnaeus, 1758) inhabiting Karasu River (East Anatolia, Turkey)

Karasu Nehri'nde (Doğu Anadolu, Türkiye) yaşayan *Squalius cephalus* (Linnaeus, 1758)'un yaş ve bazı büyüme parametreleri

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Abstract: The present study was carried out concerns a research of the age determination and some growth parameters of chub, *Squalius cephalus* (Linnaeus, 1758) living in 14 different station from Karasu River (East Anatolia, Turkey). For this purpose, a total of 196 fish specimen (100 females and 96 males) of *S.cephalus* were captured between 2014 and 2016 by electroshocker. Female/male ratio was 1/0.96. Minimum-maximum length and weight of captured fishes were determined as 7.6-23.9 cm and 4.8-198.2 g, respectively. The age groups were determined between 0 and 6. The parameters of von Bertalanffy growth function estimated as L_∞=31.98 cm, k=0.136 year^{-1}, t_0=-1.40 year for all individuals. The growth performance index (Φ') value was computed as 2.143. The length and weight relationships W=0.0060L$^{3.27}$ (R^2=0.98) for all individuals. Significant statistical differences in condition factors between age groups and sexes were not found (P > 0.05, t-test).

Keywords: Squalius cephalus, age, von Bertalanffy growth function, Karasu River, Turkey

Öz : Bu çalışma, Karasu Nehri'nin 14 farklı istasyonunda yaşayan tatlısu kefali, *Squalius cephalus* (Linnaeus, 1758)'nin yaş tayini ve bazı büyüme özelliklerinin araştırılması ile ilgilidir. Bu amaçla, 2014 ve 2016 yılları arasında elektroşokerle toplam 196 *S.cephalus* balık örneği (100 dişi ve 96 erkek) yakalandı. Dişi/erkek oranı 1/0,96 idi. Yakalanan balıkların minimum-maksimum uzunluk ve ağırlığı 7,6-23,9 cm ile 4,8-198,2 g olarak belirlendi. Yaş grupları 0-6 idi. von Bertalanffy büyüme parametreleri tüm bireyler için L∞=31,98 cm, g, k=0,136 yıl-1, t_0=-1,40 yıl olarak hesaplandı. Büyüme performans indeks değeri (Φ') 2,143 olarak hesaplandı. Tüm bireyler için boy ve ağırlık ilişkisi W=0,0060L$^{3.27}$ (R^2=0,98) dir. Yaş grupları ve cinsiyetler arasındaki kondisyon faktörlerinde farklılıklar istatistiksel olarak anlamlı bulundu (P > 0,05 t-test).

Anahtar Kelimeler: Squalius cephalus, yaş, von Bertalanffy büyüme fonksiyonu, Karasu Nehri, Türkiye

INTRODUCTION

Cyprinidae is the largest of fish family in Turkey. *S. cephalus* (Linnaeus, 1758) is widely distributed all over Europe, the Black Sea, Caspian Sea, and Azov Sea basins (Geldiay and Balık, 1988; Kottelat and Freyhof, 2007). Several studies conducted at different localities in Turkey have investigated the age, growth and length-weight relationships of *S. cephalus* (Erdoğan et al., 2002; Kara and Solak, 2004; Torcu-Koç et al., 2007; Şen and Saygın, 2008; Bostancı and Polat, 2009; Innal, 2010; Benzer, 2013; Kaptan, 2014; Özay, 2014; Demirol et al., 2016; Kılıç and Becer, 2016; Benzer and Gül, 2017; Özcan et al., 2017; Şaşı and Özay, 2017; Özpiçak et al., 2018).

Age and growth studies are important for problems associated with management of fisheries (Polat et al., 1999). It forms the basis for calculations leading to a knowledge of the growth, mortality, recruitment and other fundamental parameters of their populations. Thus knowledge of biological characteristics is critically important in understanding, the future of the species due to environmental changes. This study provides

useful information on basic biological characteristics such as age, growth, condition factor, length-weight relationship of *S. cephalus* freshwater fish species in Karasu River (14 different station, between Erzincan and Erzurum).

MATERIAL AND METHODS

The study area, which is in the tributary of Karasu in the East Anatolia region of Turkey (Table 1; Figure 1). Samples were caught by electroshocker from Karasu River. Fish samples were transported to the laboratory and fixed with 5% formaldehyde. Fish samples were measured to the nearest 0.1 cm for total length (TL) and to the nearest 0.1 g for total weight (W) and sexes were determined with macroscopic care of gonads. Female/male ratios were checked by chi-square test according to 1/1 difference.

