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Assessing age, growth, and reproduction of *Alburnus mossulensis* and *Acanthobrama marmid* (Cyprinidae) populations in Karakaya Dam Lake (Turkey)

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Abstract: In total, 626 individuals of *Alburnus mossulensis* and 586 individuals of *Acanthobrama marmid* were collected monthly from Karakaya Dam Lake on the upper Euphrates River. The gonadosomatic index, somatic condition, oocyte size, and fecundity were calculated on a monthly basis. Reading of scales indicated that the maximum age was 4+ years for *A. mossulensis* and *A. marmid*. The estimated length–weight relationships were $W = 0.206 \times FL^{2.065}$ for females and $W = 0.119 \times FL^{2.138}$ for males in *A. mossulensis*, and $W = 0.029 \times FL^{2.678}$ for females and $W = 0.030 \times FL^{2.631}$ for males in *A. marmid*. Growth in length equations were $L_t = 19.6[1 - e^{-0.14(t + 1.39)}]$ for females and $L_t = 20.1[1 - e^{-1.40(t + 1.04)}]$ for males in *A. mossulensis* and $L_t = 17.3[1 - e^{-1.37(t + 1.04)}]$ for females and $L_t = 16.6[1 - e^{-1.29(t + 1.04)}]$ for males in *A. marmid*. This study investigated oocyte size and fecundity for *A. mossulensis* and *A. marmid* in Turkey for the first time. The spawning period was between May and August for *A. mossulensis* and between May and June for *A. marmid*. These 2 species usually play a key role in the food web of temperate freshwater systems. In addition to water quality, biological data of these 2 species are very important in terms of future water management of the basin of Karakaya Dam Lake.

Key words: *Acanthobrama marmid*, *Alburnus mossulensis*, age, growth, reproduction, Karakaya Dam Lake, upper Euphrates River

1. Introduction

The freshwater fishes *Alburnus mossulensis* (Heckel, 1843) and *Acanthobrama marmid* (Heckel, 1843) are cyprinid fish found in the Euphrates and Tigris rivers in Turkey and their adjacent basins in Iran (Kuru, 1978; Coad, 2010). The distribution of *A. mossulensis* in Asia extends from the Tigris–Euphrates basin to the very upper parts of the delta of the Kor, Mand, and Kul rivers in Iran (Bogutskaya, 1997). *A. marmid* is present in the Tigris, Euphrates, and Orontes river systems, the Berdan River, and Seyhan Dam Lake (www.fishbase.org).

Several studies conducted at different localities in Turkey have investigated the growth and reproduction characteristics of *A. mossulensis* and *A. marmid* (Polat, 1988; Ünlü et al., 1994; Türkmen and Akyurt, 2000; Yıldırım et al., 2003; Başusta and Şen, 2004). However, information regarding the biological characteristics of both species in the upper Euphrates River has been insufficient.

Weight–length relationships are used to estimate the weight corresponding to a specified length, and condition factors are used to compare the condition, fatness, or well-being of fish, based on the assumption that heavier fish of a specified length are in better condition (Froese, 2006). Information about the relationship between length and weight of fish is useful for fisheries management (Froese, 2006; Nascimento et al., 2012). Even though it is not difficult to obtain them, data on the length–weight relationship are still unavailable for many fish species (Froese, 1998).

Assessment of growth and reproductive conditions, which are key parameters of fish populations, is crucial for several reasons (Bariche et al., 2009; Arantes et al., 2010). This assessment gives information about fish communities and is an element enabling ecological monitoring in rivers, lakes, and transitional waters. Therefore, the purpose of this study was to determine age, growth and reproductive characteristics, and knowledge of the recent situation of *A. mossulensis* and *A. marmid* in the Karakaya Dam Lake on the upper Euphrates River. Our results will be beneficial for future fish-population and water-quality monitoring studies in the water assessment program for the transboundary river basin.

2. Materials and methods

Being one of the most important rivers in the world, the Euphrates River is a transboundary river originating from

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the eastern part of Anatolia and flowing into the Persian Gulf. The study area is Karakaya Dam Lake, located on the upper Euphrates River. It was created for a hydroelectric power plant and has been affected by many pollutants, such as the direct transfer of sewer and industrial wastes (Gokce and Ozhan, 2011). In total, 626 individuals of *A. mossulensis* and 586 individuals of *A. marmid* were collected monthly from Karakaya Dam Lake using gill nets between December 2008 and November 2009. Four sampling points were selected and the lower basin of the reservoir was studied (Figure 1).

Fish samples were brought to the laboratory after being placed on ice. Precision for total length and fork length measured was 1 mm, and precision for total body weight (W) measured was 0.01 g. Gonads were weighed (W_g) with a precision of 0.01 g. Upon visual and microscopic examination of the gonads, sex and maturity stages were determined. The scales were collected from the right side of each fish between the lateral line and the dorsal fin base (Lagler, 1966; Hussein, 1986; Oymak et al., 2011). Scales were kept in 5% sodium hydroxide solution for 2 h to remove the flesh and mucilage. Nondegenerate scales (15 scales) were glued between 2 glass microscope slides (Chugunova, 1963). They were scanned using a light microscope in order to determine the ages of the fish. All scales were read in triplicate.

Length–weight growth parameters and von Bertalanffy growth equations were calculated for males, females, and all individuals. The von Bertalanffy growth equation was used to determine the age–length relationship:

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

where L_t is the fork length at age t; k is a growth constant, determining the rate of change in the length increment; and t_0 is the hypothetical age when the length is zero.

In each of the age groups, the proportional length extension (OL) was calculated where L_t is length at age t (Chugunova, 1963):

