

Reproduction Properties of Pike (*Esox lucius* L., 1758) Population in Lake Karamık (Afyonkarahisar/Turkey)

İsmet BALIK, Hıdır ÇUBUK, Remziye ÖZKÖK, Rahmi UYSAL
Fisheries Research Institute, 32500 Eğirdir, Isparta - TURKEY

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Abstract: In this study, the spawning period, length at first sexual maturity and fecundity of the pike (*Esox lucius* L., 1758) population in Lake Karamık between March 2002 and February 2003 were investigated. Mean length at first reproduction (L_m) was determined as 19.7 cm for female pike. The monthly values of the gonadosomatic index indicated that spawning occurred between February and March. The relative fecundity was determined as 45.7 ± 4.9 eggs g^{-1} total body weight. Fecundity (F) – fork length (L) and Fecundity – weight (W) relationships were estimated as $F = 2.8963 L^{2.3722}$ ($r = 0.590$) and $F = 58.998 W^{0.9354}$ ($r = 0.668$), respectively. Mean egg diameter was 2.08 ± 0.07 mm.

Key Words: Lake Karamık, pike, spawning period, sexual maturity length, fecundity.

Karamık Gölü'ndeki (Afyonkarahisar/Türkiye) Turna (*Esox lucius* L., 1758) Populasyonunun Üreme Özellikleri

Özet: Mart 2002 ile Şubat 2003 tarihleri arasında Karamık Gölü'nde yapılan bu çalışmada turna (*Esox lucius* L., 1758) populasyonunun üreme periyodu, ilk eşeyssel olgunluk boyu ve yumurta verimi (fekondite) araştırılmıştır. Dişi turnalar için ilk eşeyssel olgunluk boyu (L_m) 19,7 cm olarak belirlenmiştir. Aylık gonadosomatik indeks değerleri, yumurtlama zamanının Şubat ve Mart ayları olduğunu göstermiştir. Göreceli fekondite $45,7 \pm 4,9$ yumurta g^{-1} total vücut ağırlığı olarak tespit edilmiştir. Fekondite (F) – çatal boy (L) ve Fekondite - ağırlık (W) ilişkileri sırasıyla $F = 2,8963 L^{2,3722}$ ($r = 0,590$) ve $F = 58,998 W^{0,9354}$ ($r = 0,668$) olarak hesaplanmıştır. Ortalama yumurta çapı ise $2,08 \pm 0,07$ mm'dir.

Anahtar Sözcükler: Karamık Gölü, turna balığı, üreme periyodu, eşeyssel olgunluk boyu, yumurta verimi.

Introduction

Pike (*Esox lucius* L., 1758) are large keystone piscivores that are important for predatory regulation of fish populations. They can tolerate a wide range of environmental conditions. Pike prefer primarily to shallow cool-waters which has productive and mesotrophic-eutrophic environments (Casselman and Lewis, 1996). This species is a species that inhabits the Northern Hemisphere and it has a large distribution area (Lenhardt and Cakić, 2002). It has been reported that in Anatolia, pike lives in Sakarya and Seyhan Rivers, in Lakes Küçükçekmece, Sapanca, Manyas, Uluabat, Eber, Çivril (Demirsoy, 1988; Geldiay and Balık, 1988), Mogan (Tanyolaç and Karabatak, 1974), Akşehir (Karabatak, 1982) and in Kesikköprü Dam Lake (Altındağ et al., 1999). However, in recent years pike disappeared in Lake Akşehir.

