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Research article

The growth feature of pike, *Esox lucius* L., 1758 inhabiting Lake Ladik

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Abstract: In this study, some growth parameters such as age, growth, length-weight relationships (LWR) condition factor (CF), and length-length relationships (LLR) of *Esox lucius* individuals were examined in Lake Ladik. Maximum age observed was 6 years in samples. The fork length and weight of specimens ranged 25.5-70.5 cm and 115.2-3174 g, respectively. The von Bertalanffy growth parameters (VBGE) were estimated as L_∞ = 97.57 cm, k = 0.15, t_0= -0.76, W_∞ = 8492.32 g for females and L_∞ = 65.31 cm, k = 0.30, t_0 = - 0.32, W_∞ = 8593.90 g for males. Length-weight relationships (LWR) for female and male samples were found as W = 0.0039 $FL^{3.189}$ and W= 0.0031 $FL^{3.246}$, respectively. LWRs indicated a positive allometric growth in female, male and all samples. The mean condition factor value (CF) was computed 0.785 for females and 0.767 for males. CF values showed an upward trend with reference to age and length groups in both sexes. All length-length relationships were statistically significant. The outcomes on growth characteristics in pike is the first data for Lake Ladik. Also, we found that the pike exhibits good development in this habitat.

Keywords: Growth parameters, *Esox lucius*, Lake Ladik, length-weight relationships

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Introduction

Esox lucius, pike a member of the Esocidae which is comprised only one genus *Esox* known for its duck-billed snouts, elongated bodies, and voracious feeding behavior (Grande et al., 2004; Kovalchuk et al., 2017). Pike exhibits a circumpolar distribution in the northern hemisphere (North America, Europe, and Asia) (Grande et al., 2004; Kovalchuk et al., 2017) and it can be found in many different habitats such as rivers, lakes, and weakly saline waters (Craig, 2008). Pike is a very important species both commercial fisheries (Yazicioglu et al., 2018) and in recreational fisheries (Milardi et al., 2014).

Top predators may have strong cascading both negative effects on prey fish abundance (Craig 1996) and cascading effects down to lower trophic levels (Byström et al., 2007). Pike is keystone species cool water habitat, and it is top predatory fish of the food chain (Craig, 2008). Pike population exhibits strong effects in lake ecosystems what influence fish communities regulating composition as well as abundance and distribution of their prey (Craig, 2008; Alp et al., 2008; Yazicioglu et al., 2018).

The knowledge on the growth characteristics of the keystone species (primarily pike) is very important for fisheries management, fish community, and in terms of the future aquatic habitat. Studies about some growth features of pike, *Esox lucius* were performed in different habitat (Bregazzi end Kenndey, 1980; Altındağ et al., 1999; Roche et al., 1999; Lorenzoni et al., 2002; Çubuk et al., 2005; Žiliukienė ve Žiliukas, 2010; Milardi et al., 2014; Moslemi-Aqdam et al., 2017). However, there is no information on some biological characteristics such as age, growth rate, length-weight relationships, condition factor, and length-length relationships of pike in Lake Ladik. The aim of this study is to reveal on its effects aquatic areas and living fish communite by determining

the growth features, population structure and condition of pike.

Material and Methods

Sampling Area

Lake Ladik which is located on the southwest of Samsun province and between 40°54′20″N to 40°55′16″N, 35°58′53″E to 36°03′2″E has got 10 km far from east of the Ladik district. This lake has 6 m maximum dept, 10 km total surface area, and 867 m altitude (Yazicioglu et al., 2018). The lake located in the tectonic depression of Ladik are classified is eutrophic (Apaydin Yagci et al., 2015).

