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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Some Reproductive Characteristics of the Beysehir Dace (*Squalius anatolicus* Bogutskaya, 1997) in Oymapınar Dam Lake Antalya, Turkey [*]

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Abstract: This study was conducted in Oymapınar Dam Lake from March 2016 to February 2017. The study investigated the age composition, spawning season, sex ratio, age and length at first sexual maturity, and fecundity of Beysehir dace (*S. anatolicus*). The ages of the 422 Beysehir daces sampled from Oymapınar Dam Lake ranged from II to VIII of which 200 (47.39%) were females and 222 (52.61%) were males. The fork lengths and weights of female Beysehir daces varied between 20.0 cm and 55.1 cm and 93.37 g and 2307.88 g respectively. The oldest age group was VIII for females and VII for males. The length at first sexual maturity for females and males were 26.0 cm and 23.0 cm, respectively and the age at first sexual maturity for females and males were III and II, respectively. This shows that males mature earlier than females. Monthly gonadosomatic index values showed that the peak spawning period for Beysehir daces was between April and June. The fecundity (F) - length relationship of *S. anatolicus* was LogF = -0.44697 + 3.33868 * LogL (R^2 = 0.7168). The mean egg diameter of *S. anatolicus* was 0.93 mm and the average fecundity was 78408.

Keywords: Beysehir freshwater mullet, oymapınar dam lake, reproduction, sexual maturity, *Squalius anatolicus*.

Oymapınar Baraj Gölü'ndeki (Antalya, Türkiye) Beyşehir Tatlısu Kefalinin (*Squalius anatolicus* Bogutskaya, 1997) Bazı Üreme Özellikleri

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Öz: Bu çalışmada; Oymapınar Baraj Gölü'nden Mart 2016 - Şubat 2017 tarihleri arasında örneklenen Beyşehir tatlısu kefalinin (*S. anatolicus*)'nin yaş kompozisyonu, yumurtlama zamanı, eşey oranları, ilk eşeysel olgunluğa erişme boyu ve yaşı, fekonditesi araştırılmıştır. Oymapınar Baraj Gölü'nden örneklenen 422 Beyşehir tatlısu kefalinin yaşları II-VIII arasında dağılım göstermiş, Örneklerin % 47,39'nu dişiler, % 52,61'ini erkekler oluşturmuştur. Dişilerin çatal boylarının 20,0 cm ile 55,1 cm arasında, ağırlıklarının ise 93,37 g ile 2307,88 g arasında değiştiği saptanmıştır. En büyük yaş dişiler için VIII, erkekler için VII olarak belirlenmiştir. İlk eşeysel olgunluk boyu dişi ve erkek Beyşehir tatlısu kefali bireylerinde sırasıyla 26,0 cm ve 23,0 cm olarak hesaplanmıştır. İlk eşeysel olgunluk yaşı dişi bireyler için III, erkek bireyler için ise II olarak bulunmuştur. Bu, erkeklerin dişilerinden daha erken olgunlaştığını göstermektedir. Aylık gonadosomatik indeks değerleri, yumurtlama zamanın yoğun olarak Nisan-Haziran ayları arasında olduğunu göstermiştir. Fekondite (F) - boy ilişkisi, LogF=-0,44697+3,33868*LogL (R^2 =0,7168) olarak saptanmıştır. Ortalama yumurta çapının 0,93 mm ve ortalama yumurta veriminin 78408 adet/birey olduğu belirlenmiştir.

Anahtar kelimeler: Beyşehir tatlısu kefali, eşeysel olgunluk, oymapınar baraj gölü, *Squalius anatolicus*, üreme.

[*] *This study was produced from the master thesis.*

INTRODUCTION

Dam lakes, which have been constructed for irrigation, hydroelectric energy, flood protection, fishing, drinking and irrigation water purposes in many regions of Turkey play an important role in aquaculture production. In addition, the reservoirs formed behind the dams possess important potential in terms of sport and commercial fishing. Closing the river with a set causes extremely important changes to occur in terms of living creatures in the environment (Kırankaya & Ekmekçi, 2007). Oymapınar Dam Lake, which constitutes the research area of this study is one of the dam lakes established to provide hydroelectric power generation, drinking and irrigation water in Turkey.