Table 1. Geographic locations of the Karasu River during the study area

Station	Location	Coordinate
1	Yeşildağ Stream	40º08'13''N 41º25'49''E
2	Yeşildere Stream	40º08'21'' N 41º24'25''E
3	Köşk Stream	40º05'45''N 41º24'48''E
4	Ağasuyu Stream	39º59'35' N 41º08'56''E
5	Sincan Stream	39º59'40'' N 41º07'21''E
6	Çiğdemli Stream	39º58'18'' N 41º01'23''E
7	Han Stream	39º56'53'' N 40º46'08''E
8	Taşağıl Stream	39º57'44'' N 40º34'40''E
9	Karataş Stream	39º56'13'' N 40º07'51''E
10	Büyükgözenin Stream	39º56'39'' N 40º15'03''E
11	Deliçay Stream	39º38'08'' N 39º20'18''E
12	Karnı Stream	39º40'24'' N 39º13'34''E
13	Eriç Stream	39º30'36'' N 38º53'14''E
14	Kırık Stream	39º29'23'' N 38º44'37''E

The scales of fish species were used for age determination. Scales were taken between the lateral line and the dorsal fins. Scale preparation for ageing was done according to method of Chugunova, 1963. Age readings were made with an OLYMPUS BX53 microscope. Each scale was read least two times by independent readers. The index of the average percentage error (IAPE) was assessed to utilize the accuracy of the age designates between readers. The equation is stated as follows: $IAPE = 1/N \sum (1/R) \sum (x_{ij} - x_j/x_j)$, where N is the number of fish aged, *R* is the number of times each fish was aged, *xij* is the *ith* age determination of the *jth* fish, and *xj* is the mean age calculated for the *jth* fish (Beamish and Fournier, 1981).

The von Bertalanffy growth function (VBGF) was calculated with as follows equation (von Bertalanffy, 1938): $L_t = L_\infty [1 - e^{-k(t-t0)}]$, where Lt is the expected total length at age t years, L_∞ is the asymptotic average maximum total length, k is the growth coefficient, and t_0 is the theoretical age at zero length.

The growth performance index was calculated as follows (Pauly and Munro, 1984): $\Phi = \log_{10}(k) + 2\log_{10}(L_\infty)$, where k and L_∞ are the von Bertalanffy growth equation parameters.

Total length-weight relationships were determined using the equation: $W = a L^b$, where W is weight (W), L is total length (TL), a is the intercept, and b is the slope. The degree of association between the variables was calculated by the assess index, R^2 (Ricker, 1975). Condition factors were calculated with the equation: $CF = (W / TL^b) * 100$ where W is weight; TL is total length and b is the index of allometric of relationship (Le Cren, 1951).
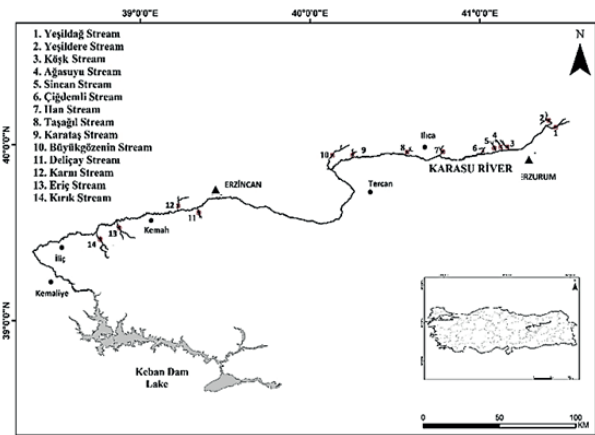

Figure 1. Sampling stations on the Karasu River

RESULTS

The minimum, maximum and average total length (cm), weight (g) and condition factor with standard error (SE) for female and male according to age groups a total of 196 *S. cephalus* are given in Table 2. The total length and weight of individuals ranged from 7.6-23.9 cm to 4.8-198.2 g.

The ages of *S. cephalus* ranged from 0 to 6 years and the age-one was dominant, fish population was 51.0% female and 49.0% male (Figure 2). The differences in length and weight between sexes was statistically insignificant in all age groups (P>0.05). The sex ratio (female/male) was calculated as 1/0.96 and chi-square test showed that significantly different from equality (P >0.05).

