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Growth and reproduction of *Cyprinion macrostomus* (Heckel, 1843) and *Cyprinion kais* (Heckel, 1843) populations in Karakaya Dam Lake (Euphrates River), Turkey

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Abstract: This study investigated the age–length relationship, length–weight relationship, somatic condition, gonadosomatic index, and reproduction properties of *Cyprinion macrostomus* and *Cyprinion kais*. *C. kais* is an endemic species included on the IUCN Red List of Threatened Species in the Tigris–Euphrates Basin. A total of 153 *C. macrostomus* and 114 *C. kais* were collected. The estimated length–weight relationships were $W = 0.725 \times FL^{2.92}$ ($r^2 = 0.87$) for *C. macrostomus* and $W = 0.417 \times FL^{3.02}$ ($r^2 = 0.93$) for *C. kais*. The age–length relationships were $L_t = 15.0\ [1 - e^{-0.212\ (t + 0.407)}]$ and $L_t = 15.4\ [1 - e^{-0.205\ (t + 0.503)}]$ for *C. macrostomus* and *C. kais*, respectively. Mean fecundity ranged from 313 to 1647.08 eggs/fish for *C. macrostomus* and from 295.1 to 1255.2 eggs/fish for *C. kais*. Mean oocyte diameter ranged between 0.13 and 1.34 mm for *C. macrostomus* and between 0.14 and 0.86 mm for *C. kais*. Based on gonadosomatic index, the spawning periods of *C. macrostomus* and *C. kais* were determined to be between June and August in the area of the study.

Key words: *Cyprinion kais*, *Cyprinion macrostomus*, endemic species, Karakaya Dam Lake, reproduction, growth

1. Introduction

The genus *Cyprinion* (type species: *Cyprinion macrostomus* Heckel, 1843) is a western Asian genus of minnow, distributed from western Syria and the southern Arabian Peninsula to the western tributaries of the Indus River in Punjab (Pakistan). Including the 3 species of *Cyprinion* inhabiting the Tigris–Euphrates Basin, 5 species have been observed in Iran (Coad, 1995), but their taxonomic positions have not been fully resolved yet. However, distributions and morphological characteristics of *C. macrostomus* and *C. kais* have been investigated in Turkey by Ünlü (1999). Furthermore, karyotypes of 3 species, *C. tenuiradius*, *C. macrostomus*, and *C. kais*, have been studied (Esmaeili and Piravar, 2006; Nasri et al., unpublished data). The karyological analysis of *C. macrostomus* has been examined as well (Gaffaroğlu and Yüksel, 2004). Daştan et al. (2012) reported the genetic diversity of *C. macrostomus*. The revision of *C. macrostomus* and *C. kais* was studied by Banarescu and Straschil (1995). The length–weight and length–length relationships of *C. macrostomus* have been determined (Sedaghat and Hoseini, 2012; Bibak et al., 2013). There has been no study on the reproduction characteristics of *C. macrostomus* or the growth and reproduction characteristics of *C. kais* in the literature. Failure to study various aspects of these species in order to take necessary conservation measures may lead to depletion of its populations in the near future. *C. macrostomus* is an edible and valuable species for sport fishing (Abdoli, 2000) and is also used as an aquarium fish. It is called the "doctor fish", because it plays a therapeutic role in medical treatment (Ündar et al., 1990), and it is also known as "stone fish" due to its feeding activities. *Cyprinion kais*, an endemic freshwater fish in the Tigris–Euphrates Basin, is distributed in inland waters of Iran, Iraq, Turkey, and Syria (Coad, 1995, 1996; Abdoli, 2000; Fricke et al., 2007; Nasri, 2008; Nasri et al., unpublished data).

We compared the data of this study with previously reported data to improve our understanding of the growth parameters and reproduction periods of *C. macrostomus* and *C. kais* inhabiting Karakaya Dam Lake. The aim of this study is to determine growth and reproduction characteristics of *C. kais*, which is an endemic species on the IUCN Red List of Threatened Species in the Tigris–Euphrates Basin, and *C. macrostomus*.

