

Some Biological Properties of the *Leuciscus cephalus* (L., 1758) Population Living in Karakaya Dam Lake in Malatya (Turkey)

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Received: 25.11.2002

Abstract: The sex distribution, growth in length and weight, growth rates and condition factors of Chub (*Leuciscus cephalus* (L., 1758)) in Karakaya dam lake were examined. Females made up 63.64% and males 36.37% (1.75:1) of 527 samples. The females and males were in the I-VI and I-V age groups, respectively. The reproductive properties of *L. cephalus* such as spawning period, age at attainment of maturity, egg diameter and ovarium weight were investigated. Student's t test showed that differences in length and weight between females and males of the same age groups were statistically insignificant ($P > 0.05$). The growth, both in length and weight, was calculated according to the von Bertalanffy equation for females and males respectively:

$$L_t = 37.8 [1 - e^{-0.4125(t - (-1.0013))}], W_t = 775.3 [1 - e^{-0.4125(t - (-1.0013))}]^{3.0272} \text{ and}$$

$$L_t = 35.45 [1 - e^{-0.6062(t - (-0.1883))}], W_t = 590.5 [1 - e^{-0.6062(t - (-0.1883))}]^{2.4878}.$$

The calculated length-weight relation for females was $W = 0.013 L^{3.0272}$ and for males $W = 0.0824 L^{2.4878}$. The average condition factor was 1.42 ± 0.05 for females and 1.43 ± 0.25 for males.

According to gonado-somatic index (I_G) results and the development of egg diameter, it was determined that the spawning period of *L. cephalus* occurs in May and June. Sexual maturity was attained in the third year. The mean diameter of ripe eggs was 1.06 mm and the mean number of eggs per gram of gonads was 1265.

Key Words: *Leuciscus cephalus*, growth, von Bertalanffy's parameters, length and weight relationships, condition factor, sexual maturity, spawning period, Karakaya dam lake.

Karakaya Baraj Gölü (Malatya)'nde Yaşayan *Leuciscus cephalus* Populasyonunun (L., 1758)'ün Bazı Biyolojik Özellikleri

Özet: Karakaya Baraj Gölü'nde yaşayan *Leuciscus cephalus* (L., 1758) populasyonuna ait 527 adet balık örneği, büyüme ve üreme özelliklerinin araştırılması amacı ile aylık periyotlarla incelendi. Bu çalışmada adı geçen türün yaş kompozisyonu ve eşey dağılımı, yaş – boy, yaş – ağırlık, boy – ağırlık ilişkileri, kondisyon faktörü ve üreme ile ilgili bazı temel biyolojik özellikleri (üreme periyodu, üreme yaşı ve yumurta verimliliği) saptandı. İncelenen örneklerin % 63,64' ü dişi, ve % 36,37'si ise erkek bireylerden oluşmaktadır. Dişiler I-VI, erkekler ise I-V yaş grupları arasında bir dağılım göstermektedir Erkek ve dişi bireyler arasında ortalama boylar ve ortalama ağırlıklar farkının Student-t testine göre önemsiz olduğu bulunmuştur ($P > 0,05$). von Bertalanffy büyüme denklemlerine göre yaş – boy, yaş – ağırlık ilişkileri dişilerde ve erkeklerde sırası ile;

$$L_t = 37,8 [1 - e^{-0.4125(t - (-1.0013))}], W_t = 775,3 [1 - e^{-0.4125(t - (-1.0013))}]^{3.0272} \text{ ve}$$

$$L_t = 35,45 [1 - e^{-0.6062(t - (-0.1883))}], W_t = 590,5 [1 - e^{-0.6062(t - (-0.1883))}]^{2.4878} \text{ dir.}$$

Boy – ağırlık ilişkisi dişilerde $W = 0,013 L^{3.0272}$ ve erkeklerde $W = 0,0824 L^{2.4878}$ olarak hesaplandı. Kondisyon faktörü dişilerde $1,53 \pm 0,05$ ve erkeklerde $1,42 \pm 0,25$ olarak bulunmuştur.