The fact that the dams and ponds in Turkey have a great potential in terms of aquaculture has revealed the need to evaluate the areas from this perspective, and biological studies on fish species in many dams and natural lakes have increased. There are very few biological studies on the Beysehir dace population in the different dam lakes of Turkey. The few studies from the lakes and dam lakes of Turkey on the growth, reproduction age and condition factors of chubs are reviewed in this study. However, in Oymapınar dam lake, there has not been any work related to fisheries. There is no information on the reproductive biology of Beysehir dace in Oymapınar dam lake. Due to this, there is no information on the changes in the reproductive characteristics, reasons for the increase or decrease in the population of Beysehir daces in Oymapınar dam lake.

Therefore, the purpose of this study was to determine some reproductive characteristics of *S. anatolicus* in the Oymapınar dam lake monthly for one year, and establish baseline data on the sex ratio, fecundity, age, and length at first sexual maturity, and spawning seasons of Beysehir dace population in Oymapınar Dam Lake. The knowledge of fish reproductive biology is very important for the rational utilization of fish stocks and their sustainable production (Cochrane, 2002; Temesgen, 2017). Understanding the reproductive aspects of fish is also very important for providing sound scientific advice in fishery management (Hossain et al., 2017; Khatun et al., 2019; Tessema et al., 2020). The findings of this study will contribute to future studies and measures to be implemented in fisheries management studies in terms of determining and evaluating the status and design management strategy for the population of Beysehir daces in the Oymapınar dam lake.

MATERIALS AND METHODS

Study Area and Fish Sampling: The study was conducted in Oymapınar dam lake. Oymapınar dam lake is in the district of Manavgat, Antalya Province, in southern Turkey. Oymapınar dam lake, which is 76 km away from Antalya province, is a dam lake built on the Manavgat river between 1977-1984 to generate electrical energy. The dam, which is a concrete arch type, has a body volume of 575,000 m^3, a height of 185 m from the stream bed, a lake volume of 300.00 hm^3 at normal water elevation, and a lake area of 4.70 km^2 at normal water elevation Aykurt & Altınok, (2009). Oymapınar dam lake produces 1620 GWh of electrical energy per year with a hydroelectric power plant with a power capacity of 540 MW (Anonymous, 2021). The lake lies between latitude 36.908628°N and longitude 31.531694°E in the Antalya province of Turkey.

Fish samples were collected from March 2016 to February 2017. A total of 422 Beysehir daces were sampled using 100 m long and 2.5 m depth monofilament gillnets (20, 30, 40, 50 mm mesh size) from seven stations across different parts of the Oymapınar dam lake. The random sampling method was applied in this study. The nets were thrown and collected the next day.

Determination of some Reproduction Characteristics of Beysehir Daces

***Sex Ratio*:** The sexes of the sampled fish were determined by opening the abdominal regions with the help of a dissecting scissors and macroscopic and microscopic examination of the gonads. The ovaries and testes maturities were evaluated based on milky white, smooth surface gonads testis, granular surface, yellowish colours (Karataş et al., 2005).

Maturity Estimation: The age and length at first sexual maturity, according to the maturity ratio of the fish in the spawning period was evaluated using the logistic regression model:

$P= 1/[1+\exp^{(-r(L-Lm)}]$ and $P= 1/[1+\exp^{(-r(t-tm)}]$.

"P" in the equation shows the sexual maturity rates (%) of each length and age group, "L" is the average length of each age group (cm), "Lm" is the first sexual maturity length, "t" is the age group, "tm" refers to the age at first sexual maturity, "r" refers to the curve of the logistic function (Ricker, 1973).

***Spawning Season*:** The spawning seasons of Beysehir daces were determined based on monthly variations of the gonadosomatic index (GSI). The GSI value was calculated using Ricker's (1975) equation: GSI= (GW/W)*100

In the equation, "GW" indicates gonad weight, "W" indicates body weight. The spawning season was determined from the monthly GSI values.

Egg Diameter: Eggs taken from the gonads of mature fish that did not shed their eggs during the breeding period were used to measure the egg diameter. The gonads of the dissected individuals were removed, weighed, and stored in 4% formaldehyde solution. Ten eggs were taken from mature ovaries from the anterior, middle, and posterior parts of the gonads, and their diameters were measured by taking photographs with the SOIF MD30 branded imaging microscope with the help of the M-shot v1.0 computer software.