2. Materials and methods

This study was conducted in Karakaya Dam Lake, which is located on the upper Euphrates River in the eastern part of Turkey and is one of the most important water sources in terms of both irrigation and fishery. Four sampling points

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were selected; the field of the study was down-basin of the reservoir (Figure 1).

In all, 153 *C. macrostomus* individuals and 114 *C. kais* individuals were captured monthly from December 2008 to November 2009 by using gill-nets with a 7-mm mesh size. Each net was 100 m long and 2 m deep, and nets were left at sampling points overnight. Sampling was begun in December 2008, but *C. macrostomus* and *C. kais* individuals were seen from May 2009 onwards. Sex was determined by examining the gonads under a stereomicroscope or by visual examination. While fork length (*FL*) of each individual was measured to the nearest 1 mm, total weight (*W*) and gonad weight (*Wg*) were measured to the nearest 0.01 g. Scales on the left side of the body between the lateral line and dorsal fin were collected and analyzed in order to determine age (Lagler, 1966). The length–weight relationship was calculated as follows:

$L_t = L_\infty [1 - e^{-k(t-t0)}]$,

where L_t is the length at age t, k is the growth constant determining the rate of change in the length increment, and t_0 is the hypothetical age when the length is zero (von Bertalanffy, 1938). The length–weight relationship was estimated by using the following equation:

$W = a\ FL^b$,

where W is the body weight (g), FL is the fork length (mm), a is a coefficient for the body form, and b is an exponent indicating isometric growth when equal to 3 (von Bertalanffy, 1938). The hypothesis of isometric growth (Ricker, 1975) was tested by using Student's t-test. The growth performance index was calculated by using the following equation (Gayanilo and Pauly, 1997):

$\emptyset = log\ (k) + 2\ log\ (L_\infty)$,

where k and L_∞ are the von Bertalanffy growth equation parameters. Female-to-male ratio was examined using the chi-square test (Nikolsky, 1963). The somatic condition (K) was estimated for male and female individuals by using the following formula:

$K = (W / FL^3) \times 100$,

where W is the body weight (g) and FL is the fork length (mm) (Tesch, 1968). The monthly gonadosomatic index (GSI) was used to determine the spawning period with the following formula:

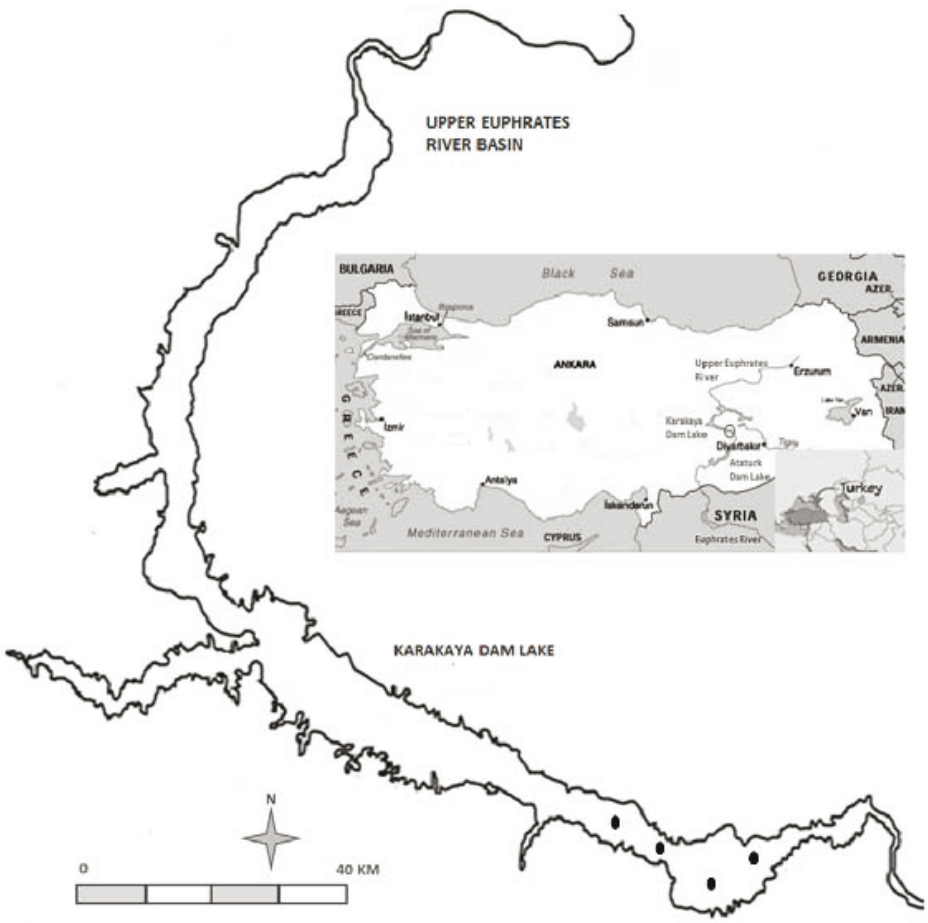

Figure 1. The map of the study field.

$GSI = (Wg / W) \times 100$,

where Wg and W are gonad weight and total weight of fish in grams, respectively (Lagler, 1966; Bagenal, 1978). Mean length at maturity (M_L) for females collected just before reproduction was measured by using the formula from De Master (1978) as adapted by Fox and Crivelli (2001):

$$\alpha = \sum_{x=0}^{w} (x)\,[f(x) - f(x-1)]\,,$$

where α is the mean length at maturity, $f(x)$ is the proportion of fish mature at length x, and w is the maximum length in the sample. Intraovarian oocyte size was measured using a stereomicroscope (Leica MZ 7.5 with DFC 280 camera attachment, Leica Application Suite software, version 2.4.0 R1) with a scale of 0.01 mm. Absolute fecundity was investigated by using the gravimetric method (Bagenal, 1978).

In this study, SPSS 10 was used to conduct statistical analysis. Analysis of variance (ANOVA) was used to evaluate the monthly differences of growth and reproduction parameters, and Tukey's multiple range test was used to determine the significance of differences (Zar, 1996).

3. Results and discussion

3.1. Growth parameters

3.1.1. *Cyprinion macrostomus*

The male-to-female ratio of 153 individuals was 70:83 = 1:0.84 (χ^2 = 0.6, P > 0.05; Table 1). Chi-square analysis showed that there was no significant difference from the expected ratio of 1:1. The sex ratio of *C. macrostomus* was 0.75:1 in the Dalaki River (Sedaghat and Hoseini, 2012), and it was 0.80:1 in the Murat River (Aydın et al., 2008) (Table 2). The sex ratio of the fish populations changed based on spawning season, life stage of the fish, spawning ground, and migration (Nikolsky, 1963; Bartulovic et al., 2004). Fork length of all *C. macrostomus* specimens ranged from 8.0 to 13.10 cm. Most of the captured specimens' fork length measurements ranged from 10.0 to 11.0 cm (Figure 2).

The oldest specimens of *C. macrostomus* reported were 6 years old in the Murat River (Aydın et al., 2008) (Table 2). In this study, age distributions were between age groups 0 and IV, and the majority of specimens belonged to age group I for both species, which proved that the fish populations were young.

Length–weight relationships show the nature of the allometry between length and weight. The slope b provides

Table 1. Sex ratio of *C. macrostomus* in monthly samples.

Month	Sample observed	Males	Females	% of males	% of females	Sex ratio (F:M)
May	24	11	13	44.44	55.56	1.25:1
Jun	15	7	8	46.66	53.34	1.14:1
Jul	17	6	11	35.29	64.71	1.83:1
Aug	30	12	18	40	60	1.5:1
Sep	36	20	16	55.55	44.45	0.8:1
Nov	31	14	17	45.16	54.84	1.21:1

Table 2. The length–weight relationships (b value) and age groups of *C. macrostomus* and *C. kais* taken from different locations.