Gonadosomatik indeks (I_G) ve yumurta çapının gelişmesinden yararlanarak, bu türün üreme periyodunun Mayıs – Temmuz ayları, ilk eşeyssel olgunluk yaşının III olduğu bulundu. Tesadüfen seçilen olgun yumurtaların çapı 1,06 mm, yumurta sayısı ise bir gramda ortalama 1265 olarak tesbit edildi.

Anahtar Sözcükler: *Leuciscus cephalus*, büyüme, von Bertalanffy parametreleri, uzunluk ve ağırlık, uzunluk ve ağırlık ilişkileri, kondisyon, eşeyssel olgunluk yaşı, üreme periyodu, Karakaya baraj gölü.

Introduction

Leuciscus cephalus (L., 1758) (chub) is one of the most common and widely distributed Cyprinid species in Europe, Anatolia and the Caucasus and the basins of the Black and Azov seas (1-14). Many studies have been carried out on *L. cephalus* in Turkey and other countries. Biological features depending on ecological conditions of the freshwater mullet in a widespread geographic area were studied in Turkey and other countries. Determination of the growth and reproductive features of fish stocks in seas and fresh waters are important for economical utilization of this natural resource. Climate and geographic and ecological conditions affect the growth and reproductive features of living creatures differently. Karakaya dam lake contains fish that provide a large proportion of the protein supply for the region.

Consequently, differences occur in the growth and reproductive features between populations of the same species in different regions. The density, growth and reproduction of *L. cephalus* in Czechoslovakia's Klicava Rezervoirs (11), its autoecology in a Greek stream (12), and its sexual ratio, age determination and growth in the River Lugg, England (13), were previously examined. The biology of samples in Pınarbaşı spring waters (1),

systematic and growth characteristics of the fish in the Sakarya river basin (2), the growth features and sex ratio of samples in Müceldi water, East Anatolia (3), and the growth performance of 4 Cyprinid species in Almus dam lake, Tokat (4), were examined. The reproductive features of individuals in Savur stream (5), and the growth and reproductive features in Tödürge lake, Zara-Sivas, for *L. cephalus* were also investigated (6).

This study was carried out to determine the biological characteristics of the sex distribution, growth and growth rates, condition factor, age at attainment of maturity, spawning period, number and diameter of eggs and fecundity of the *L. cephalus* population in the River Fırat (Figure 1).

Materials and Methods

The River Fırat is in eastern Anatolia (Figure 1). Karakaya dam lake was constructed for electric generation and irrigation purposes 17 km from Malatya city center. It is the third largest dam lake (29.8 ha, maximum depth is 69.3 m and 935 m above sea level) which in term of area constructed on the Fırat river (15). Samples (499 females and 28 males) were caught in