$$OL = L_t - L_{t-1} / L_{t-1},$$

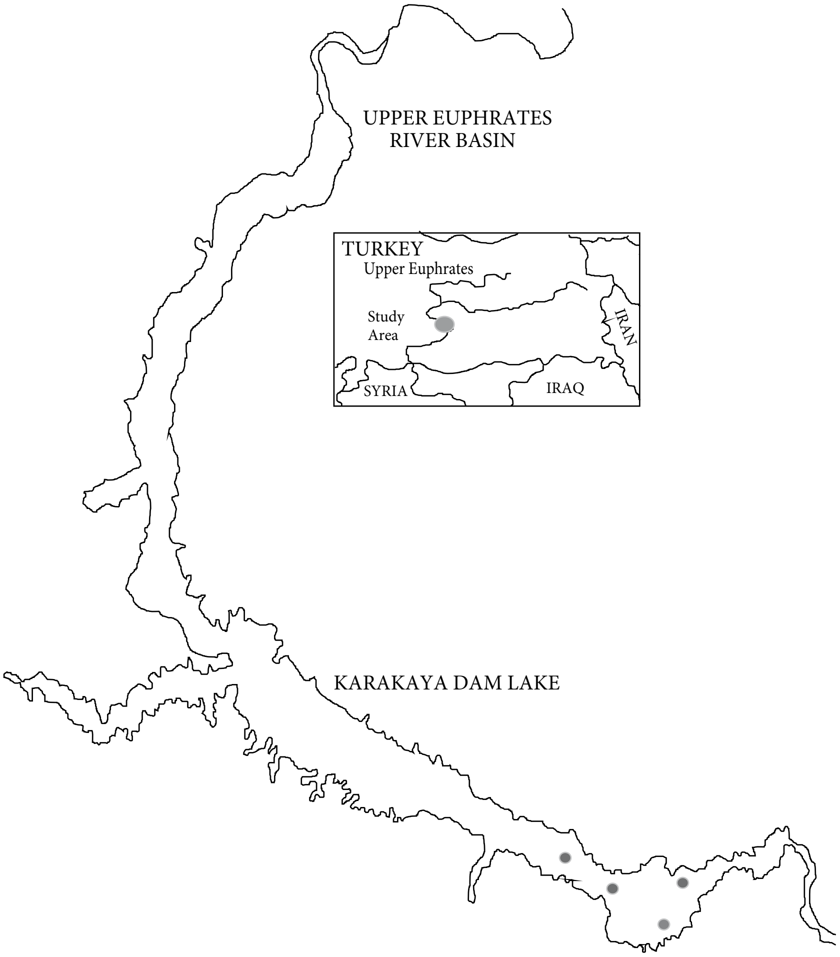

Figure 1. Map of the study area (modified from Gokce and Ozhan, 2011).

and the proportional weight increase (*OW*) was calculated using this equation where W_t is weight at age *t* (Chugunova 1963):

$$OW = W_t - W_{t-1} / W_{t-1}.$$

The regression equation for the length–weight relationship was calculated using the least-squares method; the data were commonly used in this equation:

$$W = a \times L^b,$$

where *W* is the body weight (g) and *L* is the fork length (mm) (von Bertalanffy, 1938). The hypothesis of isometric growth (Ricker, 1975) was tested with Student's t-test.

The growth performance index was calculated as follows (Gayanilo and Pauly, 1997):

$$\O = \log_{10}(k) + 2\log_{10}(L_\infty),$$

where *k* and L_∞ are the von Bertalanffy growth equation parameters.

The female-to-male ratio was examined using the chi-square (χ^2) test (Nikolsky, 1963). The somatic condition was determined in terms of sex, age groups, and months. Condition factors were estimated using the following equation:

$$C = (W / L^3) \times 100,$$

where *W* is the body weight (g) and *L* is the fork length (cm) (Tesch, 1968). Condition factors were calculated according to sex, age groups, and months.

The spawning period was estimated based on the monthly changes in gonads and monthly variations in oocyte sizes of samples (Lagler, 1966). Gonadosomatic index (*GSI*) was calculated using the equation:

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

where W_g and *W* are gonad weight and total weight of fish in grams, respectively (Lagler, 1966; Bagenal, 1978).

Mean length at maturity (M_L) was measured for females collected just before reproduction using the formula from DeMaster (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 of maturity, $f(x)$ is the proportion of fish that are mature at length *x*, and *w* is the maximum length in the sample. A modified version of this formula (10-mm *FL* intervals in place of length classes) was used to calculate mean fork length at maturity (Fox and Crivelli, 2001).

Intraovarian oocyte size was measured using a stereo microscope (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. Fecundity was investigated based on the gravimetric method (Bagenal, 1978). The subsamples of 1 g were taken from the front, middle, and back parts of the ovaries. Oocyte samples were kept in 4% formaldehyde for counting.

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

3. Results

3.1. Growth parameters

3.1.1. *Alburnus mossulensis*

The ratio of males to females in 626 samples was 163:463 = 1:2.84 ($\chi^2 = 1.02$, $P < 0.05$; Table 1). The distribution of the total length ranged between 12.3 and 20.12 cm for females and between 14.0 and 20.4 cm for males. The weights of the samples varied between 16.87 and 56.57 g for females and between 18.32 and 45.90 g for males (Table 2). The samples consisted of female and male individuals of 5 age groups (from 0 to 4). Age group 1 was the dominant age group for both sexes. Relative growth in length and weight was examined in terms of means of fork length and total weight of each age group. Maximum increase in growth of all 3 groups was determined from age group 0 to age group 1 in terms of length, and from age group 3 to age group 4 in terms of weight (Table 3; Figures 2 and 3).

Table 4 and Figure 4 illustrate the equations of length–weight relationship: $W = 0.206 \times L^{2.065}$ for females and $W = 0.119 \times L^{2.138}$ for males. The *b* values of both sexes were less than 3, which represents negative allometry (Student's t-test; $P < 0.05$). The correlation coefficients demonstrated a positive relationship between length and weight ($P < 0.05$; Table 4). The linear growth parameters of the von Bertalanffy equation were $L_t = 19.6[1 - e^{-0.14(t + 1.39)}]$ for females and $L_t = 20.1[1 - e^{-1.40(t + 1.04)}]$ for males. The $L\infty$ value of females was lower compared to that of males (Table 4). Considering the $L\infty$ and k values, growth performance index values (Ø) were calculated to provide a basis for the comparison of growth characteristics as 1.731, 2.753, and 2.561 for females, males, and both sexes, respectively.

The condition factor values for age were 0.54–1.96 with an average of 0.90 ± 0.1 in females. The highest mean value was observed in age group 0 (0.97) for females. On the other hand, these values were 0.51–1.31 with an average of 0.84 ± 0.11 in males. The highest mean value was in age group 0 (0.9; Table 5). Considering condition factor values

Table 1. Sex ratio of *A. mossulensis* in monthly samples during the study period.

