Full Length Article

Growth and Reproduction of Chub (*Squalius cephalus*) in Lake Yeniçağa, Bolu, Turkey

Savaş Kılıç[1*] and Z. Arzu Becer[2]
[1]*Konyaaltı District Directorate of Food, Agriculture, and Livestock, 07070 Antalya, Turkey*
[2]*Akdeniz University, Fisheries Faculty, 07059 Antalya, Turkey*
*For correspondence: savasyay@gmail.com; abecer@akdeniz.edu.tr

Abstract

Growth and reproduction of chub population were investigated in Lake Yeniçağa, Bolu, Turkey. A total of 729 chub were sampled between March 2009 and July 2010. The age of sampled chub ranged from 1+ to 8+. According to the sex ratios of female and male (2.98:1.00), female was dominant in this population. For all individuals, von Bertalanffy growth parameters were $L\infty$ = 36.88 cm, $W\infty$ = 713.01 g, k = 0.248, t_0 = -1.278 and b = 3.109. The average condition factor (CF) was 1.48. The lengths at first sexual maturity of female and male chub were 19.2 cm and 15.3 cm respectively. Reproduction period was between the months April to July, egg diameter 1.29 mm and average egg yield were determined to be 25349 unit/individual. The minimum landing size and prohibition season of fishing of chub, which was regulated by the Republic of Turkey Ministry of Food, Agriculture and Livestock were compatible with this study. © 2016 Friends Science Publishers

Keywords: Chub; *Squalius cephalus*; Growth; Reproduction; Lake Yeniçağa

Introduction

Chub is widely distributed all over Europe, the Black Sea, Caspian Sea, and Azov Sea basins (Geldiay and Balık, 1988; Kottelat and Freyhof, 2007). It was spread all inland water of Turkey except around Lake Van (Çelikkale, 1994). While there have been several researches on growth and reproductive characters of chub living lakes, dam lakes, and rivers in Turkey (Ekmekçi, 1996; Kalkan *et al.,* 2005; Koç *et al.,* 2007; Ünver and Kekilli, 2010, 2012), there has been no research on biological properties and stock assessment of chup in Lake Yeniçağa, Turkey.

Determination of age, length, weight and growth characters which are condition factors and length-weight relationships, assume an important prerequisite in fishery biological investigations and stock assessment methods. Length at first sexual maturity have been applied as size-based reference points and reproduction period can be used to time restriction for the fishery to conservation of commercial fishery resources (Cochrane, 2002).

The aim of this study was to determine growth and reproduction properties of Chub (*Squalius cephalus*) in Lake Yeniçağa. The provided scientific data on these parameters are expected to be helpful in fishery management of the chub in Lake Yeniçağa.

Materials and Methods

Lake Yeniçağa is a natural lake located in west Black Sea region of Turkey (Fig. 1). Lake Yeniçağa is a shallow eutrophic freshwater lake with maximum depth of 5.2 m (Saygı and Demirkalp, 2004), 988 m above sea level and surface area of about 260 ha. As monthly, five different gillnets (18, 22, 30, 40 and 50 mm mesh size) were used for sampling of the fish from five different locations (Fig. 1). The fork length and dry weight of chub were measured. The age of chub was determined by using the scales (Lagler, 1966). Growth was determined as absolute and proportional considering sex. Values of relative growth rate (R) in length (RL) and weight (RW) were calculated using equations $RL = (L_t - L_{t-1})/L_{t-1}$ and $RW = (W_t - W_{t-1})/W_{t-1}$, respectively (Chugunova, 1963). Length-weight relationship was calculated according to $W = aL^b$ equation described by Le Cren (1951). Age-length and age-weight relationships were evaluated using von Bertalanffy growth equations, which were adapted to fishery by Beverton and Holt (1957). Growth equations $L_t = L_\infty (1 - e^{-k(t-t_0)})$ and $W_t = W_\infty (1 - e^{-k(t-t_0)})^b$ were used to estimate the age-length and age-weight relationships, respectively. Isometric growth equation $KF = (W/L^3) \times 100$ of Lagler (1966) was used to calculate the condition factor (CF).