Sampling and Laboratory Procedures

Fish samples were monthly collected from different areas of Lake Ladik from November 2009 toOctober 2010. The fish were caught using gillnets of various mesh sizes (18, 20, 25-, 30-, 35- and 40-mm knot to knot), trammel nets of various mesh sizes (30, 35, 45, 50, 55, 60, 70, and 80 mm knot to knot) and fyke nets. Total length (TL), fork length (FL) and standard length (SL) of each fish were measured precision ± 0.1 cm, their weights (W) were weighed to ± 0.01 g precision. Sex determination was determined by macroscopic examination of the gonads. The scales were used in age determination (Yazıcıoğlu et al., 2016)

Growth analyzes

The von Bertalanffy growth function (VBGE) was used for computing the age-length equation described as $L_t = L_\infty [1-e^{-k (t-t_0)}]$ and age-weight equation defined as $W_t = W_\infty [1-e^{-k (t-t_0)}]^b$. In the equations, L_t is the fork length at age t, L_∞ is the asymptotic length (cm), k is the body growth coefficient (year^{-1}), t_0 is the theoretical age at zero length (year), W_t is the body weight at age t, W_∞ is the asymptotic weight (g), b is power constant of length-weight relationship (Sparre and Venama, 1998). Growth performance index, $\Phi' = \text{Log } k + 2 \text{ Log } L_\infty$ was used in comparing fish growth (Munro and Pauly, 1983). Whereas the parameters L_∞, k, and t_0 in growth equation and Φ' values are calculated with FISAT II packaged software (Gayanilo et al., 2005), the parameters W_∞ and b were obtained from length-weight relationship. The length-weight relationship (LWR) was calculated by the formula $W = a \times L^b$, where W is the body weight (g), L is the fork length (cm), a is the intercept, and b is the slope (Bagenal and Tesch, 1978). The parameters a and b of LWR were obtained by linear regression of the transformed equation: $\text{Log } W = \text{Log } a + b \text{ Log } L$. The determination coefficient (r^2) was used as an indicator of the quality of the linear regression. The Fulton's condition factor was computed using the formula $CF = 100 \text{ W } L^{-3}$, where K is the Fulton's condition factor (CF), W is the body weight (g), and L is the fork length (cm) (Ricker, 1975). In addition, relationships between TL vs FL, FL vs SL, and SL vs TL were determined separately according to females, males, and overall samples.

Statical Analyzes

The differences between mean length and weight values of females and males were checked with Mann-Whitney U test ($\alpha = 0.05$) (Zar, 1999). Length–frequency and weight–frequency distributions of sexes were compared by using Kolmogorov-Smirnov Z test ($\alpha = 0.05$) (Zar, 1999). The student's t-test was used to determine differences between the mean lengths and weights of females and males in the same age groups (Zar, 1999). Whether the growth of fish was isometric (b= 3) or allometric (b > 3, b < 3) was estimated by the student's t-test (Zar, 1999). Difference between condition factor values of females and males were controlled by employing the student's t-test (Zar, 1999).

Results

In this study, a total of 204 individuals were examined. The pike population was represented by five age groups, ranging from 2 years to 6 years. Age group III was dominant with 48.53% The second dominant age group was determined as II year with 22.06 % (Table 1).

Table 1. Age distribution related to sexes of pike population in Lake Ladik

Age groups	Female		Male		All samples	
	N	%	N	%	N	%
2	27	13.24	18	8.82	45	22.06
3	67	32.84	32	15.69	99	48.53
4	15	7.35	22	10.79	37	18.14
5	7	3.43	9	4.41	16	7.84
6	7	3.43	-	-	7	3.43
Total	**123**	**60.29**	**81**	**39.71**	**204**	**100**

The fork lengths of females ranged from 25.5 to 70.5 cm and the mean fork length was determined as 43.9 cm. The length group of 40.0-44.9 cm was dominant in samples (Figure 1). The fork lengths of male individuals varied between 26.7 and 56.0 cm and the mean fork length was calculated as 41.9 cm. The dominant length group was determined as 40.0-44.9 cm length group for both female and male individuals (Figure 1). The difference between mean fork length values of males and females was not statistically significant (Mann-Whitney U test, $P > 0.05$). It was seen that fork length distributions of sexes were not different from each other (Kolmogorov-Smirnov test, $Z= 0.808$, $P>0.05$).