Fecundity: Egg yield (Fecundity) was determined gravimetrically (Bagenal & Tesch, 1978), by counting the number of eggs in the ovaries of mature fish that did not shed their eggs during the spawning period. The exponential relationship between fecundity and length ($F = a.L^b$) was converted into a linear equation by taking the Ln of both sides of the equation, and the fecundity (F)-length relation (L) was determined using the equation:

$LogFL = Loga + b * LogL.$

The linear relationship between fecundity (F) and weight (W), and fecundity (F) and age (A) was determined using the formulas: $FW = a + b * W$ and $FA = a + b * A$, respectively (Avşar, 2005).

Data Analysis: Descriptive statistics (frequency, percentages, graphs, and tables) and chi-square (χ^2) test were used to compare the number of males and females in age groups (Düzgüneş et al., 1987; Kaptan, 1995).

IBM SPSS Statistics 21 for Windows" package program and (FİSAT II) (Gayanilo et al., 1996) were used to summarize the collected data. P = 0.05 confidence limit was used for statistical significance control. All means are given with ± standard errors (SE).

In groups with two or more independent groups, the homogeneity of the variances of the data before the t-test was performed with the Levene's test, and before the t-test, to see whether the data showed normal distribution, the data were tested with the Kolmogorov-Smirnov (K-S) test. In cases where the t-test could not be performed, the Mann-Whitney U Test, an alternative nonparametric test, was used.

RESULTS

Population Structure

Age and Sex Distribution: The age of the 422 Beysehir daces sampled from Oymapınar Dam Lake ranged from age group II to VIII, of which 200 (46.39%) were females and 222 (52.61%) were males. The ratio of females to males was 0.90: 1.00. The most dominant age group in the population, in both sexes, was age group II. Sex distributions according to age groups are given in Figure 1. The Chi-square (χ^2) test analysis showed that the differences between all age groups and the sex ratio of Beysehir daces were not statistically significant ($P \geq 0.05$).

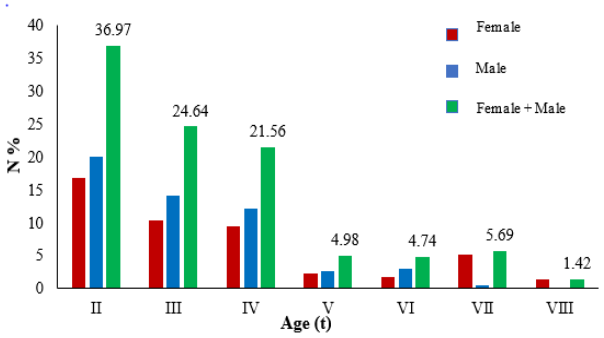

Figure 1. Sex distribution of Beysehir dace by age group (N %).

Length Distribution: The fork lengths of the 422 Beysehir daces sampled from Oymapınar Dam Lake, ranged between 20 cm and 55.1 cm, and individuals in the 26 cm and 30 cm length groups were found to predominate in the population with a total rate of 47.16% (Figure 2). The fork lengths of the female fish varied between 20 cm and 55.1 cm, and the fork lengths of the male fish ranged from 20 cm to 51 cm.

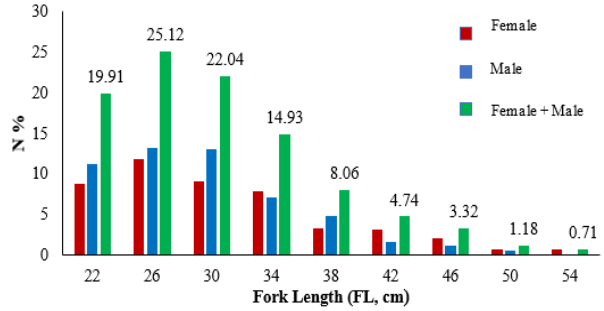

Figure 2. Length distribution of Beysehir dace by sex group (N %).