Pike has rather high economic importance for inland fisheries of Turkey. The annual catch of this species in Turkey was 237 t in 2003 (Seçer et al., 2005). Many studies have been carried out to determine the various biological characteristics of pike in the different habitats (Karabatak, 1982 and 1995; Altındağ et al., 1999; Çubuk et al., 2000-2001; İlhan and Balık, 2003). Pike is also the most important fish species in Lake Karamık. Despite of its economical importance, there is no adequate recent information about biological characteristics of pike population in this lake. Some biological characteristics of pike population in Lake Karamık were investigated by Aksun (1987a and 1987b) and Aksun and Kuru (1987) between 1982 and 1984. In addition, zooplanktons, the water fleas fauna and planktonic Bacillariophyta of Lake Karamık were investigated by Gündüz (1984), Gündüz (1987) and Şen

et al., (1994), respectively. At the beginning of 1980s, Seka Paper Factory was constructed near Lake Karamık and its wastewaters have been discharged to the lake since that time. Therefore, the water of this lake has been gradually polluted since the beginning of 1980s (Gündüz, 1984; Şen et al., 1994). Fish populations may be negatively affected due to pollution of the lake water. However, there is no information about its effects on fish populations in this lake.

The aim of this study was to determine some reproduction properties such as the spawning period, length at first sexual maturity and fecundity of the population of pike in Lake Karamık.

Materials and Methods

Lake Karamık is located in the southeast of the city of Afyonkarahisar, in the west of central Anatolia region of Turkey. The lake has a surface area of 38 km² and is at an altitude of 1067 m. The mean depth of Lake Karamık is about 2-3 m. Most of surface area of the lake is covered by vegetation, and it is an eutrophic lake (Gündüz, 1984). Beside pike, many other fish and crustacean species also live in the lake (Gündüz, 1984). These species are *Cyprinus carpio* (common carp and mirror carp), *Alburnus orontis*, *Gambusia affinis*, *Cobitis turcica*, *Knipowitschia caucasica* and *Astacus leptodactylus*.

During the study, a total of 1097 (737 male and 360 female) pike were collected at the three different localities of Lake Karamık (Figure 1) in 2002 and 2003. Specimens were caught monthly with gillnets in mesh sizes (stretched mesh) of 36, 40, 44, 50, 60, 70, 80 and 90 mm, and trammel nets in mesh size of 100, 120, 140 and 160 mm. The fork length ($L \pm 1$ mm) and weight ($W \pm 1$ g) of each specimen were recorded. Determination of sex was accomplished by macroscopic examination of gonads. Sexual maturity was determined by observation of the stages of maturation of gonads. The ovaries were removed and weighed to the nearest 0.1 g. Thereafter they preserved in 4% formaldehyde to determine fecundity and egg diameter.

Spawning period was established with monthly variations of the gonadosomatic index (GSI). GSI was calculated monthly by the equation:

$$GSI = W_g / (W_t - W_g) * 100$$

Where; W_g and W_t are gonad weight and total weight in grams of fish, respectively. Condition factor was calculated using the equation $K = (W/L^3) * 100$ (Ricker, 1975).

The method used to estimate the maturity ogive of mature females was based on fitting of the sigmoid, logistic curve. Estimation of the length at first sexual maturity is as follows (Skúladóttir, 1998; DeMartini et al., 2000):

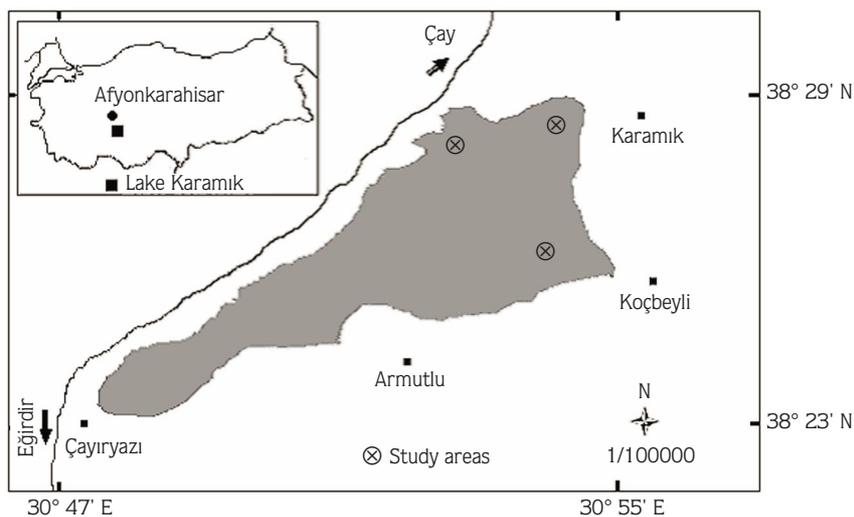


Figure 1. Map of Lake Karamık showing the study areas.