Species	Sex	N	Sex ratio (female:male)	b	Age	Locality	Author(s)
C. macrostomus	♀	30		3.27		Dalaki River, Iran	Sedaghat and Hoseini, 2012
	♂	40	0.75:1	3.02			
C. macrostomus	♀ + ♂	91		3.13		Dalaki River, Iran	Bibak et al., 2013
C. macrostomus	♀ + ♂	80		2.94		Shahpur River, Iran	Bibak et al., 2013
C. macrostomus	♀	35			2–6	Murat River, Turkey	Aydın et al., 2008
	♂	44	0.8:1				
C. macrostomus	♀	83		2.95	0–4	Karakaya Dam Lake,	Present study
	♂	70	1.19:1	2.86	0–4	Turkey	
C. kais	♀	59		3.01	0–4	Karakaya Dam Lake,	Present study
	♂	50	1.07:1	3.04	0–3	Turkey	

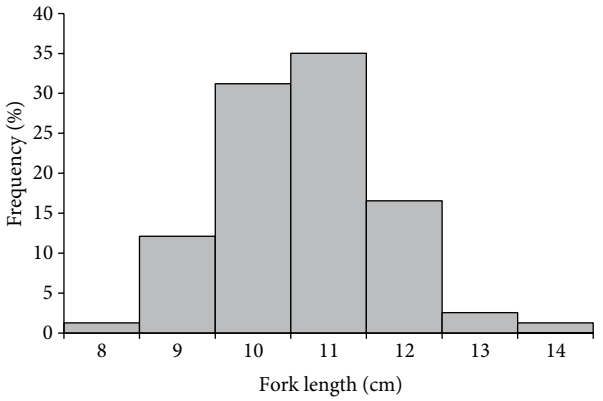

Figure 2. Fork length frequency distribution of *C. macrostomus*.

valuable information on fish growth (Morey et al., 2003). Length–weight relationships were computed as $W = 1.320L^{2.95}$ for females and $W = 0.607L^{2.86}$ for males (Table 3). The *b* values of both sexes were less than 3, which means negative allometry (b_{female}: 2.95; b_{male}: 2.86; Student's t-test; $P < 0.05$). The correlation coefficients demonstrated a positive relationship between length and weight ($P < 0.05$; Table 3). The values of *b* in the Dalaki River were 3.27 for females and 3.02 for males in *C. macrostomus* (Sedaghat and Hoseini, 2012) (Table 2). In the Dalaki and Shahpur rivers, the values of *b* were determined as 3.13 and 2.94 for all *C. macrostomus* individuals (Bibak et al., 2013) (Table 2). The age–length relationships were $L_t = 15.0\ [1 - e^{-0.214\ (t + 0.447)}]$ for females and $L_t = 13.9\ [1 - e^{-0.231\ (t + 0.309)}]$ for males (Table 3). Considering $L\infty$ and *k* values, growth performance index values (Ø) were calculated as 1.683 and 1.650 for females and males, respectively.

The somatic conditions were calculated according to sexes, age groups, and months. The highest mean values were observed in age group IV (1.57 ± 0.11) for females and in age group II (1.60 ± 0.09) for males (Table 4). The monthly values of condition factor were highest in May (1.98 for females and 1.89 for males). In general, seasonal variation of condition factors is affected by feeding activity, fish size, gonadal development, reproduction period, disease, and parasites of the fish (Bagenal and Tesch, 1978; Doddamani et al., 2001; Welcomme, 2001).

3.1.2. *Cyprinion kais*

The male-to-female ratio of 114 individuals was 55:59 = 0.93:1 ($\chi^2 = 0.6$, $P > 0.05$; Table 5). Chi-square analysis showed that there was no significant difference from the expected ratio of 1:1. Fork length of all *C. kais* specimens ranged from 8.5 to 13.0 cm (Figure 3). Female individuals ranged between age groups of 0 and IV, and age groups of male individuals were between 0 and III; age group I was the most abundant.

Length–weight relationships were calculated as $W = 0.549L^{3.01}$ for females and $W = 0.354L^{3.04}$ for males (Table 3). The *b* values of both sexes were equal to 3, which means isometric allometry (b_{female}: 3.01; b_{male}: 3.04; Student's t-test; $P < 0.05$). The correlation coefficients demonstrated a positive relationship between length and weight ($P < 0.05$; Table 3). The age–length relationships were $L_t = 15.4\ [1 - e^{-0.216(t + 0.501)}]$ for females and $L_t = 13.8\ [1 - e^{-0.186(t + 0.465)}]$ for males (Table 3). The growth performance index values (Ø) were 1.71 and 1.55 for females and males, respectively.