Reproduction in the Population

***Age and length at First Sexual Maturity*:** For the age and length of Beysehir dace at first sexual maturity, 184 individuals sampled between March and June 2016 were taken into consideration. The maturation rates by age groups and the length range of the Beysehir dace sampled from Oymapınar Dam Lake are given in Table 1 and Table 2, respectively. The age distribution in the examined female Beysehir dace samples showed that 19 % of age group II were sexually matured, 80 % of age group III were sexually matured, 79 % of age group IV were sexually matured while all individuals belonging to higher age groups were sexually matured. While for the examined male Beysehir dace samples, 66% of the age group II were sexually matured, 94 % of age group III were sexually

matured and all individuals belonging to higher age groups were sexually matured.

When the maturation rates of Beysehir dace samples were examined according to length groups, it was observed that female individuals reached sexual maturity from 26 cm length and male individuals from 23 cm length (Table 1). The application of the sigmoid logistic curve model to the rate at which male and female individuals reach sexual maturity, the length (Lm_{50}) at which 50 % of the females got to maturity was 25.51 cm. Sigmoid curves created using the formula:

$$P(L) = 100 / [1 + \exp(-0{,}417 * (L-25{,}51)]$$

The length at which 50% of the male individuals reach maturity (Lm_{50}) was 23.35 cm and the sigmoid curve formula is given as:

$$P(L) = 100 / [1 + \exp(-0.154 * (L-23.35))]$$ as given in Figure 3.

Table 1. Maturation rates of Beysehir dace samples by age groups.

		Age						
		II	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Female	**N**	16	30	14	6	6	11	2
	N %	19	80	79	100	100	100	100
Male	**N**	38	32	23	1	4	1	-
	N %	66	94	100	100	100	100	-

Table 2. Maturation rates of Beysehir dace samples by length ranges

		Length (cm)												
		21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34≥**
Female	**N**	-	4	1	3	7	4	7	6	4	7	4	2	6	30
	N	-	0	0	33	29	50	71	83	50	100	100	100	83	100
Male	**N**	3	4	7	9	11	8	5	9	5	6	6	5	4	17
	N	0	0	57	55	100	100	100	78	100	100	100	100	100	100

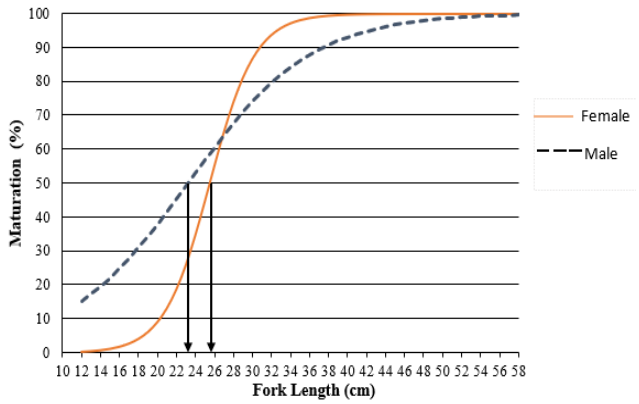

Figure 3. The logistic curve showing the maturity of 50% of female and male Beysehir dace.

***Spawning Season*:** The spawning season was determined by monitoring the average gonadosomatic index values (GSI) of mature fish monthly. Gonad's development was determined by microscopic examination of the ovary and testicles (Figure 4a, b). The monthly average gonadosomatic index values of female and male Beysehir daces are given in Table 3. Table 3 shows that the female Beysehir daces reached the highest GSI value (3.32) in April. The values started decreasing from May and the lowest recorded GSI value of 1.20 was in June (Table 3). In male Beysehir dace, the GSI values was highest in March (4.02) and started decreasing from April till the lowest recorded GSI value of 0.78 in June Table 3.

Table 3. Monthly average GSI values of Beysehir dace.