Month	Samples observed	N. males	N. females	% of males	% of females	Sex ratio (F:M)
December	37	15	22	40.54	59.46	1.46:1
January	65	9	56	13.84	86.15	6.22:1
February	75	13	62	17.33	82.66	4.76:1
March	75	14	61	18.66	81.33	4.35:1
April	74	15	59	20.27	79.23	3.93:1
May	41	13	28	31.7	68.29	2.15:1
June	56	24	32	42.86	57.14	1.33:1
July	33	11	22	33.33	66.66	2:1
August	40	7	33	17.5	82.5	4.71:1
September	28	8	20	28.57	71.82	2.5:1
October	57	17	40	29.82	70.17	2.35:1
November	45	17	28	37.77	62.22	1.64:1

Table 2. The distribution of fork length (cm) and total weight (g) by sex in *A. mossulensis* and *A. marmid* (N: number of individuals; SD: standard deviation).

	Sex	N	Fork length, mean ± SD [min–max]	Total weight, mean ± SD [min–max]
A. mossulensis	♀	463	14.78 ± 0.89	28.38 ± 4.40
			[10.8–18.6]	[16.87–56.57]
	♂	163	14.50 ± 0.99	27.05 ± 4.43
			[12.5–19]	[18.32–45.90]
	♀ + ♂	626	14.71 ± 0.93	28.03 ± 4.45
			[10.8–19]	[16.87–56.57]
A. marmid	♀		12.56 ± 1.1	21.80 ± 6.41
		342	[9.6–16.3]	[9.99–67.48]
	♂		12.12 ± 1.03	19.89 ± 4.67
		244	[10–15.7]	[11.15–47.67]
	♀ + ♂		12.38 ± 1.09	21 ± 5.82
		586	[9.6–16.3]	[9.99–67.48]

monthly, the mean values were highest in May (1.10 and 1.07) and lowest in September (0.78 and 0.65) for females and males, respectively.

3.1.2. *Acanthobrama marmid*

The ratio of males to females in 586 samples was 244:342 = 1:1.4 ($\chi^2 = 1.0$, $P < 0.05$; Table 6). The distribution of the total length ranged between 11 and 19.20 cm for females and between 11.50 and 17.20 cm for males (Table 2). The weight of the samples varied between 9.99 and 67.48 g for females and between 11.15 and 47.67 g for males. The specimens consisted of 5 age groups (from 0 to 4) for both females and males. Age group 1 was the dominant age

Table 3. The growth in length and weight due to age and sex groups in *A. mossulensis* (N: number of individuals; L_t: length at age t; W_t: weight at age t).

Sex	Age	N	%N	Lt	$Lt - (Lt^{-1})$	OL	t-test	Wt	$Wt - (Wt^{-1})$	OW	t-test
♀	0	55	8.77	13.8				25.17			
	1	146	23.39	14.7	0.9	0.065	$P < 0.05$	26.89	1.72	0.068	$P < 0.05$
	2	142	22.49	14.94	0.24	0.016	$P < 0.05$	29,53	2.64	0.098	$P < 0.05$
	3	89	14.19	15.36	0.42	0.028	$P < 0.05$	31.9	2.37	0.080	$P < 0.05$
	4	31	4.78	16	0.64	0.042	$P < 0.05$	35.2	3.3	0.103	$P < 0.05$
♂	0	22	3.51	13.54				23.79			
	1	73	11.76	14.2	0.66	0.049	$P < 0.05$	25.66	1.87	0.079	$P < 0.05$
	2	36	5.96	14.77	0.57	0.040	$P < 0.05$	29.12	3.46	0.135	$P < 0.05$
	3	25	3.97	15.07	0.3	0.020	$P < 0.05$	31.32	2.2	0.076	$P < 0.05$
	4	7	0.79	15.52	0.45	0.030	$P < 0.05$	40.79	9.47	0.302	$P < 0.05$
♀ + ♂	0	77	12.28	13.73				24.78			
	1	219	35.09	14.31	0.58	0.042	$P < 0.05$	26.48	1.7	0.069	$P < 0.05$
	2	178	28.39	14.91	0.6	0.042	$P < 0.05$	29.44	2.96	0.112	$P < 0.05$
	3	114	18.18	15.3	0.39	0.026	$P < 0.05$	31.77	2.33	0.079	$P < 0.05$
	4	38	5.58	16.2	0.9	0.059	$P < 0.05$	36.23	4.46	0.140	$P < 0.05$

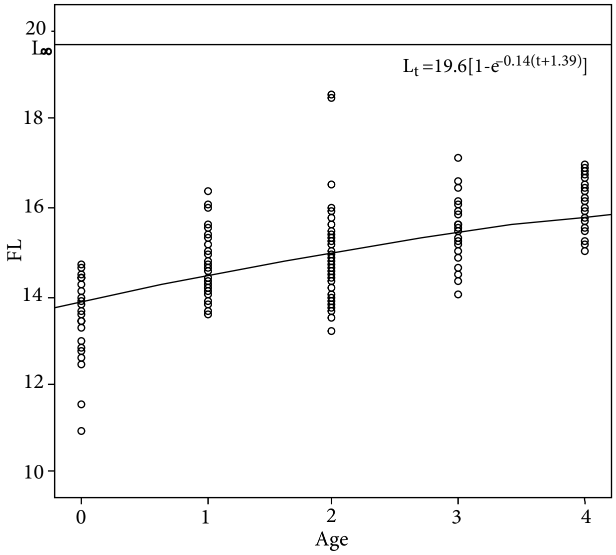

Figure 2. Age and length (FL) relationship due to age groups in *A. mossulensis* females.

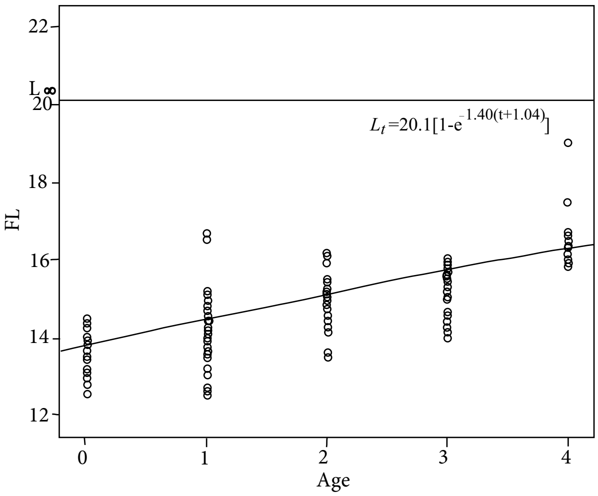

Figure 3. Age and length (FL) relationship due to age groups in *A. mossulensis* males.

group for both sexes. The maximum increase of relative growth in all 3 groups was determined to be from age 3 to age 4 (Table 7; Figures 5 and 6).