The sex and maturity stage of chub were determined morphologically. The stages of maturation were classified according to eight stages of total spawning fish (Holden and Raitt, 1974). The third and later stages of fish were considered mature. The age and length at first maturity were calculated according to mature fish in reproduction period using logistic regression model with formulas P =

$1/[1+e^{(-r (L - Lm)}]$ and $P = 1/[1 + e^{(-r (t - tm)}]$ (Ricker, 1973). Spawning period was determined by monitoring monthly changes in the gonadosomatic index (GSI). GSI values were calculated using equations GSI = (GW/W) × 100 (Ricker, 1975). Both egg diameter and fecundity (F) were determined from the mature fish, not spawned just before the spawning period. Diameter of 15 eggs, taken from the anterior, middle and posterior parts of the ovary of each fish were measured using microscope. Fecundity (F) was determined using the gravimetric method described by Bagenal (1978). Relationship between fecundity and fork length, weight, and age were calculated using equations LogFL = Loga + b × LogL, FW = a + b × W, and FA = a + b × A, respectively (Avşar, 2005).

Chi-square (χ^2) and t-test were used for statistical analysis. Statistical significance was tested at the 0.05 probability level. All tests were performed using the statistical program SPSS 15.0.

Results

The age of sampled chub ranged from 1+ to 8+ (Table 1). The age group 2+ was dominant for both females and males in the population. The ratios of female and male in this population were 74.9 and 25.1%, respectively. Sex ratio of female to male was 2.98:1.00. The difference between sex rations was statistically significant (P<0.05).

Fork-length ranged from 12.8 to 34.6 cm and 22 cm length group was at the highest percentage with 22.1% in the population (Table 1). Weight ranged from 31.8 g to 643.1 g, and 200 g weight group was at the highest percentage with 20.3% (Fig. 2). For all individuals, von Bertalanffy growth parameters were determined as L∞ = 36.88 cm, W∞ = 713.01 g, k = 0.248, t_0 = -1.278 and b = 3.109. For all individuals, length-weight relationship was calculated as W = 0.010FL$^{3.109}$ (R^2= 0.977) (Fig. 3).

Average condition factors (CF) of female, male, and for all individuals of chub were calculated as 1.49 ± 0.01, 1.43 ± 0.01 and 1.48 ± 0.01, respectively. Average CF of females was higher than males, and difference between them was statistically significant (P<0.05).

A total of 353 chub sampled between March and June were taken into account to determine age and length at first maturity. It was determined that 86% of female and 90% of male reached maturity at age 2+. The lengths at first maturity of female and male, gonad maturity in 50% were calculated to 19.18 and 15.32 cm, respectively (Fig. 4).

Monthly changes in the gonadosomatic index (GSI) values in female started to increase dramatically in March, reached to peak in April, decreased end of the July, and stopped in August (Fig. 5). It was determined that spawning period of chub in Lake Yeniçağa was between the months April and July according to monthly changes of GSI.

The mean egg diameter was calculated 1.29 mm. The largest and the smallest egg diameter were measured 1.62 mm in May 2009 and 1.00 mm in April 2009, respectively.
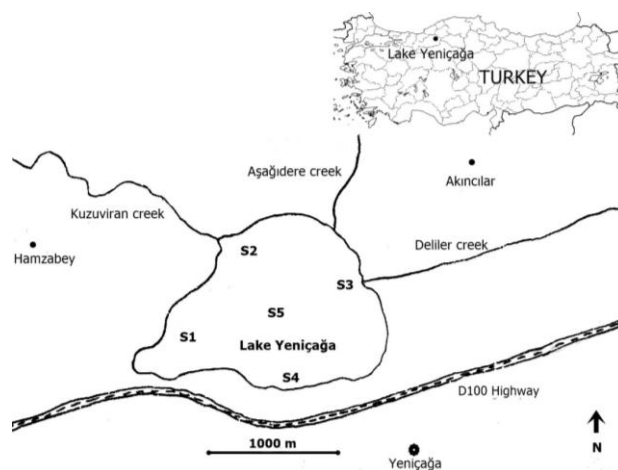