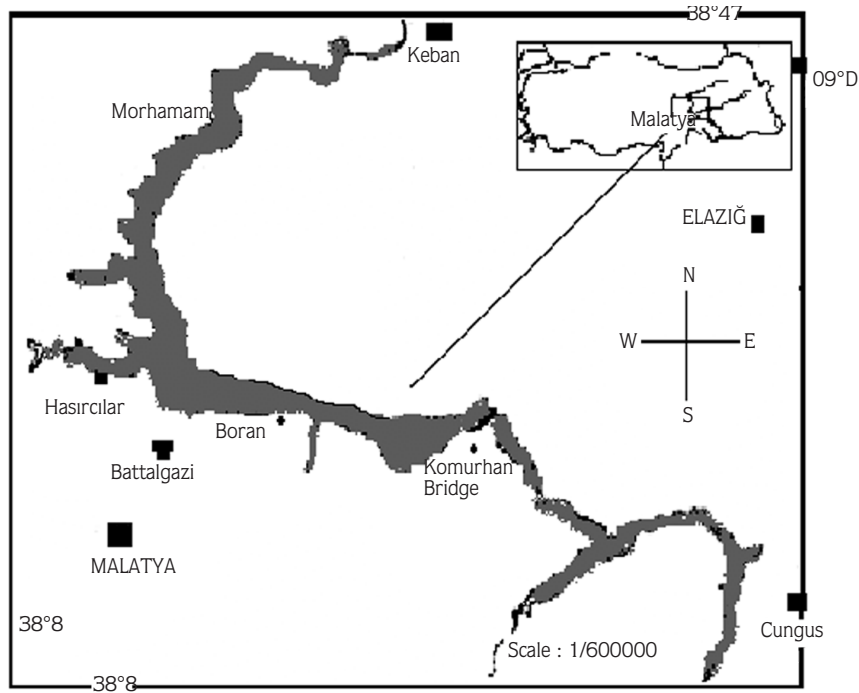


Figure 1. Map of the Karakaya dam lake

Karakaya dam lake, outside the reproductive period to determine their growth features and during the reproductive period and to determine their reproductive features. The sampling was performed using gill nets of various mesh sizes (12 x 12, 18 x 18, 24 x 24, 32 x 32 mm). After being caught, fish samples were brought to the laboratory, and the fork lengths (L_f) and weights (W) were measured and weighed to the nearest 1.0 mm and 0.1 g, respectively. For age determination scales were taken from the region between L. lat. and the anterior of the dorsal fin. The scales were kept in 5% KOH for 24 h and then 10 scales from each fish were transferred into 70% ethyl alcohol for 3 min and age was determined under a binocular microscope (16,17).

Growth was examined according to length and weight. The relative growth in length (RGL) and weight (RGW) were computed by the following formulas (18,19):

$$RGL = \frac{L_t - L_{t-1}}{L_{t-1}} \times 100, \quad RGW = \frac{W_t - W_{t-1}}{W_{t-1}} \times 100$$

Age-length, age-weight and length-weight relationships was calculated for age groups. Von Bertalanffy formulas (20), $L_t = L_\infty[1 - e^{-k(t-t_0)}]$ and $W_t = W_\infty[1 - e^{-k(t-t_0)}]^n$, were used to determine the age-length and age-weight relationships (1-12). The growth parameters k , L_∞ and t_0 were estimated by the Ford-Walford method (7-10,18-21). To calculate length-weight relationships the equation of Le Cren, $W = a.L^n$, was used (22). Relation diagrams obtained from this equation were recorded with calculations. The condition factors were determined using the formula $K = W/L^3 \times 100$ (20). With the growth characteristic diagram, growth density and youth, ripeness and old age periods for the entire life span of fish were determined (18-21).

$$\text{Growth Characteristic} = \frac{\text{Log}L_n - \text{Log}L_{n-1}}{0.4343(n - (n-1))}$$

Sex was determined by macroscopic observation of the gonads. The overall sex ratio and stages of sexual maturity were also determined. The gonads were removed and weighed to the nearest 0.01 g. The spawning period was determined by means of monthly changes in the gonado-somatic index (I_G), ovarium weight, egg diameter and egg number per gram of ovarium. The gonado-somatic index was calculated using the following equation:

$$\text{Gonado-somatic Index } (I_G) = \frac{\text{Gonad Weight (g)}}{\text{Total Living Weight (g)}} \times 100.$$

The number of eggs was estimated by the gravimetric method using ovaries that had been preserved in 4% formalin solution in order to enumerate the total number of eggs in the particular ovary (16,23). Twenty ova selected at random from each ovary were measured by means of a micrometer eyepiece, and the mean egg diameter was then computed for the entire sample. The relationship between body weight (W) and gonad weight was calculated by linear regression. Statistically significant differences between sex and age groups were tested with Student's t test (24).

Results

Sex Ratio and Age Composition

The obtained sex ratio and age composition of the fish samples are given in Table 1. The females were more abundant than males; the sex ratio was 1.75 (female) to 1 (male) of 77 samples. Studies have shown that the fish samples caught in Karakaya dam lake were between ages I and VI. Ages II and III were dominant for both females and males overall (Figure 2).