The highest somatic condition value was observed in age group I (1.38 ± 0.12) for females and in age group 0 (1.43 ± 0.12) for males (Table 4). The monthly values of condition factor were highest in May (1.77 for females and 1.71 for males). The somatic conditions of *C. macrostomus* and *C. kais* increased during spring and summer in relation to feeding activity and growth of the gonads.

Table 3. The parameters of length–weight and age–length relationships due to sex in *C. macrostomus* and *C. kais*. N: Number of individuals; *a*: y-axis crossing point of the curve that determines the length–weight relationship; *b*: slope of the length–weight relationship; r^2: correlation coefficient. L_∞: average asymptotic length; *k*: growth coefficient determining the rate of change in the length increment; t_0: the hypothetical age when the length is zero.

	Growth parameters					Age–length parameters		
	Sex	N	*a*	*b*	r^2	L_∞	*k*	t_0
C. macrostomus	♀	83	1.32	2.95	0.88	15	0.214	–0.447
	♂	70	0.607	2.86	0.87	13.9	0.231	–0.309
	♀ + ♂	153	0.725	2.92	0.87	15	0.212	–0.407
C. kais	♀	59	0.549	3.01	0.91	15.4	0.216	–0.501
	♂	55	0.354	3.04	0.95	13.8	0.186	–0.465
	♀ + ♂	114	0.417	3.02	0.93	15.4	0.205	–0.503

Table 4. Condition factor values according to sex and age (mean ± standard deviation). N: Number of individuals; SD: standard deviation.

	Age	N♀	Mean ± SD ♀	N♂	Mean ± SD ♂	t-test	P
			[min–max]		[min–max]		
	0	9	1.44 ± 0.17	25	1.59 ± 0.12	1.082	0.287
			[1.10–2.08]		[0.93–2.35]		
	1	31	1.46 ± 0.12	25	1.58 ± 0.15	–0.784	0.437
			[0.97–2.83]		[1.01–2.38]		
C. macrostomus	2	28	1.37 ± 0.12	8	1.60 ± 0.09	1.076	0.29
			[1.03–2.27]		[1.17–2.49]		
	3	9	1.42 ± 0.09	8	1.33 ± 0.11	0.391	0.701
			[1.06–2.33]		[1.15–1.72]		
	4	6	1.57 ± 0.11	4	1.18 ± 0.10	0.305	0.768
			[0.96–2.67]		[0.79–1.58]		
	0	5	1.37 ± 0.17	12	1.43 ± 0.12	0.025	0.98
			[0.87–1.96]		[0.87–2.03]		
	1	21	1.38 ± 0.12	23	1.18 ± 0.15	0.037	0.971
			[0.79–2.40]		[0.63–2.14]		
	2	15	1.35 ± 0.12	15	1.05 ± 0.09	0.275	0.785
C. kais			[0.81–2.08]		[0.70–1.84]		
	3	13	1.23 ± 0.09	5	1.19 ± 0.11	–0.573	0.575
			[0.79–1.98]		[0.91–1.86]		
	4	5	1.21 ± 0.11				
			[0.84–1.70]				

Table 5. Sex ratio of *C. kais* in monthly samples.

Month	Sample observed	Males	Females	Males	% of females	Sex ratio (F:M)
May	21	11	10	52.38	47.62	0.91:1
Jun	16	6	10	37.5	62.5	1.66:1
Jul	13	5	8	38.46	61.54	1.6:1
Aug	22	9	13	40.91	59.09	1.44:1
Sep	23	14	9	60.87	39.13	0.64:1
Nov	19	10	9	52.63	47.37	0.9

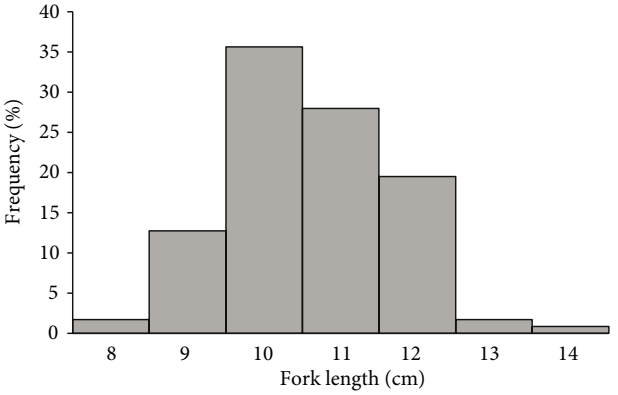

Figure 3. Fork length frequency distribution of *C. kais*.