The regression equations for the length–weight relationships were $W = 0.029 \times FL^{2.678}$ for females and $W = 0.030 \times FL^{2.631}$ for males. The length–weight relationships of both sexes are shown in Figure 7. Both sexes had negative allometry due to b values (Student's t-test, $P < 0.05$; Table 4). The linear growth parameters of the von Bertalanffy equation were $L_t = 17.3[1 - e^{-1.37(t + 1.04)}]$ for females and $L_t =$

Table 4. The parameters of length–weight and age–length relationships between different sexes in *A. mossulensis* and *A. marmid* (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; r²: correlation coefficient; L_∞: average asymptotic length; k_L: growth coefficient, determining the rate of change in the length increment; t_0: hypothetical age when the length is zero).

	Sex	N	Growth parameters					Age–length parameters			
			a	Log *a*	*b*	r²	Equations	L_∞	*k*	t_0	Equations
	♀	463	0.206	–0.686	2.07	0.95	$W = 0.206L^{2.065}$	19.6	0.14	–1.39	$L_t=19.6[1 - e^{-0.14(t + 1.39)}]$
A. mossulensis	♂	163	0.119	–0.924	2.14	0.93	$W = 0.119L^{2.138}$	20.1	1.40	–1.04	$L_t=20.1[1 - e^{-1.40(t + 1.04)}]$
	♀ + ♂	626	0.135	–0.869	2.12	0.94	$W = 0.135L^{2.116}$	20.1	0.92	–1.07	$L_t=20.1[1 - e^{-0.92(t + 1.07)}]$
	♀	342	0.029	–42.287	2.68	0.77	$W = 0.029L^{2.678}$	17.3	1.37	–1.04	$L_t=17.3[1 - e^{-1.37(t + 1.04)}]$
A. marmid	♂	244	0.03	–32.918	2.63	0.79	$W = 0.030L^{2.631}$	16.6	1.29	–1.04	$L_t=16.6[1 - e^{-1.29(t + 1.04)}]$
	♀ + ♂	586	0.026	–39.36	2.68	0.78	$W = 0.026L^{2.675}$	17.3	1.37	–1.04	$L_t=17.3[1 - e^{-1.37 (t + 1.04)}]$

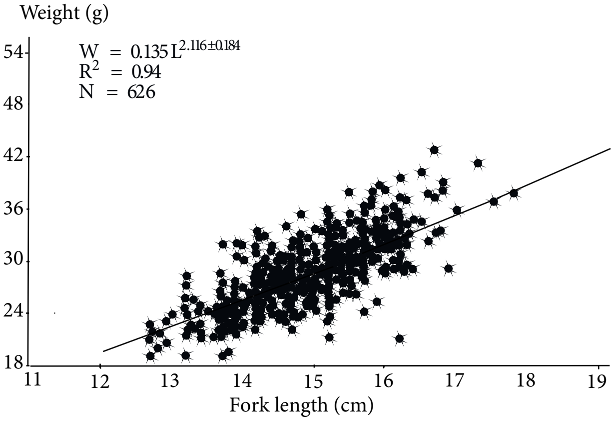

Figure 4. Length–weight relationship of *A. mossulensis* in Karakaya Dam Lake (N: number of female and male individuals).

Table 5. Condition factor values according to sex and age (N: number of individuals; SD: standard deviation).

	Age	N ♀	Mean ± SD, ♀ [min–max]	N ♂	Mean ± SD, ♂ [min–max]	t-test	P
	0	55	0.97 ± 0.17 [0.70–1.96]	22	0.91 ± 0.12 [0.70–1.31]	1.565	0.122
	1	146	0.92 ± 0.12 [0.54–1.54]	73	0.86 ± 0.15 [0.60–1.14]	3.004	0.003
A. mossulensis	2	142	0.88 ± 0.12 [0.60–1.32]	36	0.84 ± 0.09 [0.55–1.23]	1.534	0.127
	3	89	0.88 ± 0.092 [0.59–1.30]	25	0.89 ± 0.11 [0.51–1.28]	–0.377	0.707
	4	31	0.88 ± 0.11 [0.63–1.62]	7	0.80 ± 0.1 [0.64–0.94]	0.627	0.535
	0	36	1.05 ± 0.21 [0.62–1.46]	37	1.12 ± 0.24 [0.75–1.81]	0.211	0.833
	1	119	1.04 ± 0.18 [0.54–1.65]	95	1.12 ± 0.21 [0.73–2.30]	–0.942	0.347
A. marmid	2	95	1.13 ± 0.24 [0.77–2.18]	69	1.14 ± 0.24 [0.83–1.99]	0.160	0.873
	3	65	1.18 ± 0.33 [0.79–2.28]	40	1.08 ± 0.14 [0.84–1.49]	1.223	0.224
	4	27	1.12 ± 0.26 [0.78–1.78]	3	1.11 ± 0.10 [1.03–1.23]	–0.345	0.733

Table 6. Sex ratio of *A. marmid* in monthly samples during the study period.

Month	Samples observed	N. males	N. females	% of males	% of females	Sex ratio (F:M)
December	25	12	12	52	48	0.92:1
January	65	23	42	35.38	64.61	1.82:1
February	43	14	29	32.56	67.44	2.07:1
March	55	20	34	38.18	61.81	1.62:1
April	55	22	33	40	60	1.5:1
May	55	20	35	36.36	63.63	1.75:1
June	54	25	29	46.29	53.7	1.16:1
July	41	13	28	31.71	68.29	2.15:1
August	47	18	29	38.29	61.7	1.61:1
September	48	24	24	50	50	1
October	52	29	23	55.77	44.23	0.79:1
November	50	24	24	50	50	1

Table 7. The growth in length and weight due to age and sex groups in *A. marmid* (N: number of individuals; L_t: length at age t; W_t: weight at age t).