Growth in Length and Age-Length Relationships

The mean length, minimum and maximum length, standard deviation, standard error, and the significance level of differences between females and males in the same age group of *L. cephalus* are given in Table 2. The age-length relationship is given in Figure 3. The age-length relation of studied samples was calculated mathematically for females and males respectively:

$$L_t = 37.8[1 - e^{-0.4125(t - (-1.0013))}],$$

$$L_t = 35.45[1 - e^{-0.6062(t - (-0.1883))}].$$

However, Table 3 shows that the maximum yearly increase in length occurs at I-II years and they reached sexual maturity in their third year.

Relative Growth in Length

To determine the growth speed of age groups in Karakaya dam lake the increase in length between age groups and the increase in ratio and growth characteristics were calculated and are shown in Table 3.

Table 1. Sex ratio and age composition of *L. cephalus* from Karakaya dam lake.

Age Groups	Female		Male		Female + Male	
	N	%N	N	%N	N	%N
I	2	2.60	1	1.30	3	3.90
II	15	19.48	8	10.39	23	29.88
III	16	20.78	10	12.99	26	33.77
IV	7	9.09	7	9.09	14	18.18
V	6	7.79	2	2.60	8	10.39
VI	3	3.90	-	-	3	3.90
Total	49	63.64	28	36.37	77	100

Table 2. The length and absolute growth age groups of *L. cephalus* samples from Karakaya dam lake (N: Number of samples, FL: Fork length, SD: Standard deviation, SE: Standard error).

Age Groups	Sex	N	FL $\pm$ SD (Min- Max) (cm)	SE	Absolute Growth	Difference
I	♀	2	20.9 $\pm$ 0.14 (20.8-21.0)	0.10	21.24	0.34
	♂	1	17.3 $\pm$ 0.75 (17.0-20.8)	0.24	18.2	0.90
II	♀	15	26.06 $\pm$ 1.65 (23.4-29.0)	0.43	26.84	0.78
	♂	8	25.11 $\pm$ 2.03 (22.2-29.0)	0.72	26.04	0.93
III	♀	16	30.18 $\pm$ 1.24 (29.3-33.7)	0.31	30.55	0.47
	♂	10	30.21 $\pm$ 1.15 (28.8-32.2)	0.36	30.32	0.11
IV	♀	7	32.93 $\pm$ 1.03 (31.1-34.0)	0.39	32.99	0.06
	♂	7	32.86 $\pm$ 1.24 (30.6-34.3)	0.47	32.65	- 0.21
V	♀	6	34.52 $\pm$ 0.81 (33.3-34.0)	0.33	34.62	0.1
	♂	2	33.6 $\pm$ 0.57 (33.2-34.4)	0.40	33.92	0.32
VI	♀	3	35.7 $\pm$ 0.50 (35.2-36.2)	0.29	35.68	- 0.02
	♂	-	-	-	-	-

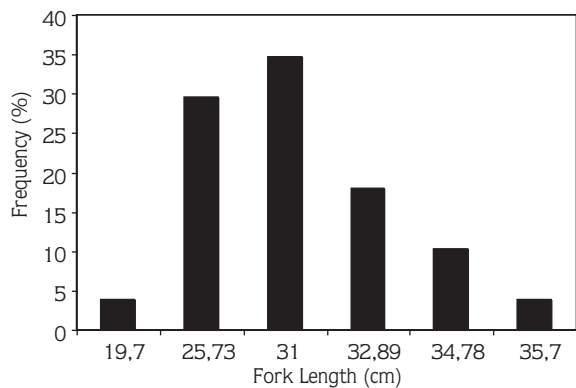


Figure 2. Distribution of length classes of *L. cephalus* samples from Karakaya dam lake.