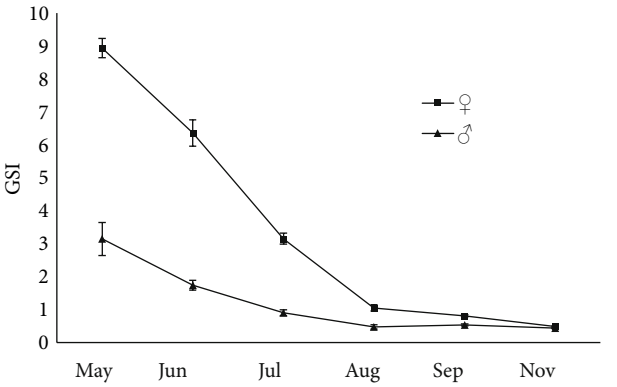

Figure 4. Monthly variation of gonadosomatic index (GSI) of *C. macrostomus* due to sex.

3.2. Reproduction

3.2.1. *Cyprinion macrostomus*

Length at maturity (M_L) was 9.9 cm for females and 8.2 cm for males. Gonad development, determined by using the gonadosomatic index (GSI %), was at maximum level for females (8.94 ± 0.29) and males (3.15 ± 0.5) in May (Figure 4; Table 6). The GSI reached its maximum value in May and gradually declined in early August (Figure 4). Based on GSI, reproductive activity of this species in Karakaya Dam Lake was observed between June and August. The GSI values between May and the other months in females and males were statistically different (ANOVA, $P < 0.05$; Table 6).

The mean oocyte size reached its maximum value in May (0.91 ± 0.05 mm), and its minimum value was observed in August (0.30 ± 0.03 mm). The lowest and the highest fecundities were determined in May (440.13 ± 19.3 eggs/female) and August (1218.63 ± 42.39 eggs/female), respectively. The differences between May and the other months were significant (ANOVA, $P < 0.05$) in terms of oocyte size and fecundity (Table 7).

3.2.2. *Cyprinion kais*

Length at maturity (M_L) was 10.2 and 8.2 cm for females and males, respectively. The highest mean value of GSI was determined in May for females (8.71 ± 0.63) and males (3.37 ± 0.19; Table 6), and it gradually decreased until

Table 6. Monthly variation of GSI by sex in *C. macrostomus* and *C. kais* in May–November 2009 (ANOVA, $P < 0.05$). N: Number of individuals; SD: standard deviation; a, b, c, d: differences between groups.

	C. macrostomus				*C. kais*			
	N ♀	Mean ± SD ♀	N ♂	Mean ± SD♂	N ♀	Mean ± SD ♀	N ♂	Mean ± SD ♂
		[min–max]		[min–max]		[min–max]		[min–max]
May	13	8.94 ± 0.29 [a]	11	3.15 ± 0.5 [a]	10	8.71 ± 0.63 [a]	11	3.37 ± 0.19 [a]
		[7–10.52]		[0.45–5.21]		[5.24–11.82]		[2.22–4.56]
Jun	8	6.36 ± 0.4 [b]	7	1.75 ± 0.15 [b]	10	5.02 ± 0.62 [b]	6	2.18 ± 0.14 [b]
		[5.18–8.32]		[1.34–2.57]		[3.95–10.97]		[1.67–2.77]
Jul	11	3.16 ± 0.17 [c]	6	0.91 ± 0.09 [b,c]	8	3.26 ± 0.13 [c]	5	1.05 ± 0.16 [c]
		[2.46–4.07]		[0.66–1.19]		[2.62–3.79]		[0.67–1.8]
Aug	18	1.06 ± 0.09 [d]	12	0.48 ± 0.07 [c]	13	0.93 ± 0.09 [d]	9	0.58 ± 0.06 [c,d]
		[0.56–1.93]		[0.18–0.89]		[0.45–1.81]		[0.24–0.83]
Sep	16	0.81 ± 0.03 [d]	20	0.54 ± 0.03 [c]	9	0.73 ± 0.13 [d]	14	0.47 ± 0.04 [d]
		[0.64–1.08]		[0.36–0.84]		[0.27–1.7]		[0.27–0.82]
Nov	17	0.49 ± 0.018 [d]	14	0.44 ± 0.014 [c]	9	0.66 ± 0.07 [d]	10	0.47 ± 0.03 [d]
		[0.34–0.59]		[0.36–0.54]		[0.36–0.97]		[0.25–0.62]