Sex	Age	N	%N	Lt	Lt – (Lt $^{-1}$)	OL	t-test	Wt	Wt – (Wt $^{-1}$)	OW	t-test
♀	0	36	6.15	11.19				16.47			
	1	119	20.34	12.06	0.87	0.078	$P < 0.05$	19.05	2.58	0.157	$P < 0.05$
	2	95	16.24	12.74	0.68	0.056	$P < 0.05$	22.66	3.61	0.190	$P < 0.05$
	3	65	11.11	13.23	0.49	0.038	$P < 0.05$	25.55	2.89	0.128	$P < 0.05$
	4	27	4.61	14.56	1.33	0.101	$P < 0.05$	34.61	9.06	0.355	$P < 0.05$
♂	0	37	6.5	11.18				16.09			
	1	95	16.24	11.83	0.65	0.058	$P < 0.05$	18.24	2.15	0.134	$P < 0.05$
	2	69	11.62	12.61	0.78	0.066	$P < 0.05$	21.9	3.66	0.201	$P < 0.05$
	3	40	6.66	13.2	0.59	0.047	$P < 0.05$	24.3	2.4	0.110	$P < 0.05$
	4	3	0.51	14.23	1.03	0.078	$P < 0.05$	33.72	9.42	0.388	$P < 0.05$
♀ + ♂	0	73	12.65	11.19				16.27			
	1	214	36.58	11.96	0.77	0.069	$P < 0.05$	18.69	2.42	0.149	$P < 0.05$
	2	164	27.86	12.7	0.74	0.062	$P < 0.05$	22.37	3.68	0.197	$P < 0.05$
	3	105	17.77	13.23	0.53	0.042	$P < 0.05$	25.15	2.78	0.124	$P < 0.05$
	4	30	5.13	14.53	1.3	0.098	$P < 0.05$	34.47	9.32	0.371	$P < 0.05$

$16.6[1 - e^{-1.29(t + 1.04)}]$ for males. The L_∞ value of females was higher than that of males (Table 4). Growth performance index values (Ø) were 2.613, 2.551, and 2.613 for females, males, and both sexes, respectively.

The condition factor values were calculated as 0.54–2.28 with an average of 1.10 ± 0.24. The highest value was observed in age group 3 (2.28) for females. As for males, the values were 0.73–2.30 with an average of 1.11 ± 0.19.

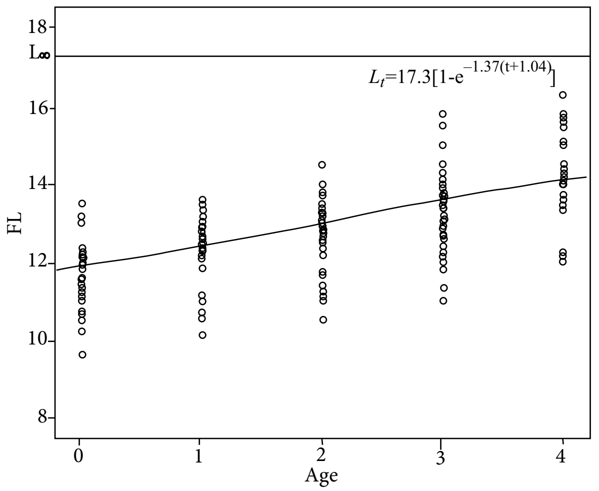

Figure 5. Age and length (FL) relationship due to age groups in *A. marmid* females.

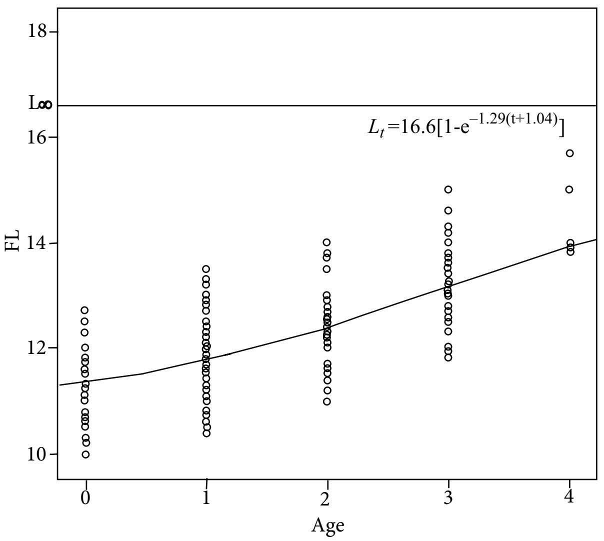

Figure 6. Age and length (FL) relationship due to age groups in *A. marmid* males.

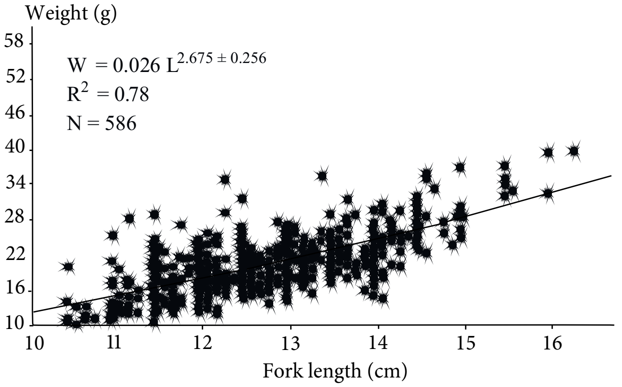

Figure 7. Length–weight relationship of *A. marmid* in Karakaya Dam Lake (N: number of female and male individuals).

The lowest mean value was 1.08 in age group 3 and the highest mean value was 1.14 in age group 2 (Table 5). Upon examination of monthly condition factor values, the lowest mean value was observed in October and February for females (0.88) and males (0.95), respectively. On the other hand, the highest mean value was in June for females (1.4) and in May for males (1.39).

3.2. Reproduction

3.2.1. *Alburnus mossulensis*

The reproductive period of *A. mossulensis* was determined through morphological observation of the gonads and a series of monthly changes. Length at maturity (M_L) was 12.8 cm. Table 8 and Figure 8 illustrate the monthly change values of *GSI*. The mean value was lowest in October (4.01) and highest in May (12.84) for females. These values for males were lowest in December (1.03), and highest in May (7.36). Both female and male individuals reached the highest mean value in May. According to these results, reproductive activity of this species in Karakaya Dam Lake began in May and continued until August. The *GSI* values were found to be statistically different between May and the other months in both females and males (ANOVA, $P < 0.05$; Table 8).

Oocyte sizes of 255 female individuals were measured (Table 9). The mean oocyte size reached its peak value in May (1.35 ± 0.098 mm), while its minimum size was measured in September (0.31 ± 0.024 mm). A sudden decrease was observed in oocyte size from May to June. The lowest and highest fecundity were 1777.47 eggs/female in May and 3814.02 eggs/female in September (Table 9). The differences between March and April, August, and September were significant (ANOVA, $P < 0.05$), and differences between May and the other months were also significant (ANOVA, $P < 0.05$) in terms of oocyte size, except for April. The differences between May and the other months were significant (ANOVA, $P < 0.05$) in terms of fecundity, except for June and July (Table 9).