Table 2. Min, max and average TL (cm), W (gr) and CF with standard error (SE) for female and male according to age groups of *S. cephalus* from Karasu River

Age	Sex	n	%n	TL(Min-Max)	TL±SE	W(Min-Max)	W±SE	CF±SE
0	♀	15	10.43	8.0-10.5	8.8±0.51	4.9-12.7	7.5±1.43	1.050±0.03
	♂	14	9.56	7.6-9.5	8.4±0.37	4.8-9.6	6.8±1.01	1.107±0.04
I	♀	23	11.30	10.1-12.5	11.6±0.28	10.1-21.1	17.6±1.40	1.110±0.03
	♂	21	13.04	10.8-12.4	11.6±0.21	13.8-21.6	17.7±0.94	1.131±0.02
II	♀	15	7.82	12.4-14.6	13.44±0.37	24.4-37.3	29.7±2.24	1.216±0.05
	♂	14	9.56	12.5-15.5	14.04±0.43	23.7-44.4	31.8±3.15	1.135±0.04
III	♀	16	6.95	15.3-16.8	16.15±0.28	42.2-55.4	48.8±3.39	1.163±0.09
	♂	20	6.08	15.6-16.8	16.33±0.26	55.1-57.6	56.6±3.32	1.309±0.12
IV	♀	19	6.95	17.7-20.0	18.6±0.50	89.2-109.7	98.3±8.17	1.514±0.10
	♂	16	6.95	17.1-18.6	17.75±0.31	56.2-80.6	67.8±7.54	1.209±0.11
V	♀	11	5.21	18.3-20.4	19.5±0.24	87.4-109.6	99.56±4.42	1.186±0.09
	♂	10	4.34	19.7-20.2	19.9±0.17	102.0-112.7	107.4±3.90	1.350±0.01
VI	♀	1	0.86	-	22.2	-	133.9	1.223
	♂	1	0.86	-	23.9	-	198.2	1.451
All groups	♀	100	51	8.0-22.2	13.81±0.38	4.9-133.9	40.6±3.79	1.194±0.02
	♂	96	49	7.6-23.9	14.49±0.39	4.8-198.2	47.5±4.00	1.205±0.02

According to the age estimations; the index of the average percentage error (IAPE), the index of the mean percentage error was found 7.37 by 2 independent readers. This means that the confidence interval for the reliability of estimations made are within 5 to 15%, indicating that our aging method represents a precision approach to the age determination (Girgin and Başusta, 2016).

The parameters of von Bertalanffy growth, the mean observed total lengths-at-age estimated as $L_t=31.98[1-e^{-0.136(t+1.40)}]$ for *S. cephalus* (Figure 3; Table 3). The growth performance index (Φ') value (all individuals) was computed as 2.143.
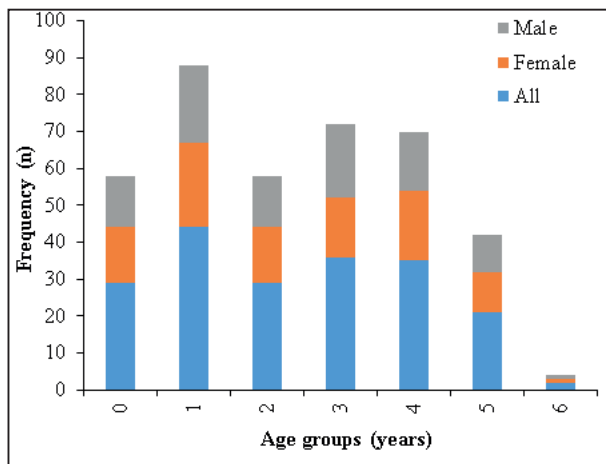

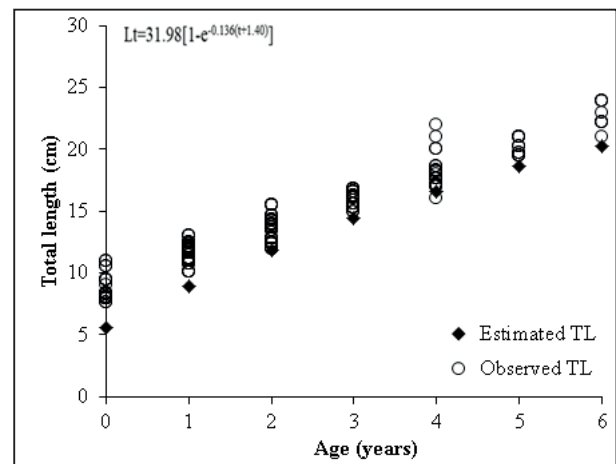**Figure 2.** Age groups-frequency for *S. cephalus* from Karasu River

Figure 3. Age-total length relationships according to age (all individuals) for *S. cephalus*

Table 3. The parameters of the growth and age-length for *S. cephalus* from Karasu River