Months	Female				Male			
	N	GSI ± SE	min	Max	N	GSI ± SE	Min	max
March 2016	13	3.14±0.72	0.41	7.98	16	4.02±0.54	0.77	7.65
April 2016	42	3.32±0.59	0.33	15.84	36	3.13±0.41	0.31	8.81
May 2016	18	2.26±0.42	0.54	6.84	25	1.74±0.31	0.24	5.03
June 2016	11	1.20±0.40	0.44	5.17	22	1.05±0.12	0.31	2.27
July 2016	8	0.73±0.10	0.49	1.35	15	0.72±0.05	0.21	1.20
August 2016	12	0.96±0.12	0.57	2.16	16	0.78±0.05	0.38	1.09
September 2016	17	1.12±0.17	0.18	3.42	20	1.09±0.13	0.42	3.05
October 2016	17	1.06±0.17	0.17	2.74	21	0.94±0.10	0.19	2.39
November 2016	26	1.79±0.31	0.19	5.46	24	1.16±0.16	0.18	2.92
December 2016	15	2.00±0.49	0.54	6.36	12	2.14±0.26	0.19	3.72
January 2017	12	1.39±0.57	0.19	7.06	3	2.69±0.11	2.51	2.90
February 2017	8	2.30±0.54	0.56	4.46	12	2.50±0.36	0.42	4.86

***Egg Diameter*:** The monthly egg diameter (mm) of 42 female Beysehir daces in the breeding period are given in Table 4. The largest mature egg diameter measured was in April (1.39) while the smallest mature egg diameter measured was in February (0.66).

Table 4. Monthly measured mean, minimum and maximum egg diameter values (mm) of Beysehir daces during the spawning season.

Months	**N**	**Egg diameter ± SE**	**Min**	**Max**
March, 2016	8	0.93±0,08	0.70	1.38
April, 2016	13	1.09±0,06	0.84	1.39
May, 2016	6	0.96±0,05	0.78	1.08
June, 2016	1	1.22	1.22	1.22
November, 2016	6	0.71±0,05	0.54	0.87
December, 2016	3	0.75±0,06	0.68	0.87
January, 2017	1	0.87	0.87	0.87
February, 2017	4	0.78±0,05	0.66	0.92
Total	42	0.93±0,03	0.54	1.38

Egg yield (Fecundity): The fecundity (F) was determined by counting the eggs in the ovaries of 42 mature Beysehir daces. The total number of eggs in individual Beysehir dace varied between 16116 and 208134. The relative egg yields of female Beysehir daces, whose eggs were counted varied according to age, fork length and body weight as shown in Table 5. It was observed that the egg yields and the number of eggs per unit length (F/FL) increased with age except for age group VI. The relationships between total egg number and fork length, body weight and age and the regression curves of these relationships are presented in Figure 4, Figure 5, and Figure 6.

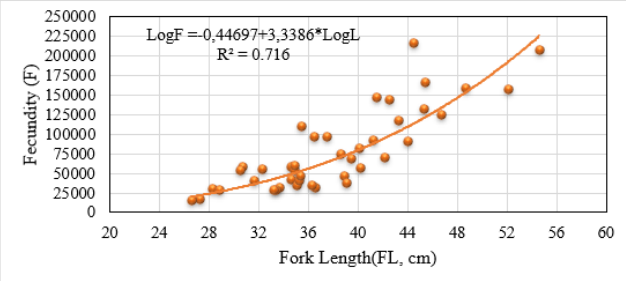

Figure 4. Fecundity-fork length relationship of Beysehir dace.

Table 5. Relative egg yields of Beysehir dace determined by age, fork length and body weight.

Age	N	FL ± SE (min - max)	W ± SE (min - max)	F ± SE (min – max)	F/FL ± SE (min - max)	F/W ± SE (min - max)
III	5	28.30 ± 0.93 (26.60-30.50)	307.79 ± 25.74 (255.59-380.00)	29306 ± 6750 (16116-53776)	1016 ± 208 (606-1763)	92 ± 93 (60-142)
IV	12	33.70 ± 1.03 (30.70-35.50)	489.39 ± 66.77 (387.57-597.02)	50349 ± 6496 (28458-115139)	1489 ± 182 (853-3114)	102 ± 11 (57-185)
V	6	36.26 ± 1.78 (35.30-37.30)	671.76 ± 67.05 (546.67-776.31)	58084 ± 12415 (31675-96875)	1593 ± 329 (865-2469)	86 ± 15 (41-136)
VI	4	39.02 ± 2.40 (38.60-39.50)	824.42 ± 117.26 (773.46-880.75)	57191 ± 8824 (38184-74760)	1466 ± 227 (977-1937)	70 ± 11 (97-279)
VII	12	43.70 ± 2.00 (40.10-46.70)	1128.98 ± 97.27 (921.55-1450.98)	120086 ± 13021 (57221-216801)	2767 ± 282 (1423-4872)	105 ± 9 (62-165)
VIII	3	51.80 ± 6.06 (48.70-54.60)	1927.44 ± 406.68 (1535.22-2158.34)	174710 ± 16730 (156643-208134)	3364 ± 236 (3007-3812)	92 ± 8 (75-104)