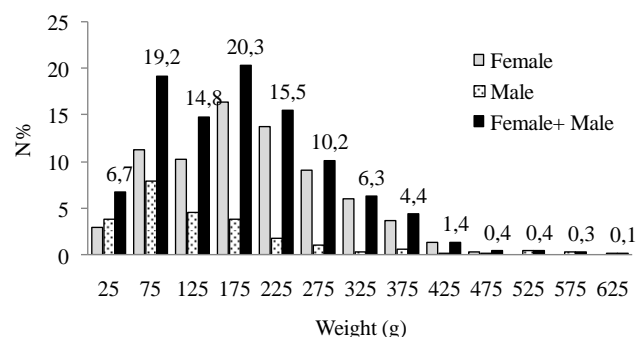**Fig. 1:** Map of the Lake Yeniçağa and fish sampling locations (S1, S2, S3, S4, S5)

Fig. 2: Weight (g) distribution of the sampled chub. N%, percentage of the weight group
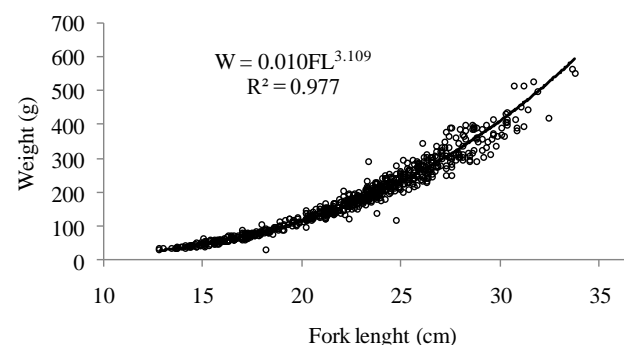

Fig. 3: Length-weight relationship of the sampled chub

The fecundity ranged from 4365 to 65982, and mean fecundity was calculated 25349. It was found that there was a non-linear relationship between fecundity and fork length (Fig. 6), and a linear relationship between fecundity and weight (Fig. 7) and age (Fig. 8).
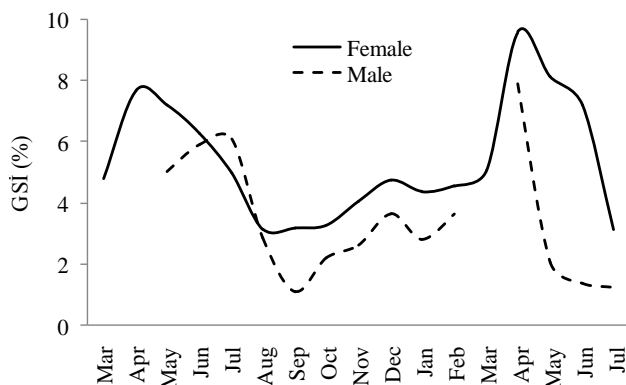
Discussion

This study was conducted between March 2009 and July

Table 1: Age, fork length, and sex distribution of the sampled chub

FL	1+ ♀	1+ ♂	2+ ♀	2+ ♂	3+ ♀	3+ ♂	4+ ♀	4+ ♂	5+ ♀	5+ ♂	6+ ♀	6+ ♂	7+ ♀	7+ ♂	8+ ♀	8+ ♂	n	%
12	2	8															10	1.4
14	21	27	14	2													64	8.8
16	18	6	33	30													87	11.9
18	3		23	22		1											49	6.7
20			69	22	8	1											100	13.7
22			62	20	67	10	1	1									161	22.1
24			8	2	66	7	25	2									110	15.1
26					13		53	6	9	2							83	11.4
28							14	1	21	3	2						41	5.6
30									3	1	8	3	2	2			19	2.6
32													1	2			3	0.4
34																2	2	0.3
Σn	44	41	209	98	154	19	93	10	33	6	10	3	3	4	0	2	729	100.0
%	5.9	5.6	28.8	13.4	21.1	2.6	12.8	1.4	4.5	0.8	1.4	0.4	0.4	0.6	0	0.3		

FL, fork length (cm); ♀, female; ♂, male, *n*, number of individuals, *Σn*; total number of individuals; *%*, percentage of total individuals
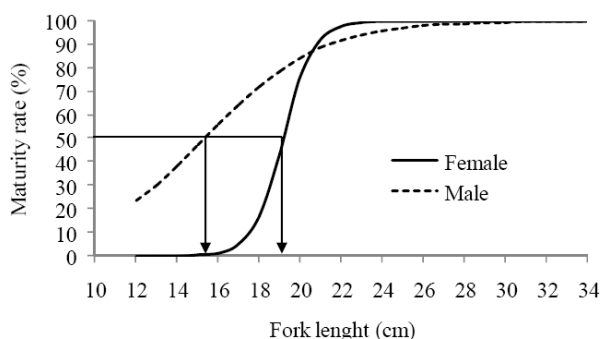
Fig. 4: Length at first maturity of chub