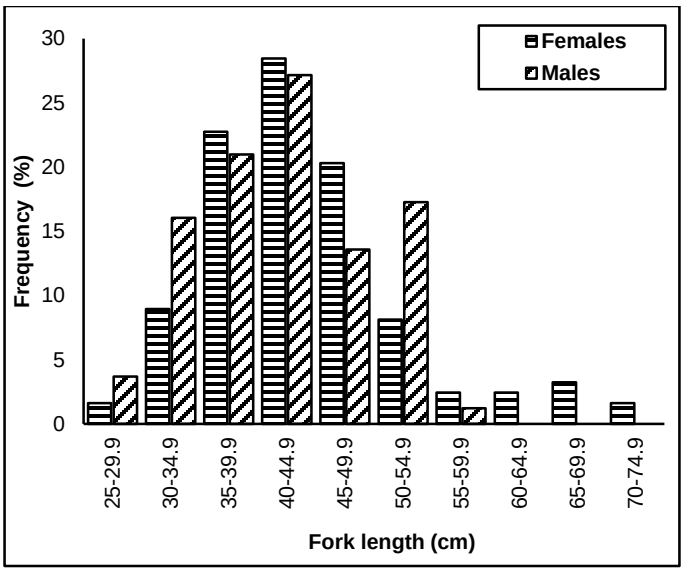

Figure 1. The fork length distribution of pike in Lake Ladik

The body weights of females varied between 115.2 and 3174.0 g, and the mean weight value was obtained as 772.0 g. The most samples were in the 415-714.9 g weight group. It was observed that most female individuals (64.22%) were under 7115 g (Figure 2). The weights of male specimens changed between 127.3 and 1432.0 g, and the average weight was computed as 621.3 g (Ss=319.5). The highest number of male fish was in the group of 415-714.9 g. Almost all the male fish (65.43%) were lower than 715 g (Figure 2). The weight distributions of sexes were not different from each other (Kolmogorov-Smirnov test, $Z=1.029$, $P>0.05$).

The mean fork lengths and weights according to age and sex groups were offered in Table 2. It was seen that mean fork lengths and weights of females were greater than males in all age groups. The mean fork lengths and weights of male and female individuals in the same age group showed statistical differences (t-test, $P<0.05$).

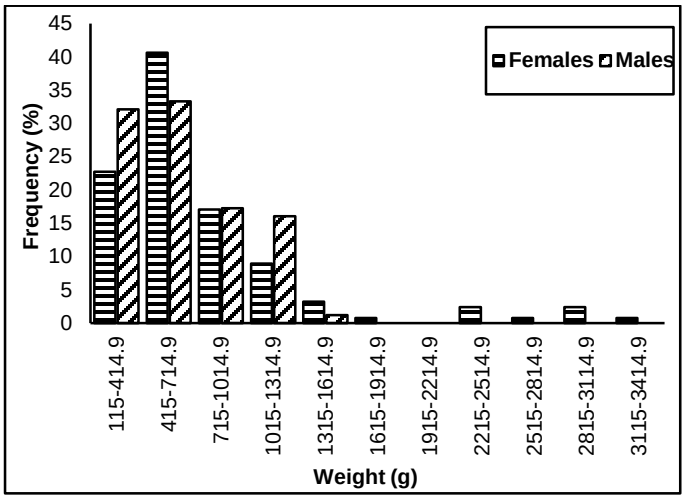

Figure 2. The weight distribution of pike in Lake Ladik

The parameters of the von Bertalanffy growth equations (VBGE) and length-weight relationships (LWR) for male, female and all sample are showed in Table 3. The asymptotic weight (W_∞) and length (L_∞) values of females were greater than males. The growth performance index (Φ') values were found as 3.15, 3.11, 3.13 for females, males, and all fish, respectively.

The average value of Fulton's condition factor (CF) was calculated as 0.785 for females, 0.767 for males, and 0.778 for all fish. CF values of sexes were found same as each other ($P > 0.05$). The highest mean CF values of females and males were obtained in 67.5 cm (0.899) and in 57.5 cm (0.815). CF values showed an upward trend with length groups in both sexes (Figure 3).