3.2.2. *Acanthobrama marmid*

Length at maturity (M_L) was 11.4 cm. The lowest mean value of *GSI* was determined in October for females (1.27) and in November for males (0.51). The mean value was the highest in June for females (5.23) and in May for males (4.70; Table 8). These results revealed that reproductive activity of this species occurred between May and August (Figure 9). The differences between June and the other months were statistically significant in females except for July (ANOVA, $P < 0.05$). The differences between May and

Table 8. Monthly variation of *GSI* in females and males in *A. mossulensis* and *A. marmid* from December 2008 to November 2009 (ANOVA, P < 0.05) (N: number of individuals; SD: standard deviation; a, b, c, d, e, f: differences between groups).

Months	*A. mossulensis*				*A. marmid*			
	N♀	Mean ± SD, ♀ [min–max]	N♀	Mean ± SD, ♂ [min–max]	N♀	Mean ± SD, ♀ [min–max]	N♀	Mean ± SD, ♂ [min–max]
December	22	4.35 ± 0.31 ^{a} [1.49–6.23]	15	1.03 ± 0.07 ^{a} [0.59–1.49]	12	1.52 ± 0.09 ^{a} [1.06–2.18]	12	0.89 ± 0.08 ^{a,b,c} [0.63–1.71]
January	56	5.87 ± 0.28 ^{a,b,c} [1.16–10.98]	9	2.43 ± 0.16 ^{a,b,c} [1.61–3.29]	42	1.69 ± 0.1 ^{a} [0.82–4.21]	23	1.54 ± 0.21 ^{b,c,d} [0.48–4.15]
February	62	6.29 ± 0.24 ^{b,c} [3.35–12.7]	13	2.78 ± 0.38 ^{a,b,c} [0.77–5.11]	29	2.47 ± 0.2 ^{a,b} [0.52–6.32]	14	1.03 ± 0.13 ^{a,b,c,d} [0.55–2.53]
March	61	6.46 ± 0.31 ^{c} [2.45–16.99]	14	4.19 ± 0.39 ^{c,d,e} [1.62–7.91]	34	2.43 ± 0.19 ^{a,b} [0.49–5.19]	20	1.76 ± 0.18 ^{c,d,e} [0.3–2.81]
April	59	9.41 ± 0.33 ^{d} [4.76–20.17]	15	5.1 ± 0.48 ^{d,e} [2.7–8.8]	33	2.5 ± 0.16 ^{a,b} [0.64–5.28]	22	1.97 ± 0.27 ^{d,e} [0.3–4.02]
May	28	12.84 ± 0.90 ^{e} [3.33–23.49]	13	7.36 ± 0.38 ^{f} [4.51–9.72]	35	3.65 ± 0.33 ^{b,c} [0.91–10.98]	20	4.7 ± 0.34 ^{f} [0.51–6.64]
June	32	8.46 ± 0.69 ^{d} [2.1–17.97]	24	5.73 ± 0.47 ^{e,f} [1.5–10.33]	29	5.23 ± 0.54 ^{d} [0.82–12.78]	25	2.68 ± 0.3 ^{e} [0.41–4.27]
July	22	6.5 ± 0.48 ^{c} [3.18–10.62]	11	3.94 ± 0.31 ^{c,d,e} [2.13–6.16]	28	4.66 ± 0.34 ^{c,d} [1.17–8.75]	13	1.25 ± 0.23 ^{a,b,c,d} [0.15–2.53]
August	33	4.94 ± 0.28 ^{a,b,c} [1.48–8.13]	7	3.67 ± 0.33 ^{b,c,d} [2.29–5.12]	29	2.44 ± 0.23 ^{a,b} [0.83–4.16]	18	0.91 ± 0.09 ^{a,b,c} [0.37–1.55]
September	20	4.32 ± 0.43 ^{a} [1.57–8.47]	8	2.09 ± 0.21 ^{a,b} [1.27–3.32]	24	1.31 ± 0.12 ^{a} [0.57–2.77]	24	0.71 ± 0.05 ^{a,b} [0.27–1.12]
October	40	4.01 ± 0.11 ^{a} [2.6–6.25]	17	1.80 ± 0.16 ^{a} [0.9–3.57]	23	1.27 ± 0.09 ^{a} [0.66–2.48]	29	0.57 ± 0.03 ^{a} [0.33–1.04]
November	28	4.01 ± 0.14 ^{a} [2.44–5.37]	17	1.86 ± 0.12 ^{a,b} [0.87–2.63]	24	1.43 ± 0.19 ^{a} [0.54–4.03]	24	0.51 ± 0.03 ^{a} [0.33–0.77]

the other months were statistically significant in males (ANOVA, P < 0.05).

Oocyte sizes of 212 female individuals were measured on a regular basis for each sampling, and monthly differences in egg diameter are shown in Table 9. The mean oocyte size reached its maximum value in June (1.10 ± 0.07 mm), and its minimum size was observed in September (0.23 ± 0.014 mm). A sudden decrease was observed in oocyte size from June to July. The lowest and highest fecundity were determined in June (560.08 ± 26.73 eggs/female) and in September (1468.77 ± 54.88 eggs/female), respectively. The differences between June and the other months were significant in terms of oocyte size (ANOVA, P < 0.05). The differences between March and the other months were significant except for August (ANOVA, P < 0.05; Table 9).

Table 9. Distribution of oocyte sizes and fecundity in *A. mossulensis* and *A. marmid* by months (ANOVA, $P < 0.05$) (N: number of individuals; SD: standard deviation; a, b, c, d: differences between groups).