Sex	n	Growth parameters			Age-length parameters			
		a	b	R²	L_∞ *(cm)*	k *(year-1)*	to *(year)*	Φ′
♀	100	0.0058	3.27	0.98	30.69	0.140	-1.20	2.120
♂	96	0.0069	3.20	0.99	34.31	0.128	-1.59	2.178

n, sample size; L_∞, asymptotic length; t_0, theoretical age; k, body growth coefficient; Φ′, growth performance index

The length-weight relationships and 95% confidence intervals of b (all individuals) were calculated as W= 0.0060L$^{3.27}$ (R²=0.98; b=3.12-3.33; p<0.001). The growth type of *S. cephalus* was positive allometric growth (b>3) from Karasu River (Figure 4). The highest condition factor values were observed as 4 in age group (1.340).
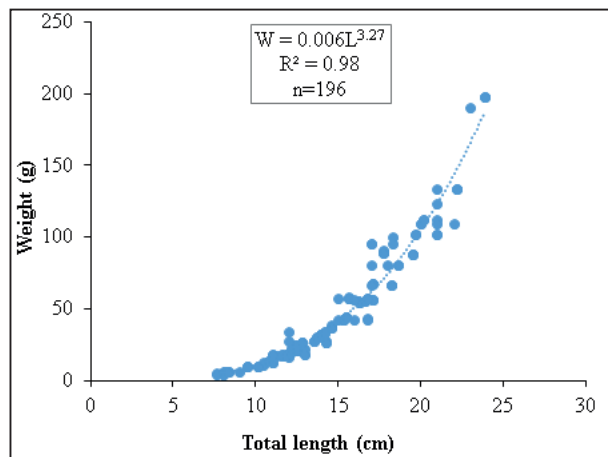
Figure 4. Total length-weight relationships for *S. cephalus* (all individuals)

DISCUSSION

In this study, total length and weight ranged from 7.6 to 23.9 cm and from 4.8 to 198.2 g, respectively in the Karasu River. Average length and weight values were 13.81±0.38 cm and 40.6±3.79 g for females, 14.49±0.39 cm and 47.5±4.00 g for males. These results indicated that males had higher averages in terms of length and weight than females from Karasu River. The maximum lengths of *S. cephalus* were reported as 27.5 cm in the Aras River (Türkmen et al., 1999); 26.2 cm in the Topçam Dam Lake (Şaşı and Balık, 2003); 40.5 cm in the Karasu River (Muş), (Şen and Saygın, 2008); 35.3 cm in the Çamlıdere Dam Lake (Bostancı and Polat, 2009); 27. 9 cm in the Tödürge Lake (Unver and Erk'akan, 2012)

and 22.8 cm in the Akçay River (Şaşı and Özay, 2017). In this study, the maximum lengths of females and males were found to be 22.2 to 23.9 cm, respectively, in the Karasu River. The scale age readings were between 0 and 6 years of age. 1 age group was the dominant group. Previous studies on the age of *S. cephalus* were as follows: Karasu River (Erzurum, 1995-1997) 1-9 (Erdoğan et al., 2002); Sır Dam Lake 1-6 (Kara and Solak, 2004); Karasu River 1-8 (Şen and Saygın, 2008); Uzunçayır Dam Lake 0-11 (Demirol et al., 2016);Tödürge Lake 1-7 (Ünver and Erk'akan, 2012) and Devres Stream 1-6 (Benzer and Gül, 2017). Age distributions give information about important population parameters (death, reproduction and development).

Asymptotic length of males was higher than females (L_∞ = 34.31 and 30.69); (Table 3). The reason for this is that males grow faster than females and live longer (Weatherley, 1972). While the maximum L_∞ values 74.0 cm in Sır Dam Lake (Kara and Solak, 2004) and 60.75 cm in Karasu River (Muş) (Şen and Saygın, 2008); the minimum L_∞ values 26.71 cm in İkizcetepeler Dam Lake (Torcu-Koç et al., 2007) for *S. cephalus*. Some species, most of them short-lived, have a high value of k (Sparre and Veneme 1998). In this study, Generally k values were less than the same values observed other studies (Table 4). These differences can be caused such as the size and number of the largest individuals

The LWRs were highly significant; all species were determined between length and weight very strong positive relationship in Karasu River (R²>0.98). The equations for derivation of the lengths measurements presented may enable researchers to gain useful information about length conversions. The growth of *S. cephalus* was positive allometric growth (b>3). There have been different studies on the length-weight relationships of *S. cephalus* are presented in Table 3 and these values were similar with this study. These high values of R² show that the length relationships are linear observed range of values. Regression analyses are

shown that fish length have high significant correlation with weight (P <0.001). Furthermore, when the t-test results were analyzed for the significance of regression coefficients (P <0.01).