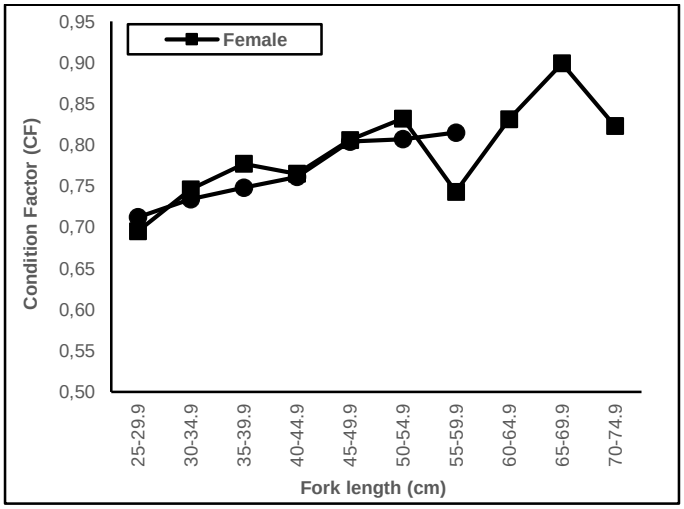

Figure 3. Mean CF values per fork length group for females and males individuals of pike in Lake Ladik

Table 2. The mean length and weigth values according to sex and age groups in pike from Lake Ladik n: sample size, Min: minimum, Max: maximum, Se: standart error

Sex	Age group	n	Fork length (cm)		Body weight (g)	
			Min-Max	Mean+Se	Min-Max	Mean+Se
Female	II	27	25.5-43.3	35.9±0.84	115.2-652.0	366.00±27.00
	III	67	34.6-52.6	42.0±0.44	300.0-1226.96	587.25±20.10
	IV	15	45.3-54.5	49.6±0.73	707.66-1379.41	1027.12±46.40
	V	7	52.7-66.9	59.1±2.02	1115.57-2461.03	1666.81±187.00
	VI	7	58.8-70.5	66.9±1.68	1610.0-3174.0	2665.44±158.00
Male	II	18	26.7-35.9	32.9±0.59	127.32-338.00	263.80±13.50
	III	32	34.5-47.3	40.4±0.51	260.0-862.0	506.60±23.20
	IV	22	40.9-53.2	47.3±0.74	465.44-1222.0	862.04±43.90
	V	9	50.1-56.0	52.3±0.59	1054.21-1432.0	1156.02±40.50
All samples	II	45	25.5-43.3	34.7±0.60	115.2-652.0	325.12±18.50
	III	99	34.5-52.6	41.4±0.35	260.0-1226.96	561.18±16.00
	IV	37	40.9-54.5	48.3±0.56	465.44-1379.41	928.63±34.50
	V	16	50.1-66.9	55.2±1.58	1054.21-2461.03	1379.49±104.00
	VI	7	58.8-70.5	66.9±1.68	1610.0-3174.0	2665.44±158.00

Table 3. The parametrs of the von Bertalanffy growth equation (VBGE) and length-weight relationships (LWR) of pike in Lake Ladik.

		VBGE					LWR		
Sex	**N**	**L_∞ (cm)**	**W_∞ (g)**	**k (yıl^{-1})**	**t_0 (yıl)**	**Φ'**	**a**	**b**	**r^2**
Female	123	97.57	8492.32	0.15	-0.76	3.15	0.0039	3.186	0.981
Male	81	65.31	2414.27	0.30	-0.32	3.11	0.0031	3.246	0.979
All samples	204	97.74	8593.90	0.14	-1.02	3.13	0.0035	3.211	0.980

The length-length relationships between total length, fork length and standard length were presented in Table 4. The coefficient of determination of females, males, and overall samples were greater than 0.997 (Table 4) and highly significant ($P < 0.001$).