Months	*A. mossulensis*			*A. marmid*		
	N	Oocyte size, mean ± SD [min–max]	Fecundity, mean ± SD [min–max]	N	Oocyte size, mean ± SD [min–max]	Fecundity, mean ± SD [min–max]
March	61	0.86 ± 0.075 ^{a} [0.07–3.06]	3766.15 ± 202.05 ^{c} [987.6–7542.1]	34	0.40 ± 0.025 ^{a} [0.15–0.82]	1126.9 ± 113.5 ^{c} [457.96–4466.45]
April	59	1.16 ± 0.073 ^{b,c} [0.39–2.75]	3149.5 ± 168.12 ^{c} [958.1–5418.1]	33	0.41 ± 0.025 ^{a} [0.06–0.82]	774.66 ± 26.45 ^{a,b} [470.09–1152.6]
May	28	1.35 ± 0.098 ^{c} [0.36–2.25]	1777.47 ± 157.69 ^{a} [885–4002.87]	35	0.84 ± 0.07 ^{b} [0.31–1.79]	617.76 ± 22.62 ^{a,b} [249.2–905.5]
June	32	0.98 ± 0.066 ^{a,b} [0.56–2.03]	2121.78 ± 145.3 ^{a,b} [1007.5–4450.7]	29	1.10 ± 0.07 ^{c} [0.4–1.71]	560.08 ± 26.73 ^{a} [291.05–885.3]
July	22	0.84 ± 0.042 ^{a,b} [0.53–1.25]	2861.68 ± 236.23 ^{a,b,c} [1489.1–4734.8]	28	0.66 ± 0.032 ^{b} [0.27–0.94]	853.42 ± 35.20 ^{b} [502.65–1324.52]
August	33	0.54 ± 0.053 ^{d} [0.12–1.25]	3784.87 ± 295.8 ^{c} [912.1–6600.1]	29	0.32 ± 0.014 ^{a} [0.17–0.45]	1243.85 ± 33.9 ^{c,d} [926.78–1576.85]
September	20	0.31 ± 0.024 ^{d} [0.15–0.53]	3814.02 ± 221.05 ^{c} [1533.05–5561.4]	24	0.23 ± 0.014 ^{a} [0.14–0.36]	1468.77 ± 54.88 ^{d} [955.62–1948.2]

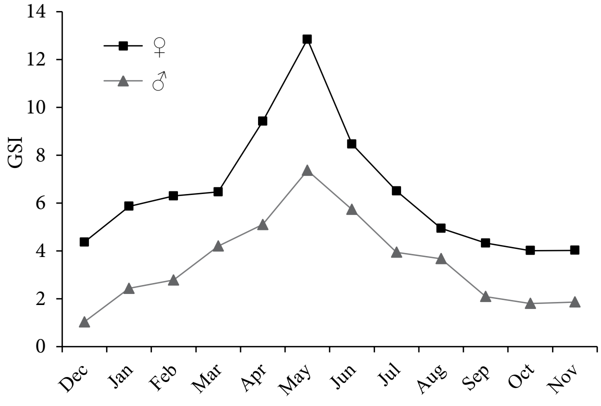

Figure 8. Monthly variation of gonadosomatic index (*GSI*) of *A. mossulensis* females and males in Karakaya Dam Lake.

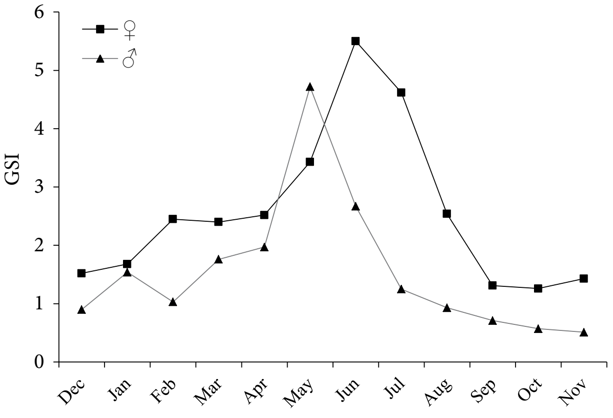

Figure 9. Monthly variation of gonadosomatic index (*GSI*) of *A. marmid* females and males in Karakaya Dam Lake.

4. Discussion

The number of biological studies about *A. mossulensis* and *A. marmid* populations in Turkey is limited (Table 10). In this study, sex composition for the *A. mossulensis* specimens taken from Karakaya Dam Lake was 72.30% females and 27.68% males among age groups 0–4. Sex composition for the *A. marmid* specimens was 57.78% females and 42.21% males among age groups 0–4.

The overall sex ratio was 3.12:1 females to males for *A. mossulensis* and 1.45:1 females to males for *A. marmid*. The χ^2 analysis revealed that the female-to-male ratio was significantly different from the expected situation ($P < 0.05$). The sex ratio of fish populations changes based on spawning season, life stage of the fish, spawning ground, and migration (Nikolsky, 1963). According to Mouine et al. (2011), the sex ratio depends on the fishing area, since

Table 10. The length–weight relationships of *A. mossulensis* and *A. marmid* from 6 different locations in Turkey.

Species	Sex	N	Age	b	$L\infty$	Locality	Author(s)
A. mossulensis	♀		1–5	2.885		Kalecik Dam Lake, Turkey	Şen, 1985
	♂		1–5				
A. mossulensis	♀		1–4			Tercan Dam Lake, Turkey	Ergene, 1993
	♂		1–4				
A. mossulensis	♀ + ♂	40	2–5	2.046		Keban Dam Lake	Özdemir et al., 1996
A. mossulensis	♀	375	1–6	3.082	21.59	Karasu River, Turkey	Türkmen and Akyurt, 2000
	♂			2.828	20.41		
A. mossulensis	♀	850	1–7	3.136	21.87	Karasu River, Turkey	Yıldırım et al., 2003
	♂			2.913	19.58		
A. mossulensis	♀	463	0–4	2.065	19.6	Karakaya Dam Lake, Turkey	present study
	♂	163	0–4	2.138	20.1		
A. marmid	♀			3.4		Tigris River, Turkey	Ünlü et al., 1994
	♂			3.29			
A. marmid	♀ + ♂	212	1–6			Keban Dam Lake	Başusta and Şen, 2004
A. marmid	♀	342	0–4	2.678	17.3	Karakaya Dam Lake, Turkey	present study
	♂	244	0–4	2.631	16.6		

it is possible to determine females and males as being more abundant in heterogenic habitats. Moreover, differences in sex ratio related to corresponding differences in growth and selectivity in the sampling have also been put forward for other fish species (Bartulovic et al., 2004).

Age group 1 was the dominant age group for both species. Age distribution provides important information such as reproduction, death, and development of individuals. The range of age distribution in a population is closely related to the nutritional status of the environment (Holmgren and Appelberg, 2001; Bautista et al., 2012). Examining age groups separately, females were found to be dominant in all age groups (Tables 3 and 7). Different factors such as natural death, competition, predation, and hunting have caused a decrease in the number of fish in age group 4 for *A. mossulensis* and in age groups 3 and 4 for *A. marmid*. The age–length relationships of the local populations in the same species change due to habitat variations, water quality, and nutrients (Holmgren and Appelberg, 2001; Bautista et al., 2012). These relationships were linear due to the age groups in both sexes of *A. mossulensis* and *A. marmid* (Figures 2, 3, 5, and 6).