Firstly, it was plotted L against $\ln [(1-P_x)/P_x]$ using simple linear regression to estimate values for a and b . Where P_x is the observed proportion of mature at length x .

Secondly, the mean lengths at 50% maturity was calculated by $L_m = -a/b$.

Thereafter, the estimated proportions of mature at length L were calculated using the equation $P_L = 100/[1 + e^{b*(L-L_m)}]$ and ogive of first sexual maturity was drawn. Where P_L is the estimated proportion of mature at length L .

Fecundity was estimated using gravimetric method described by Bagenal (1978). Fecundity (F) – fork length (L) and Fecundity – weight (W) relationships were calculated by the least-squares method. The diameters of eggs taken from fish samples of various sizes caught in February and March were measured by micrometer of profile projector.

Difference of observed and calculated percentages of mature fish for different lengths was tested by χ^2 -test. The comparison of the monthly GSI values was carried out by analysis of variance (ANOVA), while the LSD test was used to compare months (Yurtsever, 1984). Correlation coefficients of fecundity – length and fecundity - weight relationships were tested by t -test (Elbek et al., 2002).

Results

Spawning period

During the study, a total of 1097 pike samples were examined. The ages of the samples ranged from I to VI for males and from I to VII for females. The number, mean length, weight and condition factor of pike in each age for both sexes were given in Table 1. In addition, the length distribution of pike samples was shown in Figure 2.

Monthly variations of the mean GSI, K and temperature values were given in Table 2. Monthly

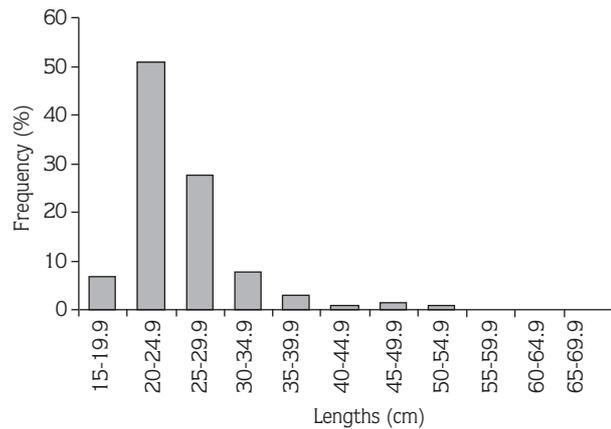


Figure 2. Length distribution of pike samples.

Table 1. The number (n), the mean length (L), weight (W) and condition factor (K) of pike in each age group for male, female and combined sexes (\pm Standard Error).

		Age groups				
		I	II	III	IV	V
Male	n	464	216	40	6	10
	L	22.2 ± 0.1	26.7 ± 0.2	35.2 ± 0.5	42.3 ± 1.8	49.5 ± 0.6
	W	89 ± 1	157 ± 3	349 ± 18	660 ± 93	1079 ± 53
	K	0.792 ± 0.003	0.807 ± 0.004	0.848 ± 0.015	0.843 ± 0.028	0.883 ± 0.016
Female	n	164	147	28	11	9
	L	22.5 ± 0.2	27.6 ± 0.2	35.9 ± 0.5	43.6 ± 1.4	50.4 ± 0.7
	W	93 ± 2	170 ± 4	356 ± 18	859 ± 77	1212 ± 48
	K	0.821 ± 0.006	0.827 ± 0.006	0.845 ± 0.013	0.909 ± 0.023	0.936 ± 0.030
Combined sexes	n	628	363	68	17	19
	L	22.3 ± 0.1	27.2 ± 0.1	35.5 ± 0.4	43.1 ± 1.1	50.0 ± 0.5
	W	91 ± 1	166 ± 3	370 ± 13	734 ± 59	1139 ± 38
	K	0.800 ± 0.003	0.815 ± 0.004	0.847 ± 0.010	0.886 ± 0.019	0.908 ± 0.017