The condition factors changed between 1.05-1.22 for females and 1.11-1.45 for males from our study area. The minimum condition factor from Ikizcetepeler Dam Lake was given as 0.77 and maximum condition factor

from Devres Stream was given as 2.75 (Table 4).

This study gives useful information on age and some growth parameters of *S. cephalus* from Karasu River, (14 different station) Turkey. Fisheries managers should consider creation of freshwater protected areas with regional fisheries organizations. This research will shed light on the comparison of growth characteristics of *S. cephalus* in different regions.

Table 4. Population characteristics of *S. cephalus* presented different studies

Habitat	Sex	N	a	b	R²	L∞	k	to	Φ′	CF	Author
Karasu River (Erzurum)	♀	376	0.0142	2.980	0.99	41.42	0.12	-1.32	-	1.35	Erdoğan et al., 2002
	♂	383	0.0150	2.952	0.98	35.88	0.12	-1.17	-	1.32	
Sır Dam Lake*	♀	234	0.0074	3.174	0.98	74.00	0.17	-0.82	2.968	1.25-1.60	Kara and Solak, 2004
	♂	191	0.0063	3.210	0.97	54.00	0.30	-0.49	2.941	1.18-1.50	
	♀+♂	425	0.0069	3.190	0.98	-	-	-	-	-	
İkizcetepeler Dam Lake	♀	172	0.023	2.87	0.90	28.89	0.224	-1.55	2,263	0.77-2.40	Torcu-Koç et al., 2007
	♂	242	0.019	2.92	0.90	26.71	0.259	- 1.55	2.251	1.30-2.03	
Karasu River (Muş) *	♀	110	0.00895	3.138	0.98	60.75	0.09	-0.32	2.521		Şen and Saygın, 2008
	♂	153	0.00828	3.162	0.97	32.93	0.12	-1.78	2.114	1.297	
	♀+♂	263	0.00844	3.156	0.98	60.75	0.08	-0.33	2.470		
Çamlıdere Dam Lake	♀	72	0.013	3.04	0.93	38.51	0.328	-1.67	-	1.38-1.99	Bostancı and Polat, 2009
	♂	29	0.014	3.01	0.94	34.12	0.371	- 1.07	-	1.27-1.91	
Sakarya River (Kirmir Stream)	♀	175	0.0122	3.06	0.91	28.1	0.149	-1.54	-	1.05-2.33	Benzer, 2013
	♂	192	0.0012	3.06	0.90	27.3	0.169	-1.31	-	1.05-2.73	
Istranca Stream	♀	171	0.0071	3.18	0.99	49.13	0.127	-0.488	-	-	Kaptan, 2014
	♂	488	0.0093	3.08	0.99	39.51	0.137	-0.682	-	-	
Akçay Stream	♀	145	0.0116	2.97	0.96	36.27	0.102	-1.372	-	-	Özay, 2014
	♂	168	0.0780	3.16	0.97	26.09	0.281	-0.393	-	-	
Uzunçayır Dam Lake	♀	161	0.0044	3.294	0.93	37.44	0.21	-1.44	2.468	0.89-1.30	Demirol et al., 2016
	♂	169	0.0102	3.027	0.95	49.25	0.09	-2.91	2.339	1.04-1.23	
	♀+♂	334	0.0073	3.135	0.95	40.29	0.16	-1.76	2.414		
Yeniçağa Lake	♀+♂	729	-	-	-	36.88	0.248	-1.278	-	-	Kılıç and Becer, 2016
Devres Stream	♀	170	0.0108	3.11	0.91	27.1	0.159	-1.47-	-	1.04-2.35	Benzer and Gül, 2017
	♂	159	0.0146	2.97	0.90	27.1	0.160	1.46	-	1.01-2.75	
Akçay River (In Upper)	♀	199	0.026	2.72	0.98	34.71	0.12	-0.87	2.160	1.03-1.99	Şaşı and Özay, 2017
	♂	167	0.025	2.75	0.98	32.87	0.13	-0.72	2.140	0.96-1.97	
Karasu River (Erzin- can-Erzurum)	♀	100	0.0058	3.27	0.98	30.69	0.140	-1.20	2.120	1.05-1.22	This study
	♂	96	0.0069	3.20	0.99	34.31	0.128	-1.59	2.178	1.11-1.45	
	♀+♂	196	0.0060	3.27	0.98	31.98	0.136	-1.40	2.143	1.05-1.45	

*fork length

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