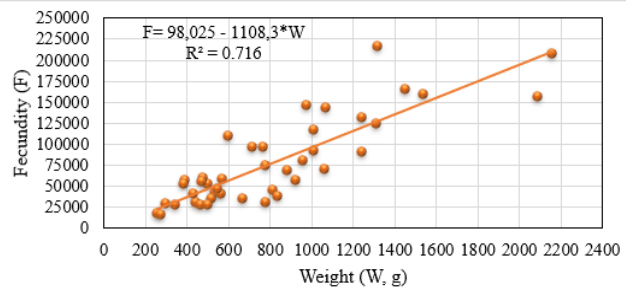

Figure 5. Fecundity-weight relationship of Beysehir dace.

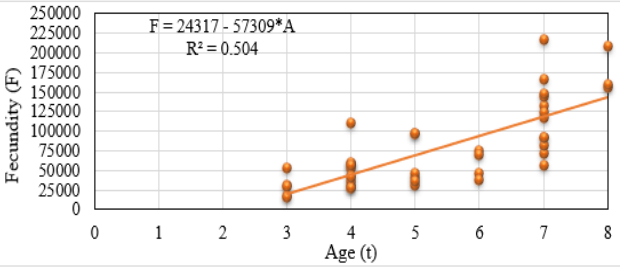

Figure 6. Age-fecundity relationship of Beysehir dace.

DISCUSSION

The study was conducted to determine some reproductive characteristics of 422 Beysehir daces (*Squalius anatolicus* Bogutskaya, 1997) in Oymapınar Dam Lake. This is the first report on the reproduction of *S. anatolicus* in Oymapınar Dam Lake and will be used as basic and baseline information. The age groups of the sampled individuals varied from II-VIII. Due to the mesh opening of the fishing gear used, 0 and I age groups of fish were not caught. The result of this study showed that the predominant age group in the population of Beysehir daces in Oymapınar Dam Lake was age group II (36.97%), this was followed by age group III and IV with 24.64% and 21.56%, respectively. In both female and male Beysehir daces, age group II predominated the population (Female 16.82%, Male 20.14%).

However, the oldest recorded age group in this study for females was VIII and VII for males. Kara and Solak reported an age range of I-VI for the chub population in Keban Dam Lake Turkey while Demirol et al., (2016) reported an age range of 0 – XI for the chub population in Uzunçayır Dam Lake Turkey. In the present study, 47.39% of the Beysehir dace in Oymapınar Dam Lake are females and 52.61% are males. The sex ratio (F: M) in this study was 0.90:1.10. The chi-square (χ^2) test analysis did not show any significant differences between all age groups and the sex ratio of Beysehir dace ($P \geq 0.05$). This result agrees with the report of Tümgelir et al., (2007) which recorded a higher male to female ratio (1:1.31) for the population of chubs in Lake Beyşehir, Turkey. The higher male ratio reported in this study is also in agreement with the findings of Demirol et al., (2016) for the chub population in Uzunçayır Dam Lake with a male/female ratio of 1:0.95. Balık et al., (2004) also reported a lower female to male ratio 40.72% for females and 59.28% for males in Işıklı Lake, Turkey. But the findings of this study disagree with the report of 72.89% for females and 27.1 l% for males, giving a female to male ratio of 2.69:1.00 in Topçam Dam Lake, Turkey (Şaşı & Balık, 2003), 55.06% for females and 44.95% for males in Sır Dam Lake, Turkey by Kara & Solak, (2004), 59.80 % female and 40.20 % male in Keban Dam Lake, Turkey by Aydın et al., (2015). The proportion of the various age groups in a population gives an important idea about the reproductive power of the population and the future status of the population (Nikolsky, 1963; King, 2007).