variations in the GSI of female pike revealed that gonad development was nearly equal between May and July. It increased slowly from August to November. After November, the GSI showed a sharp increase until February when water temperature was 4 °C. Then it decreased sharply again from February to April (Figure 3). In April, all the ovaries were spent and only a few remaining eggs were observed. The water temperature in this month was 14 °C. The mean GSI from December to March were statistically different ($P < 0.05$) from all the other months. Differences of the GSI values between December-January, December-February, January-February, January-March and February-March were also significant ($P < 0.05$). On the other hand, no significant difference was found ($P > 0.05$) between December and March. Differences of the GSI values from April to November were not statistically significant ($P > 0.05$) with each others. According to trend of the GSI values, spawning would be occurred between February and March.

The mean condition factor in winter was lower than the other seasons. No relationship was found among monthly variations of GSI and K values.

Length at first maturity

Sexual maturity for female pike in Lake Karamik began at about 18 cm fork length. The rate of mature females in this length was about 30%. This rate increased

Table 2. Monthly variations of the mean GSI, K and temperature.

Months	GSI ± CI	K ± CI	Temperature (°C)
May	0.51 ± 0.11	0.805 ± 0.016	18
June	0.63 ± 0.15	0.860 ± 0.024	20
July	0.52 ± 0.06	0.858 ± 0.035	24
August	0.72 ± 0.14	0.832 ± 0.021	24
September	1.07 ± 0.15	0.857 ± 0.022	20
October	1.37 ± 0.20	0.823 ± 0.029	14
November	1.34 ± 0.23	0.813 ± 0.059	11
December	4.47 ± 1.59	0.784 ± 0.062	3
January	7.39 ± 1.51	0.790 ± 0.029	4
February	11.94 ± 1.81	0.781 ± 0.036	4
March	5.47 ± 4.02	0.817 ± 0.050	7
April	0.38 ± 0.13	0.869 ± 0.012	14

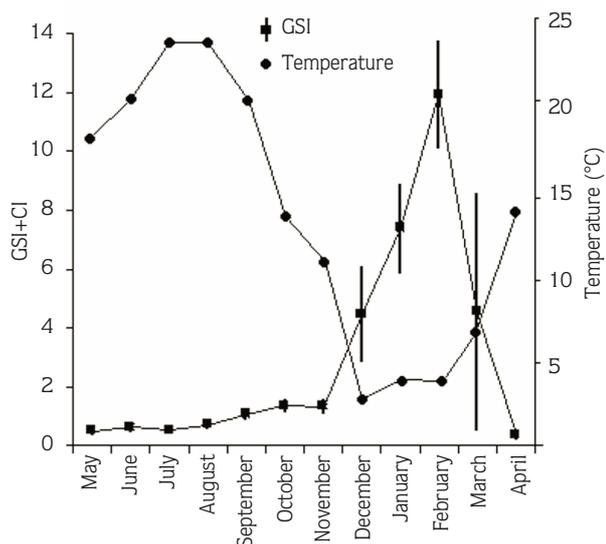


Figure 3. Monthly variations in the GSI of female pike in Lake Karamik.

to 95.7% in the 24 cm length. All of individuals greater than 24 cm long were mature. According to observed percentages of mature fish for different lengths, 50% of female pike was mature at length between 19 and 20 cm (Table 3). In addition, the length of female pike at 50% maturity was determined as 19.7 cm from $L_m = -11.768 / -0.597$ equation. Thereafter, percentages of mature fish for different lengths were calculated using the formula $P_L = 100 / [1 + e^{-0.597 * (L - 19.7)}]$ and then the maturity ogive (Figure 4) was drawn from these values. Difference between observed and calculated percentages of mature fish for different lengths was not statistically significant ($\chi^2 = 3.691$, d.f. = 4, $P = 0.4495$). During the study, length of the smallest male pike captured in the experimental nest was 17 cm and all of them were mature. Therefore, in this study first sexual maturity size for male pike in Lake Karamik could not be determined.