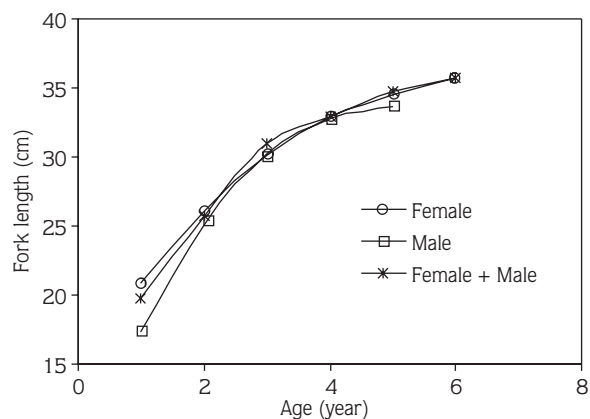


Figure 3. Age-length relationships of the *L. cephalus* population in Karakaya dam lake (O: male, +: female, Δ: female + male).

Table 3. The relative growth in length (RGL) and growth characteristics in different age groups of *L. cephalus* from Karakaya dam lake.

Age Groups	Mean FL (cm)	Yearly Increase	RGL (%)	Growth Characteristics
I	19.7	- 6.03	- 30.60	- 5.26
II	25.73	3.27	11.79	4.80
III	31.0	1.89	6.10	1.83
IV	32.89	1.89	5.75	1.84
V	34.78	0.92	2.75	0.91
VI	35.7			

Growth in Weight and Age-Weight Relationships

The mean weight, minimum and maximum weights, standard deviation, standard error, and absolute growth in weight for females and males of the different age groups, and the significance level of differences between females and males of the same age group of *L. cephalus* are given in Table 4. The age - weight relation is presented in Figure 4. Average weight growth in Table 4

was calculated according to von Bertalanffy's (3) growth equation. It was found to be

$$W_t = 775.3 [1 - e^{-0.4125(t - (-1.0013))}]^{3.0272} \text{ in females and}$$

$$W_t = 590.5 [1 - e^{-0.6062(t - (-0.188))}]^{2.4878} \text{ in males.}$$

Relative Growth in Weight

Relative growth in all age groups is shown in Table 5. The highest increase in relative weight was between age

Table 4. The weight and absolute growth in weight of the different age groups of *L. cephalus* from Karakaya dam lake (N: Number of samples, W: Weight, SD: Standard deviation, SE: Standard error).

Age Groups	Sex	N	W ± SD (Min-Max) (g)	SE	Absolute Growth (W)	Differences
I	♀	2	126.2 ± 3.38 (123.8-128.6)	2.39	135.47	9.26
	♂	1	102.6 ± 25.64 (115.4-130.0)	18.91	110.58	8.52
II	♀	15	265.6 ± 57.71 (198.5-377.9)	14.88	274.9	9.3
	♂	8	256.4 ± 66.58 (150.3-337.9)	23.54	269.87	13.48
III	♀	16	412.6 ± 44.6 (338.9-340.9)	8.00	409.65	-2.95
	♂	10	397.5 ± 34.04 (351.1-442.3)	10.77	405.72	8.19
IV	♀	7	500.6 ± 20.92 (475.1-539.6)	7.91	508.6	7.98
	♂	7	494.6 ± 54.67 (413.4-588.3)	54.67	479.8	-14.7
V	♀	6	585.4 ± 34.15 (546.4-623.6)	13.94	602.3	16.92
	♂	2	525.0 ± 55.52 (505.7-584.2)	39.26	533.4	8.4
VI	♀	3	651.0 ± 61.37 (603.4-721.5)	35.43	642.8	-8.17
	♂	-	-	-	-	-

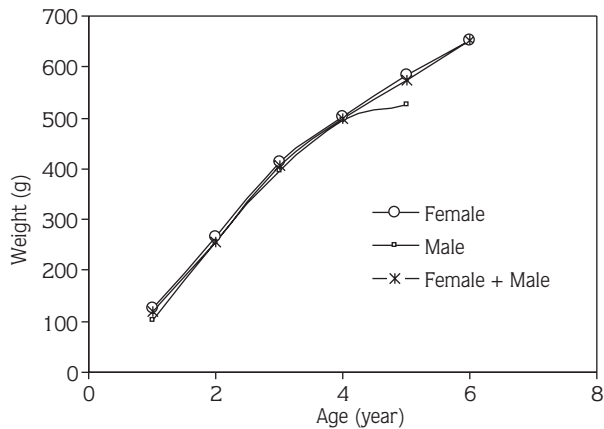


Figure 4. Age-weight diagram of female and male individuals of the *L. cephalus* population in Karakaya dam lake (O: male, +: female, Δ: female + male).