In the Beysehir dace samples in Oymapınar Dam Lake, maturation rates were examined based on length and age groups, it was observed that the females get to sexual maturity from 26 cm and males get to sexual maturity from 23 cm. The males attain sexual maturity from age II while the females attain sexual maturity from age III. In the studies by Kara & Solak, (2004) in Sır Dam Lake and Kılıç, (2011) in Yeniçağa Lake, it was reported that both females and males attained sexual maturity at age II. Nikolsky, (1963) stated that the age at first sexual maturity varies depending on water temperature, nutrition, growth rate and population density and that the growth rate of males in the first years is higher than females which might make the males reach sexual maturity one or two years earlier than females.

Appropriate identification of the maturity status of fishes is a fundamental strategy for the appropriate management of exploited stocks in the fishery and is a

commonly used tool by fisheries' biologists and managers (Rahman et al., 2018). The monthly average GSI values of males and females were high from February to June and were highest in April. The lowest and highest GSI values were 0.73 and 3.32 for females and 0.72 and 4.02 for male *S. anatolicus*. The spawning season for Beysehir daces in Oymapınar Dam Lake from this study is between April and June which falls within the highest GSI values recorded in this study. This is in close agreement with the studies conducted in Sır Dam Lake by (Kara & Solak, 2004) and Yeniçağa Lake by Kılıç, (2011), that reported the spawning seasons of chubs in these lakes to be between April and July. The spawning season of the species belonging to the *Squalius* genus may vary according to the regions and species. In a study conducted by Herzig & Winkler, (1986), the spawning period for Beysehir dace was found to be between April-May and it was stated that if the altitude is more than 1000 m, the spawning season may extend to June (Ekmekçi, 1996).

Knowledge of the fecundity of fish is important to examine the potential of its stocks, life history, practical culture, and actual management of the fishery (Islam et al., 2012). The range and mean fecundity of *S. anatolicus* in Oymapınar Dam Lake varied between 16116-53776, 29306 ± 6750 for age group III to 156643-208134, 174710 ± 16730 for age group VIII fish, respectively with an average fecundity of 78408. These values were greater than the fecundity range of 2,100-66,400 per female for chub in Topçam Dam Lake (Şaşı 2004). The mean fecundity correlated positively with the age group and fork lengths of the fish. Ekmekçi, (1996), and Erdoğan et al., (2002) also reported a positive correlation between the age group, fork length and fecundity. In these investigations, it is reported that fecundity increased, as fish length, weight, age, and gonad weight increased. Fecundity is affected by age, size, species, feeding, season, and environmental conditions (Nikolsky, 1969).

The mean egg diameters of *S. anatolicus* in Oymapınar Dam Lake varied between 0.71 mm and 1.22 mm with a mean value of 0.93 mm. The largest mean egg diameter was recorded in June while the smallest was recorded in November. The egg diameter values recorded in this study is in line with Türkmen, (1999) that reported a mean egg diameter of 0.92 to 1.45 for chubs in River Aras. The findings of this study are also close agreement with that of Kılıç & Becer, (2016) for the chub population in Lake Yeniçağa. The egg diameter of a fish might vary with the fish length, weight, age, and gonad weight (Şaşı, 2004). One of the most important parameters used to define reproductive potential is the variation of egg diameter in the ovaries. Nikolsky, (1963) stated that egg diameter may be related to the amount of food that females can metabolise.

CONCLUSION

This study is important as it was the first research on the reproductive biology of *S. anatolicus* in Oymapınar Dam Lake. The reproduction status of Beysehir dace in Oymapınar Dam Lake was good. The fecundity of Beysehir dace in Oymapınar Dam Lake was higher compared to those in other Turkish lakes and dam lakes which could be due to nutritional, environmental, or climatic factors associated with the different areas where the lakes and dam lakes are located. Furthermore, Beysehir daces have extended spawning seasons in Oymapınar Dam Lake (April - June). Therefore, during this spawning season, there should be a closed fishing season for Beysehir daces in Oymapınar Dam Lake. Long-term monitoring on reproduction potential, spawning season, and population status of Beysehir dace should be done for sustainable fishery utilization in Oymapınar Dam Lake.

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