Fecundity

Fecundity was estimated in 58 females captured just prior to spawning. According to age groups, the number, the mean length, weight and relative fecundity of fish samples were given in Table 4.

The weight of specimens ranged between 87-549 g and their average weight was 210.3 ± 92.3 (\pm SD) g. The egg numbers of these specimens ranged from 2033

Table 3. Percentages of mature female pike by lengths.

Length (cm)	Immature	Mature	Total	% of mature fish
17	4	0	4	0
18	5	2	7	28.6
19	5	4	9	44.4
20	12	15	27	55.6
21	10	15	25	60.0
22	5	27	32	84.4
23	1	22	23	95.7
24	6	31	37	83.8
25	0	34	34	100

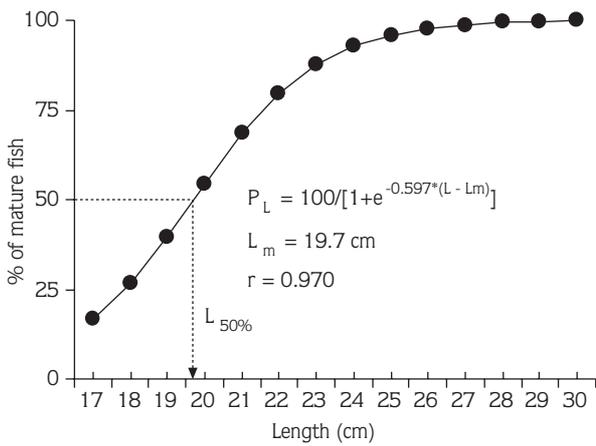


Figure 4. Ogive of first sexual maturity for female pike in Lake Karamik.

to 29050. The relative fecundity was estimated as 45.7 ± 4.9 (\pm CI, 95% confidence limit) eggs g^{-1} the total body weight. The relationships between fecundity – length (Figure 5) and fecundity – weight (Figure 6) were given below:

$$F = 2.8963 L^{2.3722} [r = 0.590 \text{ (95\% CI = 0.391 – 0.736)}]$$

$$F = 58.998 W^{0.9354} [r = 0.668 \text{ (95\% CI = 0.495 – 0.790)}]$$

Table 4. The number (n), mean length (L), mean weight (W) and relative fecundity (F) pike samples captured prior to spawning.

Age	n	L \pm CI	W \pm CI	F \pm CI
I	6	22.9 \pm 0.8	103.2 \pm 12.5	48.3 \pm 8.9
II	36	27.2 \pm 0.6	173.6 \pm 10.2	46.8 \pm 6.8
III	6	34.1 \pm 1.1	331.1 \pm 38.4	42.4 \pm 8.9