Table 5. Rational weight growth of *L. cephalus* female and male individuals (AW: Average Weight, YIW: Yearly Increase in Weight, RIW: Rational Increase in Weight).

Age Gr.	Female			Male			Female + Male		
	AW	YIW	% RIW	AW	YIW	% RIW	AW	YIW	% RIW
I	126.2	137.4	108.86	102.06	134.29	131.58	118.17	131.39	111.02
II	263.62	149.85	56.54	236.35	161.17	68.19	249.36	157.11	63.01
III	412.67	87.9	21.23	397.52	97.01	24.4	406.47	94.08	22.41
IV	500.57	84.79	16.94	494.53	50.45	10.2	497.55	77.77	15.62
V	585.36	65.68	11.22	544.98			575.27	75.77	13.17
VI	651.04						651.04		

Table 6. Length–weight relationships equations of *L. cephalus* in Karakaya dam lake.

Sex	Equations
Female	$W = 0.013.L^{3.0272}$ or $\text{Log}W = \text{Log}0.013\text{log}L + 3.0272.\text{Log}L$
Male	$W = 0.0824.L^{2.4878}$ or $\text{Log}W = \text{Log}0.0824 + 2.4878.\text{Log}L$
Female + Male	$W = 0.0262.L^{2.8201}$ or $\text{Log}W = \text{Log}0.0262 + 2.8201.\text{Log}L$

groups I and II. The relative growth in weight decreased with the subsequent ages (Table 5).

Length–Weight Relationships

Length–weight relationships were calculated with the Le Cren equation (19) by using the lengths and weights of *L. cephalus* samples (Table 6). The equations for females and males are given below:

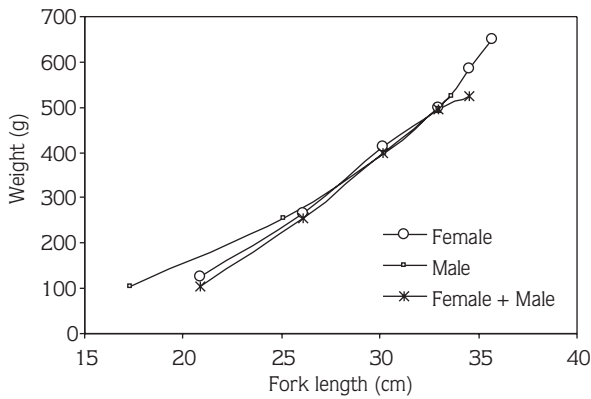
Female $W = 0.013.L^{3.0272}$

Male $W = 0.0824.L^{2.4878}$.

The curves of the length–weight relationships obtained from these equations are shown in Table 7, and the logarithmic regression curve is presented in Figure 5.

Table 7. The formation of weight values of *L. cephalus* calculated from a length-weight relation according to age groups.

Age Gr.	Female		Male		Female + Male	
	L (cm)	W (g)	L (cm)	W (g)	L (cm)	W (g)
I	20.9	126.2	17.3	102.1	19.7	118.17
II	26.1	265.6	25.11	236.39	25.73	255.45
III	31.18	412.6	30.7	397.53	31.0	406.78
IV	32.93	500.6	32.86	494.53	32.89	497.55
V	34.52	585.4	33.6	544.98	34.29	575.27
VI	35.7	651.04	-	-	35.7	651.04

Figure 5. Karakaya dam lake *L. cephalus* female, male and mixed length-weight relationships (O: male + female, Δ: female + male mixed).