Table 7. Monthly variation of oocyte sizes and fecundity in *C. macrostomus* and *C. kais* (ANOVA, P < 0.05). N: Number of individuals; SD: standard deviation; a, b, c, d: differences between groups.

Months	*C. macrostomus*			*C. kais*		
	N	Oocyte size	Fecundity	N	Oocyte size	Fecundity
		Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD
		[min–max]	[min–max]		[min–max]	[min–max]
May	15	0.91 ± 0.05 [a]	440.13 ± 19.3 [a]	11	0.78 ± 0.02 [a]	361.44 ± 23.92 [a]
		[0.63–1.34]	[313–557.1]		[0.66–0.86]	[295.1–532.62]
Jun	8	0.68 ± 0.04 [b]	678.99 ± 52.79 [b]	11	0.61 ± 0.02 [b]	557.35 ± 46.31 [a,b]
		[0.53–0.83]	[411.8–851]		[0.5–0.71]	[324.31–816.38]
Jul	11	0.47 ± 0.02 [c]	720.83 ± 48.74 [b]	9	0.43 ± 0.02 [c]	690.83 ± 41.25 [b]
		[0.38–0.58]	[437.3–921.7]		[0.36–0.49]	[501.13–889.65]
Aug	17	0.30 ± 0.03 [d]	1218.63 ± 42.39 [c]	13	0.25 ± 0.02 [d]	999.83 ± 49.39 [c]
		[0.13–0.54]	[872.32–1647.08]		[0.14–0.49]	[524.12–1255.2]

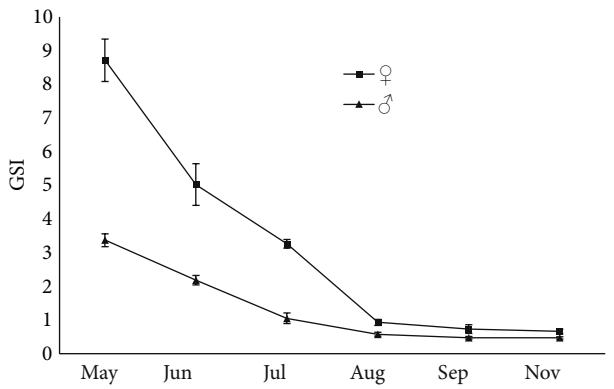

Figure 5. Monthly variation of gonadosomatic index (GSI) of *C. kais* due to sex.

August (Figure 5). The differences between May and the other months were statistically significant in females and males (ANOVA, P < 0.05; Table 6). These results revealed that reproductive activity of this species occurred between June and August.

While the highest value of the mean oocyte size was observed in May (0.78 ± 0.02 mm), the lowest value was determined in August (0.25 ± 0.02 mm). The differences between May and the other months were significant (ANOVA, P < 0.05) in terms of oocyte size (Table 7). The differences between May and the other months except for June (ANOVA, P < 0.05) were significant in terms of fecundity (Table 7). There is no information regarding growth and reproduction properties of *C. kais* in the literature; therefore, comparisons with other studies could not be done.

In the reproductive period, body weights increased due to development of the gonads. Therefore, *C. macrostomus* and *C. kais* performed reproductive activity between June and August in Karakaya Dam Lake.

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