The slope b provides valuable information on fish growth, which is isometric when $b = 3$, has positive allometry when $b > 3$, and has negative allometry when $b < 3$ (Morey et al., 2003). Considering studies conducted on lakes and streams in Turkey, Türkmen and Akyurt (2000) stated b as 3.082 for females and 2.828 for males in a population *of A. mossulensis*; Yıldırım (2003) indicated that b was 3.136 for females and 2.913 for males in a population *of A. mossulensis*. Özdemir et al. (1996) stated that b was 2.046 for both sexes for *A. mossulensis* in Keban Dam Lake. In the present study, weight and length results of *A. mossulensis* were similar to those of Özdemir et al. (1996). Ünlü et al. (1994) reported b as 3.4 and 3.29 for females and males in a population *of A. marmid*, respectively (Table 10). In our study area, the exponent b was 2.065 ($r^2 = 0.95$) for females and 2.138 ($r^2 = 0.93$) for males in the *A. mossulensis* population (Student's t-test, $P < 0.05$), and the exponent b was 2.678 ($r^2 = 0.77$) for females and 2.631 ($r^2 = 0.79$) for males in the *A. marmid* population (Student's t-test, $P < 0.05$) (Table 4). This result was most probably associated with the scarcity of food and the body shape of these species in this dam lake. As the value of b increases, the size of the fish also increases, because the fish usually grows proportionately in all directions. The changes in fish weight in general are actually greater than the changes in its length. However, the body shape of fish tends to change as the length increases. The value of b then becomes greater than 3 as the fish becomes fatter; when the b value is lower than 3, the fish is slimmer (Jobling, 2002; Isa, 2010). The reproduction process (spawning and gonadal activity) and changes in food uptake could cause negative allometry in the length–weight relationship parameters (Egbal, 2011; Okgerman et al., 2012). Such variations in *b* values may depend on various factors like the number of specimens examined, condition of places of sampling, and sampling season (Karnal et al., 2012). Change in *b* values depends primarily on the shape and fatness of the species, as well as various factors like temperature, salinity, food (quantity, quality, and size), sex, and stage of maturity (Isa et al., 2010). Furthermore, the length–weight relationship in fish is influenced by a number of other factors including gonad maturity, sex, diet, stomach fullness, health, preservation techniques, season, and habitat (Karnal et al., 2012).

While asymptotic length of males was higher than that of females (L_∞ = 20.1 and 19.6, respectively) in *A. mossulensis*, asymptotic length of females was higher than that of males in *A. marmid* (L_∞ = 17.3 and 16.6, respectively; Table 4). This may be associated with the variation in growth differences between females and males, according to Froese and Binohlan (2000). In addition, a major reduction in population size may increase the relative abundance of food, which may result in faster growth and smaller asymptotic size. Mean condition factors of the *A. mossulensis* population in Karakaya Dam Lake varied between 0.54 and 1.96 for females and 0.51 and 1.31 for males. On the other hand, they were between 0.54 and 2.28 for females and 0.73 and 2.30 for males in the *A. marmid* population (Table 5). Türkmen and Akyurt (2000) found that L_∞ was 21.59 for females and 20.41 for males in the *A. mossulensis* population. In the study conducted by Yıldırım et al. (2003), L_∞ was 21.87 in females and 19.58 in males in the *A. mossulensis* population. Some differences between the growth characteristics and the length–weight variations among populations in different regions involving the same species may be caused by environmental features such as water temperature, feeding, and nourishment abundance (Nikolsky, 1963; Bartulovic et al., 2004). Condition factor may vary based on fish size, reproduction period, disease, and parasites of fish (Tesch, 1968; Bagenal, 1978; Welcomme, 2001). Table 5 shows that the somatic condition of both species increased during spring months in relation to feeding activity. Low somatic condition was found in September for both sexes; after April, the somatic condition increased again due to growth of the gonads in *A. mossulensis*. The somatic condition factors of *A. marmid* increased during spring and summer months (May and June); the lowest condition factor values were determined in October for females and in February in males. Generally, gonad development, feeding behavior, and other factors have an effect on seasonal variation of condition factors (Doddamani et al., 2001; Simon et al., 2012).

Seasonal changes in gonads and *GSI* were followed in order to determine the time of the spawning season and reproductive behavior. The *GSI* of males and females reached its peak in May in the population of *A. mossulensis* (Figure 8). On the other hand, female individuals of *A. marmid* obtained the highest mean *GSI* value in June, and males reached this value in May (Figure 9). *GSI* indicates gonadal development and maturity of fish. The difference between male and female *GSI* suggests that the energy invested in gamete production by males is probably less than that invested by females (Hacker, 1979). *GSI* and smaller size at maturity would indicate populations that show more opportunistic life history traits than others (Tarkan et al., 2012). Lengths at maturity were 12.8 cm for *A. mossulensis* and 11.4 cm for *A. marmid*. Smaller size at maturity was higher in populations from artificial waterbodies than those inhabiting running waters. Length and age at maturity, fecundity, and *GSI* are not generally factors in relative condition and oocyte size (Tarkan et al., 2012).

Although many factors complicate analysis of fecundity, frequency of spawning, oocyte size, population density, and environmental factors (Bagenal, 1978), differences among populations can be associated either with the effects of different environmental factors or differences in species (Nikolsky, 1963; Bagenal and Braum, 1978). Oocyte size and fecundity vary through the spawning season in the majority of other fish species. In this study, egg size decreased during the reproductive season, and spawning time was found to affect egg size and fecundity. The mean oocyte size reached its maximum value in May, and its minimum size was measured in September in *A. mossulensis*; the lowest and highest fecundity were during May and September, respectively (Table 9). While the mean oocyte size reached its peak value in June, its minimum size was determined in September in *A. marmid*. The lowest and highest fecundity were observed in June and September, respectively. This study considered the evaluation of oocyte size and fecundity in *A. mossulensis* and *A. marmid* in Turkey for the first time.

Consequently, the biological data of *A. mossulensis* and *A. marmid* illustrate that both species show small differences in terms of age and reproductive season in areas where these species share geographic distribution. These differences can arise from possible seasonal and environmental factors and intra- or interspecies relationships. Although these species are not economically important species, they are an important food for other fishes; they constitute a significant link in the food web of Karakaya Dam Lake for this reason. Water constitutes a crucial framework for the integrated information related to water monitoring and management as well as the sustainable economy. Water quality and biological data (fish growth and reproduction) are very important monitoring tools. This approach concentrates on measuring all the stocks relevant to water policymaking for Karakaya Dam Lake's management in the future.

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