Condition Factor

The condition factor of the *L. cephalus* population according to age, sex and average values is shown in Table 8. The annual condition factor was calculated as 1.42 and 1.43 for females and males, respectively. Average condition factor (C) differences were statistically insignificant between females and males in the same age group and consecutive age groups in the population ($P > 0.05$). The mean condition factor varied with time and a high value was obtained from ages I to V; however, they were low in July and December during the sampling period.

Reproduction

The Age of Sexual Maturity

The maturity of specimens, 499 females, caught in Karakaya dam lake during their reproductive period, was determined by directly observing the gonads, and the results are shown in Table 10.

Table 8. The condition factors of the different age groups of *L. cephalus* from Karakaya dam lake.

Age	Female	Male	Female + Male
I	1.38	1.47	1.45
II	1.50	1.43	1.46
III	1.36	1.37	1.36
IV	1.40	1.39	1.40
V	1.47	1.44	1.37
VI	1.43	-	1.43
Mean	1.42 ± 0.05	1.43 ± 0.25	1.43 ± 0.07

According to these values, it was determined that females reached maturity between the second and fifth years of their life cycle. Species, as may be seen in Table 3, attained sexual maturity in their third year.

Reproduction Period and Spawning

The gonado-somatic index (I_G) was used to determine the reproductive period, which was calculated from ovarium samples taken monthly from females (Table 9). The maximum I_G value was 13.56 in females in May. In July, the I_G value decreased because all samples dispensed their eggs (Figure 6). After August, the gonads began to develop and the values of I_G again started to increase gradually until November. Our findings suggest that the reproductive period of this species is between April and July.

Ovarium weight and egg diameter

The values of the ovarium weight and egg diameter and the monthly changes in these values are shown in

Table 9. The monthly changes in the values of the gonado-somatic index of *L. cephalus* in Karakaya dam lake.

Months	January	February	March	April	May	June	July	August	September	October	November	December
I_G	0.58	0.69	0.95	3.31	13.56	1.08	0.39	0.41	0.44	0.46	0.46	0.48

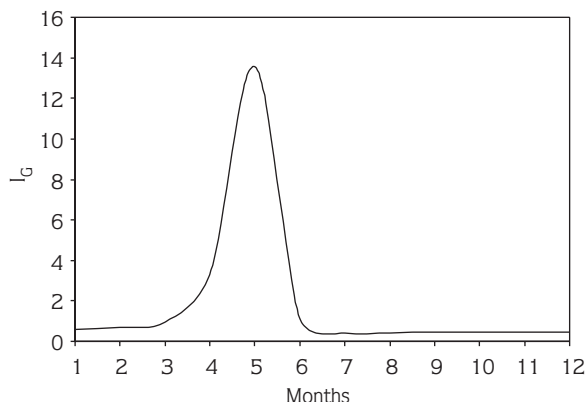
Figure 6. The monthly I_G values of female of *L. cephalus* samples from Karakaya dam lake.

Table 10. Mean ovarium weight was maximum in May (35.4) and minimum in June (1.02).

Discussion

L. cephalus is one of the most common and widely distributed Cyprinid species in the Fırat (15) and Dicle river systems. Its worldwide distribution is also reported (1-13). In this study, the sex ratio was 1.75 (female) to 1 (male). Nicolsky (25) indicates different sexual dispersions of the same species in different populations. The sex ratio was reported as 1.4 to 1 in Pınarbaşı spring waters (İzmir) (1), as 0.98 to 1 in Almus dam lake (4), 0.47 to 1 in Tödürge Lake (6) and 0.34 to 1 in Çıldır Lake (Ardahan) (7).

The *L. cephalus* caught in Karakaya dam lake showed dispersion between ages I and VI (Table 1). In other investigations on this species, dispersion was reported to be 0-IV in Pınarbaşı spring waters (1), I-V in the Sakarya river basin (2), I-IV in Müceldi water (3), and 0-IV in Almus dam lake (4). The available number of *L. cephalus* was maximum at II-III years and decreased in subsequent years due to extensive fishing. Growth speed and productivity of *L. cephalus* in Karakaya dam lake were high.