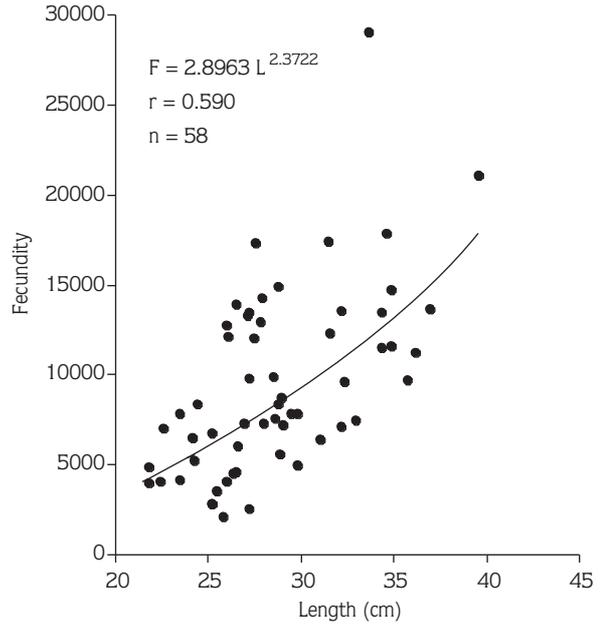


Figure 5. Relation between fecundity and length for pike in Lake Karamik.

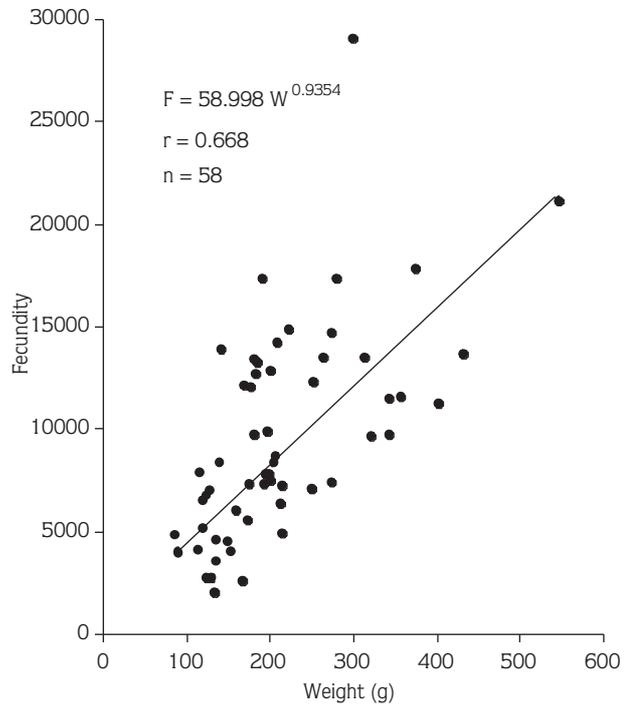


Figure 6. Relation between fecundity and weight for pike in Lake Karamik.

Correlation coefficients showed that there were no strong relations between fecundity - length ($t = 5.467$, $P < 0.05$) and fecundity - weight ($t = 6.714$, $P < 0.05$) of pike in Lake Karamık. Egg diameters of pike varied between 1.69 and 2.58 mm and the mean egg diameter was estimated as 2.08 ± 0.07 (\pm CI, 95% confidence limit) mm.

Discussion

The reproductive activity of pike population in Lake Karamık took place in February and March with a peak in February. Fishing of pike in Lake Karamık is officially prohibited by the fishing circular (TKB, 2004) from 15 December to 30 June. This season also includes the spawning period of pike population in this lake. In an early study in the same lake, spawning period of this species had also been reported in February and March (Aksun, 1987a). This result agrees with other studies in Turkey; e.g., Tanyolaç and Karabatak (1974), Karabatak (1982), Çubuk et al. (2000-2001), İlhan and Balık (2003) reported that spawning occurred between February and March for pike populations in Lake Mogan, Akşehir, Uluabat and Işıklı, respectively. Whereas, Kipling and Frost (1967), Koz'min (1980), Roche et al. (1999) and Lenhardt and Cakić (2002) reported different spawning periods in Lake Windermere and Lacha, in an Irish reservoir and in the River Danube, respectively. These comparisons showed that the spawning period of the same species may vary from one geographical area to another because of their different climatic conditions. This may result from ecological characteristics of the water system in which they live. Ecological characteristics of water systems are determined by environmental factors. Therefore, the starting and finishing time of the spawning period for the same species may include different months.