Fig. 5: Monthly changes in the gonadosomatic index (GSI%) values

$LogF = Log\, 0.6443 + 2.687\, LogL$, r = 0.719

Fig. 6: Relationship between fecundity and fork length (cm)

$F = 2680 + 96.47 \times W$ r = 0.757

Fig. 7: Relationship between fecundity and weight (g)

$F = 1526 + 7053 \times A$, r = 0.726

Fig. 8: Relationship between fecundity and age (year)

2010 to investigate growth and reproduction of chub population in Lake Yeniçağa. The age composition of chub population was ranged from 1+ to 8+. Zero age group of chub was not caught because of selectivity of the used nets (Fig. 1). The age distribution of chub in Lake Hafik (Ünver and Kekilli, 2010) was the same as in this study, the other lakes were different (Table 2). It can be stated that these changes in the age distributions resulted from differences in used fishing gear and mesh
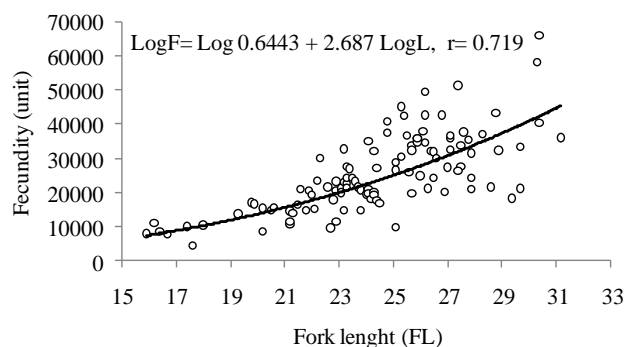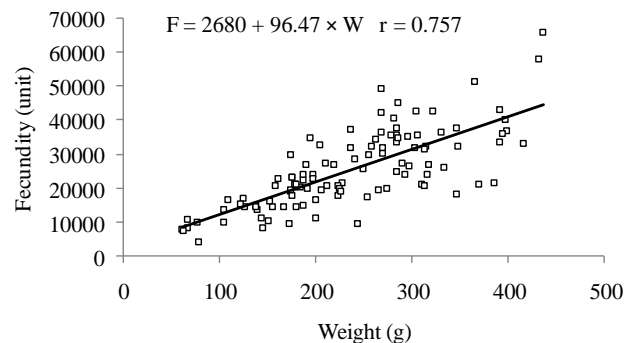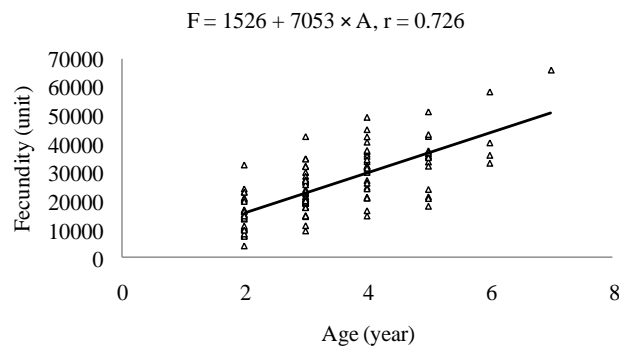
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Table 2: Mean lengths (cm) and weight (g) at age groups, total number of sampled individuals ($\sum n$) and female ($♀$) and male ($♂$) ratios of chub in different lakes