Table 4. Length-length relation parameters between total, fork and standard length of pike in Lake Ladik

Sex	n	Equations	a	b	r^2
Females	123	TL = a + b FL	0.439	1.04	0.999
		FL = a + b SL	0.362	1.06	0.999
		SL = a + b TL	-0.641	0.90	0.998
Males	81	TL = a + b FL	0.100	1.05	0.998
		FL = a + b SL	0.456	1.06	0.998
		SL = a + b TL	-0.396	0.89	0.998
All samples	204	TL = a + b FL	0.370	1.05	0.999
		FL = a + b SL	0.426	1.06	0.998
		SL = a + b TL	-0.629	0.90	0.998

Discussions

In this study, ages of northern pike were ranged from 2 to 6. The absence of 0 and 1 age groups in the sample is probably due to gill net's selectivity and equipment used in hunting. In both sexes, 3-year old individuals were dominant. The population of northern pike inhabiting Lake Ladik was consist of young individuals. In studies conducted by different researchers, age distribution ranged from 0 to 12 years, and it is generally observed that female individuals have more long life than male individuals (Bregazzi and Kennedy, 1980; Aksun, 1987; Karabatak, 1993; Avian et al., 1998; Roche et al., 1999; Altındağ et al., 1999; Çubuk et al., 2005; Epler et al., 2008; Žiliukienė and Žiliukas, 2010; Benzer and Benzer 2016; Moslemi-Aqdam et al., 2017). Also, Casselman (1996) stated that pike can live up to 30 years of age. The length and weight distributions of *Esox lucius* samples captured from Ladik Lake coincide with most studies conducted in other habitats. In this study, female individuals in the same age group seem to have larger length and weight than male. Similar results were obtained in different habitats (Kipling, 1983; Neumann et al., 1994; Margenau et al., 1998; Çubuk et al., 2005; Benzer and Benzer, 2016; Moslemi-Aqdam et al., 2017). In terms of average weight, it is noteworthy that females are heavier than males, especially at later ages. Doyon et al. (1988) reported that

females of the same size in pike populations were approximately 9% heavier than males. This is thought to be caused by changes in latitude differences and, consequently, ecological characteristics of habitats. In our study, the L∞ (97.57) value of the females was larger than the males (65.31). In contrast, the value of k is higher in males than in females. In studies on many fish populations, it has been reported that the high parameter of the L_∞ value is low or vice versa (Erkoyuncu, 1995). It was reported that the L_∞ value of the females was larger than the males, while the k value was smaller than males in different studies (Kipling, 1983; Persson et al., 2006; Benzer and Benzer, 2016; Moslemi-Aqdam et al., 2017). According to this result, it can be said that male individuals reached L_∞ value faster than females. Such a result means that in the population, males grow faster and live shorter than their females. In addition, this situation show that male individuals grow faster, and male individuals reach sexual maturity earlier than their females. It is also known that individuals with rapid growth characteristics are smaller than slow-growth individuals. Kipling (1983) reported that male pike fish are smaller than females and that their lifespan is shorter than that of their females. Casselman (1996) reported that females live longer in pike fish than males. Koščo (2001) stated that male individuals grew faster than females. On the other hand, when the growth performance index values (Φ ') used to compare the growth of populations in different habitats are examined, it can be said that the population of Ladik Lake has developed similarly to the populations in other regions of our country (Altındağ et al., 1999; Çubuk et al., 2005). On the other hand, Windermere Lake, Kruščica Dam Lake, Baykal Lake, Trasimeno Lake and Rubikiai Lake, which are located to the north, have a higher growth rate than the population of Ladik Lake.

In this study, strong relationships between fork length and weight were determined ($P < 0.001$, $r^2 > 0.97$). The b values obtained in this study differ significantly from 3. This result show that the growth of pike was positive allometric growth in the Lake Ladik. The parameters of LWR highly correspond to vary studies in other habitats. But there are some differences in these parameters (Table 5). These differences are thought to be caused by the number of samples, length-weight distributions, sampling time, type of length used and ecological conditions of the environment. As a matter of fact, the length-weight relationship parameters in fish are not constant and can vary depending on factors such as nutritional adequacy, nutritional ratio, gonad development and breeding period (Bagenal & Tesch, 1978).