The smallest mature female in the present study was 18 cm long and the length at first sexual maturity was determined as 19.7 cm for female pike. This length is fairly lower than the value reported by Aksun (1987a) for pike population in Lake Karamık. In that study, the length at first sexual maturity had been determined as 27.9 and 29.1 cm for male and female pike, respectively. It is clear from these values that the length at first sexual maturity decreased importantly within the last 20 years. It can be attributed to over-fishing. Because, both age and length

compositions of pike population in Lake Karamık showed that this fish species has been overexploited recently. It is reported that in overexploited stocks, first sexual maturity size decreases as a reaction of over-fishing (Erkoyuncu, 1995). In addition, Şen et al. (1994) reported that salinity, sulphate, phosphate, calcium, magnesium, etc. have increased from the beginning of 1980s to the beginning of 1990s, and concluded that during this period the lake has been rapidly polluted because of the wastewaters of Seka Paper Factory. The lake is still polluted by the factory. Environmental conditions such as water quality, food contents, etc. are very important for especially growth and reproduction of fish populations. Most probably, first sexual maturity size of pike population in Lake Karamık might be affected from these changes in the environmental conditions. In some lakes and reservoirs, the less maturity lengths were reported by Karabatak (1982), İlhan and Balık (2003), Kipling and Frost (1967), Kulemin et al. (1971), Volfert and Miller (1978), Koz'min (1980) and Roche et al. (1999) than that of this study.

These comparisons showed that female pike matured at a smaller length in Lake Karamık than those of the other lakes. As a regulation, fishing of pike smaller than 40 cm total length in all Turkish lakes is prohibited by the fishing circular of the Republic of Turkey, Ministry of Agriculture and Rural Affairs (TKB, 2004). The length at first maturity of pike population in Lake Karamık was fairly smaller than legal minimum fishing size. On the other hand, we observed that nearly all of commercial pike catch were smaller than 40 cm. Similarly, only 3.5% of pike samples in the study were above 40 cm long. Due to fishing pressure on pike population, the number of large pike seems to be decrease.

The total fecundity of pike in Lake Karamık varied from 2033 to 29050 eggs per female. The relative fecundity was 45.7 ± 4.9 eggs g^{-1} of total body weight. Aksun (1987a) reported that the total and relative fecundities of pike in the same lake ranged from 8975 to 48539 eggs per female and from 21.27 to 23.75 eggs g^{-1} , respectively. These comparisons showed that the relative fecundity increased from 1980s to 2000s. Fecundity is affected by fish age, length, weight (Nikolsky, 1963), the egg size, feeding of fish, season and environmental conditions. In addition, it differs between populations of the same species and does not remain constant from year to year (Yıldırım and Aras, 2000). Fecundity of pike was

reported by Çubuk et al. (2000-2001) and İlhan and Balık (2003) between 4784 - 39652 and 1461 - 48888 eggs per female in Lake Uluabat and Işıklı, respectively. Relative fecundity was estimated by Çubuk et al. (2000-2001) and Lehnhardt and Cakić (2002) as 37.4 and 40 eggs g⁻¹ for pike population in Lake Uluabat and in the River Danube, respectively. It may be roughly said that these fecundity values are similar to fecundity values of pike in Lake Karamık.

Mean egg diameter in February and March was estimated to be 2.08 ± 0.07 mm. It had been reported by Aksun (1987a) as 1.62 mm in February and 2.16 mm in March. İlhan and Balık (2003) determined it as 1.46 mm for pike population in Lake Işıklı. However, the egg

diameter may change in relation to especially fish size, different parts of ovary and maturation stage.

Consequently, it can be said in the light of the results of this study and evaluations that the present fishing regulations related to fishing season and minimum catching size are suitable for pike population in Lake Karamık. Fishing season and minimum fishing size should not be changed to safeguard the spawning stock and recruits, because the rate of individuals of the minimum fishing size (40 cm \geq) in the population is rather low. The reason of this situation should be investigated for the future of pike population and the lake fishery.

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