Location		Age										$\sum n$	$♀:♂$	References
		1+	2+	3+	4+	5+	6+	7+	8+	9+	10+			
Sarıyar	cm	8.99	13.00	19.27	23.17	26.23	29.50	30.60	33.30	-	36.95	234	1.03: 1.00	Ekmekçi (1996)
Dam Lake	g	9.35	31.20	105.22	194.29	287.74	398.29	519.71	698.75		909.50			
Topçam	cm	10.54	14.74	16.51	19.69	22.64	24.40	26.10	-	-	-	332	2.69: 1.00	Şaşı and Balık (2003)
Dam Lake	g	19.58	46.45	68.65	122.64	192.08	241.93	326.40						
Lake Işıklı	cm	14.78	16.99	18.55	20.19	21.57	-	-				528	0.69: 1.00	Balık *et al.* (2004)
	g	58.60	89.00	118.48	149.69	188.60								
Karakaya	cm	19.7	25.73	31.0	32.89	34.78	35.7	-	-	-	-	527	1.75: 1.00	Kalkan *et al.* (2005)
Dam Lake	g	118.17	249.36	406.47	497.55	575.27	651.04							
Apa Dam	cm	17.48	20.48	23.85	26.97	29.28	-	-	-	-	-	474	1.04: 1.00	Mert *et al.* (2006)
Lake	g	71.91	130.46	205.94	303.25	376.11								
Çamkoru	cm	9.19	13.54	16.92	20.70	24.22	26.83	30.12	33.34	35.30	37.38	307	2.00: 1.00	İnnal (2010)
Pond	g	9.95	37.44	68.28	127.57	204.98	272.3	365.27	478.00	584.33	764.75			
Lake Hafik	cm	12.75	13.29	15.77	19.46	22.13	26.51	27.59	31.70	-	-	242	1.70: 1.00	Ünver and Kekilli (2010)
	g	28.6	32.5	56.2	104.4	161.9	252.2	301.8	455.1					
Lake	cm	15.40	20.26	23.96	26.63	28.62	30.43	32.17	34.50	-	-	729	2.98: 1.00	This study
Yeniçağa	g	51.24	128.34	210.05	288.44	347.43	407.62	502.61	561.50					

Table 3: The von Bertalanffy growth parameters and condition factors (CF) of chub in different lakes

Location	$L\infty$ (cm)	$W\infty$ (g)	k (year^{-1})	t_0 (year)	b	CF	References
Lake Akşehir*	40.46	1231.83	0.209477	-1.35791	3.135915	1.5759	Altındağ (1997)
Lake Tödürge*	47.41	1565.39	0.10608	-0.3805	3.0964	0.81	Ünver and Tanyolaç (1999)
Topçam Dam Lake	36.24	-	0.154	-1.171	3.12	1.612	Şaşı and Balık (2003)
Lake Işıklı	29.81	485.49	0.151	-3.535	3.04	-	Balık *et al.* (2004)
Karakaya Dam Lake	37.8*	775.3*	0.4125*	-1.0013*	2.8201	1.43	Kalkan *et al.* (2005)
Çamlıdere Dam Lake	38.51*	-	0.328*	-1.67*	3.0276	1.54*	Bostancı and Polat (2009)
Lake Yeniçağa	36.88	713.01	0.248	-1.278	3.109	1.48	This study

*Female

Table 4: The age and length at first maturity (cm), spawning period, egg diameters (mm), and fecundity (unit/ individual) of chub in different lakes

Location	Age at first maturity $♀:♂$	Length at first maturity (cm) $♀:♂$	Spawning period	Egg diameter (mm)	Fecundity (unit/individual)	References
Sarıyar Dam Lake	3+:3+	19.5 - 17.5	April - June	1.03	33265	Ekmekçi (1996)
Almus Dam Lake	3+:3+	-	May - July	1.17	5382 - 28072	Karataş and Akyurt (1997)
Lake Akşehir	2+:2+	16.0 - 15.5	May - July	0.86 - 1.48	9679 - 106227	Altındağ (1997)
Topçam Dam Lake	2+:2+	14.40 - 14.50	March - April	0.391 - 0.744	2100 - 66.400	Şaşı (2004)
Karakaya Dam Lake	3+:3+	-	May - July	1.06	1265	Kalkan *et al.* (2005)
Apa Dam Lake	3+: 2+	-	May - July	0.41 - 0.88	15253 - 22976	Mert *et al.* (2006)
Lake Hafik	3+: 2+	11.4 - 11.8	April - July	0.343 - 1.900	9319 - 55139	Ünver and Kekilli (2012)
Lake Yeniçağa	2+:2+	19.2 - 15.3	April - July	1.29	25349	This study (2013)

$♀$, female; $♂$, male

size, growth rate and productivity of population, and fishing activity. The most dominant age group was 2+ for both females and males in the population. This situation was also reported for Lake Işıklı (Balık *et al.,* 2004) and Apa Dam Lake (Mert *et al.*, 2006). The 77.7% of the sampled chub were at ages 1+, 2+ and 3+, which showed that large majority of the population consisted of young individuals. It is expected that there are more young individuals than older in healthy fish population. This is the result of natural and fishing mortality, 4+ and the subsequent age groups of the chub were lesser than younger individuals.