Previous studies reported that the lengths of *L. cephalus* species were 17.54 cm (age I) in Pınarbaşı spring water (1), 34.8 cm (age IV) and 16.92 cm (age I) in Almus dam lake (4), 32.25 cm (age V) and 15.3 cm (age I) in Tödürge lake (6). The increase in length was from age I to age II (10). According to Lagler (22), the sexual ripeness of fish occurs as fast as their growth speed at early ages. The results of this study indicated that the sexual ripeness of this species was also from age I to age III. The relative increase in length decreased after age IV, which can be explained by physiological differences in reproductive age and reaching sexual ripeness. The relative increase in length of the *L. cephalus* population in Karakaya dam lake indicates a good growing performance. Growth parameters showed differences according to species, population and age group (20).

Weights of *L. cephalus* samples in Karakaya dam lake were 102.1 g (age I) and 721.5 g (age VI). Other researchers recorded 92.77 g (age I) and 517.0 g (age V)

Table 10. The monthly changes in the gonadal values of the *L. cephalus* samples (L: Length, W: Weight, OW: Ovarium weight, r: Egg diameter).

Months	N	L (cm)	W (g)	OW (g)	r (mm)
April	50	27.3 (20.2-33.8)	329.24 (128.18-515.23)	7.3 (10.70-10.07)	0.70 (0.62-0.80)
May	50	27.1 (24.2-30.2)	284.08 (243.41-473.9)	15.8 (1.6-35.4)	0.74 (0.52-0.96)
June	50	27.7 (23.2-32.2)	276.96 (124.02-469.7)	3.3 (1.02-17.02)	0.88 (0.62-1.06)

in Almus dam lake (4). Nicolsky (25) found that fish could reach 4000 g, and rarely 8000 g. The ultimate length (L_{∞}) and weight (W_{∞}) obtained from the von Bertalanffy growth equation for females is greater than that for males. On the other hand, many factors, such as physicochemical and biological factors, may have an effect on the growth rate in length and weight of fish directly or indirectly. In addition to food and population density, temperature is a factor that has been recognized to be a primary significant factor in this respect (24). The annual mean condition factors calculated for females and males, 1.43 ± 0.05 and 1.42 ± 0.25 , respectively, are similar. The condition factor value of the same species was 1.72 for females and 1.81 for males in Almus dam lake (4) and 0.81 for females and 1.02 for males in Tödürge Lake (6).

The samples taken from the *L. cephalus* population in Karakaya dam lake between March 1998 and June 1999 reached sexual ripeness at III years of age. Other reports (1-7,10-12) support this finding. The I_G reached its highest value (13.36) in May (Table 9) and the reproductive period of this species was March-July (Figure 6). Other researchers indicated the period to be May-June (5), May-July (6), April-June (8) and May-

September (9). Egg diameter (Table 10) was greatest (1.06 mm) in June and smallest (0.39 mm) in March. Other studies reported the egg diameter to be 0.55-1.38 mm (3), 0.83-1.50 mm (5), 0.46-1.04 mm (6), 1.03 mm (8) and 0.78-1.20 mm (9).

The maintenance of species and balance of density of the population are of importance in terms of economical fishing of this species in the region. Therefore the prohibition of fishing from March to August is advised. In addition, the fish under the age III and of average length 26.06 cm should not be caught during the fishing period. This will lead to improvements in both the productivity of the population and fishing. No study has been undertaken to assess the growth and reproduction of *L. cephalus* in Karakaya dam lake.

Ecological studies aiming to evaluate the relationships between *L. cephalus* and other species remain to be done. The discharge of wastewater and sewage into Karakaya dam lake would cause irreparable damage to all life forms in the lake. Necessary measures, such as remediating wastewater to be dumped, the use of small sized nets, and the scheduling of the fishing seasons should be taken.

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