Table 5. The parameters of LWR of pike in different study areas (*Total length)

Sex	a	b	r^2	Area	Referans
All	0.00004	3.115	-	Slapton Ley Lagünü	Bregazzi ve Kennedy, 1980
Female	0.0025	3.364	0.99	Dam Lake Kesikköprü	Altındağ et al., 1999
Male	0.0062	3.101	0.99		
All	0.0357	2.690	0.99		
All	0.0034	3.233	0.99	Lake Uluabat	Çubuk et al., 2000
All	0.000006	2.996	0.97	Baikal Lake	Owens & Pronin, 2000*
Female	0.0010	3.003	0.991	Trasimeno Lake	Lorenzoni et al., 2002*
Male	0.0010	3.055	0.991		
All	0.0010	3.036	0.900		
Female	0.0033	3.27	0.951	Lake Işıklı	İlhan & Balık, 2003
Male	0.0018	3.45	0.962		
All	0.0022	3.39	0.960		
All	0.0226	2.719	0.947	Lake Çapalı	Küçük & Güçlü, 2004
Female	0.0045	3.186	0.984	Lake Işıklı	Uysal et al., 2008
Male	0.0032	3.298	0.975		
All	0.0042	3.208	0.981		
All	0.0060	3.016	0.987	Rubikiai Gölü	Žiliukienė & Žiliukas, 2010*
All	0.0051	3.056	0.990	Inland water of Belgium	Verreycken et al., 2011*
All	0.007	3.08	0.98	Anzali Wetland	Moslemi-Aqdam et al., 2017
All	0.006	3.001	0.991	Elbe River	Simon et al., 2023
Female	0.0039	3.186	0.980	Lake Ladik	This study
Male	0.0031	3.246	0.980		
All	0.0035	3.211	0.980		

The difference in the condition factor values between female and male of the same age group is not statistically significant. In general, the condition factor increased with age groups. This situation is also supported by changes in average condition factor according to length classes. In parallel with the increase in fish length, the condition value also increases. Similar findings were found in different studies (Tanyolaç, 1977; Koščo, 2001).

The comparison of the values of the condition factor in this study with the values obtained in other studies is given in Table 6. When the table is examined, the condition of Ladik Lake samples is in great agreement with other populations. It is known that the condition factor, which reflects changes in gonad development and nutritional level in fish (Wootton, 1990), differs depending on habitat, year, season, age group, sex, sexual maturity, and reproduction period (Erkoyuncu, 1995). Doyan et al. (1988) reported that the pike fish survived at higher latitudes and the condition decreased at higher temperatures.

Table 6. CF values of pike in different study areas (*Total length)

Area	Sex	CF	Referans
	Female	0.793	Çubuk, 2000
Lake Uluabat	Male	0.775	
	All	0.792	
Lake Işıklı	All	0.885	İlhan &Balık, 2003
	Female	0.842	Küçük & Güçlü, 2004
Lake Çapalı	Male	0.903	
	All	0.877	
	Female	0.832	Çubuk et al., 2005
Lake Karamık	Male	0.802	
	All	0.812	
	Female	0.900	Erdem et al., 2007
Lake Uluabat	Male	0.910	
	All	0.900	
	Female	0.863	Uysal et al., 2008
Lake Işıklı	Male	0.884	
	All	0.870	
All regions of Croatia	All	0.636	Treer et al., 2009*
	Female	0.785	In this study
Lake Ladik	Male	0.767	
	All	0.778	

The preference of various length measures in different studies makes comparison and interpretation of the results difficult. When we look at the literature, it is seen that the fork length and total length are used in most of the studies related to the species and the standard length is used in a very small amount. On the other hand, very few studies have been given length transformations (Treer et al., 1998, Griffiths et al., 2004).

Conclusion, this study presents the first estimates of growth features traits for pike in Lake Ladik. Considering the length-weight distribution, growth parameters, ength-weight relationships, and conditions factors of pike in this habitat, this species shows a good development in Lake Ladik. Also, it has been observed that female fish in the same age group develop better than males. Both sampling results and age distributions give the impression that the pike population consists mostly of young individuals. This is due to the fact that hunting activities in the lake are aimed at larger individuals and the selectivity of the equipment used. In addition, this situation indicates that the pike population in Lake Ladik is growing overfished.

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Ethical Approval
All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

Conflicts of Interest
The authors declare that they have no conflict of interest.

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