Although Nikolsky (1980) indicated that sex ratio in most of the species was close to 1:1, in this study, sex ratio of female was markedly higher than the male (P<0.05) (Table 2). The result of this study was identical with the reported from Topçam Dam Lake (Şaşı and Balık, 2003) and Çamkoru Pond (İnnal, 2010) (Table 2). Piferrer *et al.* (1994) stated that sex of fish is affected from temperature and pH of lake water and stocking density especially during the early larval development.

The mean lengths and weights at age groups in this study were similar to reported from Apa Dam Lake (Mert *et al.,* 2006) (Table 2). The reason for the different values of length and weight, which studies conducted in different regions with the same species may be due to different climatic and geographical conditions, and factors affecting growth (food, water temperature, age at sexual maturity,

water quality and intraspecific and interspecific competition, etc.) of these regions. The fastest growth in length of chub in Lake Yeniçağa carried out up to age 2+, reached first sexual maturity. During this period, the foods were used to increase length and weight. Proportional increase in length and weight has been a general decline with increasing age. The growth of chub in Lake Yeniçağa showed better performance than many other lakes due to nutrient-rich and the lack of nutrient competition.

In this study, the asymptotic length (L∞ = 36.88 cm) for all individuals was found close to values reported from some lakes (Şaşı and Balık, 2003; Kalkan *et al.,* 2005; Bostancı and Polat, 2009) (Table 3). The asymptotic weight (W∞ = 713.01 g) was also found close to values reported from Karakaya Dam Lake (Kalkan *et al., 2005*).

The slope values (b = 3.109) for all individuals of the length-weight relationship indicated that chub population in Lake Yeniçağa showed a positive allometric growth (Fig. 3). The b values reported from other lakes except for Karakaya Dam Lake (Kalkan *et al.,* 2005) were close to this study (Table 3). Ricker (1975) stated that b values in fish differ according to species, sex, age, seasons and feeding.

The calculated average CF (1.48) in this study was similar to reported from Topçam Dam Lake (Şaşı and Balık, 2003), Karakaya Dam Lake (Kalkan *et al.,* 2005), and Çamlıdere Dam Lake (Bostancı and Polat, 2009), but CF in Lake Tödürge (Ünver and Tanyolaç, 1999) was much lower than this study (Table 3). The differences between the CF may be duo to feeding, climatic conditions, and having different ecologies of water resources.

The spawning periods of chub, reported from most of the lakes in Turkey, were between the months May and July (Karataş and Akyurt, 1997; Kalkan *et al.,* 2005, Mert *et al.,* 2006), but in this study was between April and July, was reported same result from Lake Hafik (Ünver and Kekilli, 2012) (Table 4) (Fig. 5). It can be said that these differences in spawning periods vary with respect to seasonal changes in water temperature of lakes, feeding, and climatic characteristics. While egg diameters may be vary for different stocks (Avşar, 2005), egg diameter values reported from Topçam Dam Lake (Ekmekçi, 1996) was close to result of this study. Diameters were reported from some of the lakes in Turkey. Because, the most important factor on egg size is fish length.

The fecundity is affected by age, length, weight, and quality and amount of feed of fish (Avşar, 2005). The reported fecundity from some of the previous study were lower than this study (Kalkan *et al.,* 2005; Mert *et al.,* 2006), whereas most of them were higher (Ekmekçi, 1996; Şaşı, 2004; Ünver and Kekilli, 2012) (Table 4). In this study, correlation of fecundity with weight was higher than with the length and age (Fig. 7 and 8).

Conclusion

This study determined growth and reproduction of chub

population in Lake Yeniçağa. Furthermore, minimum landing size of chub (total length, 20 cm), which was regulated by the Republic of Turkey Ministry of Food, Agriculture, and Livestock is compatible with the length at first maturity of female (fork length, 19.18 cm) in this study. According to regulation of the Ministry, prohibition season of fishing for cyprinid species including chub was determined between 15 March and 15 June for the region where Lake Yeniçağa is located. This time interval is also an appropriate period in terms of spawning of chub in Lake Yeniçağa.

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