ORIGINAL SCIENTIFIC PAPER **ISSN 1330-061X (print), 1848-0586 (online)**

POPULATION STRUCTURE AND GROWTH OF RUDD *Scardinius erythrophthalmus* (L., 1758) FROM A EUTROPHIC LAKE IN NORTHERN ANATOLIA

Ramazan Yazıcı[1], Savaş Yılmaz[2,*], Okan Yazıcıoğlu[3], Nazmi Polat[2]

[1]Laboratory and Veterinary Health Department, Çiçekdağı Technical Vocational Schools of Higher Education, Ahi Evran University, Kırşehir, Turkey
[2]Department of Biology, Faculty of Arts and Science, Ondokuz Mayıs University, Samsun, Turkey
[3]Organic Farming Program, Botanic and Animal Production Department, Technical Vocational Schools of Higher Education, Ahi Evran University, Kırşehir, Turkey

*Corresponding Author, Email: savasyilmaz033@yahoo.com

ARTICLE INFO

Received: 4 March 2015
Received in revised form: 12 May 2015
Accepted: 13 May 2015
Available online: 21 May 2015

Keywords:
Age
Growth parameters
Condition factor
Lapillus
Lake Ladik

ABSTRACT

A total of 1329 samples were collected from monthly sampling between November 2009 and October 2010 in order to analyze growth features and population structure of rudd *Scardinius erythrophthalmus* living in Lake Ladik which has eutrophic character. The fork length (FL) ranged from 9.8 to 21.4 cm and the body weight (W) ranged from 13.62 to 200.68 g. Based on lapillus readings, the maximum age was 7 years. The overall ratio of female to male was 1:0.16. The von Bertalanffy growth equation parameters were calculated as L_∞ = 39.32 cm, W_∞ = 1504.92 g, k = 0.08, t_0 = -1.08 for females, and L_∞ = 28.19 cm, W_∞ = 448.03 g, k = 0.13, t_0 = -1.19 for males. Length-weight relationship for females and males was found as $W = 0.0060\ FL^{3.386}$ and $W = 0.0078\ FL^{3.282}$, respectively. The Fulton's condition factor (K) showed an upward trend with reference to age and length groups in both sex. The value of mean K was computed as 1.737 for females, 1.667 for males and 1.727 for combined sexes. This study provides the initial data on population structure, growth features and condition of rudd in Lake Ladik. Obtained data have shown that population is comprised of young individuals and that the growth rate of the species is slow.

How to Cite

Yazıcı, R., Yılmaz, S., Yazıcıoğlu, O., Polat, N. (2015): Population structure and growth of rudd *Scardinius erythrophthalmus* (L., 1758) from a eutrophic lake in northern Anatolia. Croatian Journal of Fisheries, accepted article, online first, 161-176.

INTRODUCTION

In recent years, the eutrophication is one of the greatest dangers to water resources. The eutrophication reduces water quality, protection value and biodiversity of aquatic ecosystems, causing negative acceleration in economy by reducing the number of commercial species (Beklioglu et al., 2011). To understand the effect of the eutrophication on an aquatic ecosystem and to fight effectively, it is important to know biological and ecological features of cyprinid species (Jokinen and Reinikainen, 2011).

Rudd *Scardinius erythrophthalmus* (L., 1758), which belongs to the family Cyprinidae, has a wide distribution in Europe and Asia. They generally live in the lush vegetative littoral zones (edges) of lakes which have low depth and in slow moving rivers, and they have easily adapted to adverse conditions. Their main foods are aquatic plants, invertebrates, planktonic organisms, insect larvae and fish eggs (Kottelat and Freyhof, 2007). Also, it has been stated that the species shows an ontogenetic type of feeding and that the species applies a strong predation on submerged vegetation, zooplanktons and benthic invertebrates (Hicks, 2003).

There are many investigations on the biology of rudd from different water bodies (Zerunian et al., 1986; Erdem et al., 1994; Balık et al., 1997; Balkuvienė et al., 2003; Nurminen et al., 2003; Okgerman, 2005; Szypula, 2005; Tarkan, 2006, Bostancı et al., 2007; Gumus et al., 2007; Koyuncu, 2007; Çınar et al., 2008; Blackwell et al., 2009; Emiroğlu et al., 2010; Patimar et al., 2010; Piria et al., 2011; Kapuscinski et al., 2012). However, there has been no study on the rudd population inhabiting Lake Ladik, northern Anatolia. The aim of this study is to provide data for restoration works that will be conducted in the future by determining the growth features, population structure and condition of rudd living in Lake Ladik which has eutrophic character.

MATERIALS AND METHODS

Lake Ladik (40°50′N to 41°00′N, 35°40′E to 36°05′E) is 10 kilometers from Ladik district of Samsun Province, and it is located on the north of Akdağ Mountain. Morphologically, the lake is 5 km long, 2 km wide, 2.5–6 m deep and 867 m high. It has been classified as a eutrophic and shallow lake (Maraşlıoğlu, 2001), and its surface water temperature varies between 3.8–25.2ºC (Yazıcıoğlu, 2014). The fish fauna of the lake is comprised of *Abramis brama*, *Barbatula kosswigi*, *Blicca bjoerkna*, *Capoeta tinca*, *Chondrostoma regium*, *Esox lucius*, *Perca fluviatilis*, *Scardinius erythrophthalmus*, *Squalius cephalus* and *Carassius gibelio* species (Uğurlu et al., 2009; Yılmaz et al., 2012).

Fish were collected from different parts of the lake on monthly basis between November 2009 and October 2010. Specimens were caught using gill nets with meshes of 17, 20, 25, 30, 35 and 40 mm. For each fish, the total length (TL), fork length (FL) and standard length (SL) were measured with ± 0.1 cm precision, and the body weight (W) was weighed with ± 0.01 g precision. Sex determination was performed by

macroscopic examination of gonads. The utricular otolith (lapillus) was used for age determination (Yazıcı et al., 2014). Otolith pairs from each sample were taken out, cleaned and stored dry in tagged envelopes. The lapilli were placed in a black concave container filled with alcohol and read under a stereo binocular microscope with reflected light and 10 x magnifications. Readings were conducted on the axis between anterior and posterior margins at distal side of lapillus. All fish were aged by one reader. Age readings were undertaken without any reference to fish length, weight, etc. Only the date of capture was known by the reader. Ages were interpreted by considering 1 January as the birthday date. One opaque and one translucent zone were accepted as one annulus (Quist et al., 2012).

The von Bertalanffy growth function (VBGF) was used to determine age-length relationship. The VBGF is described by the following equation, $L_t = L_\infty [1-e^{-k\ (t-t_0)}]$, where L_t is the fork length at age t, L_∞ is the asymptotic length (cm), k is the body growth coefficient (year^{-1}) and t_0 is the theoretical age at zero length (year). For age-weight relationship, same function was used: $W_t = W_\infty [1-e^{-k\ (t-t_0)}]^b$, where 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 to compare fish growth (Munro and Pauly, 1983). The parameters L_∞, k and t_0 in growth equation and Φ' values are calculated with FISAT II program package (Gayanilo et al., 2005), and the parameters W_∞ and b were obtained from length-weight relationship. The length-weight relationship was calculated via the formula $W = aL^b$, 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 length-weight relationship were estimated 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 $K = 100\ W\ L^{-3}$, where K is the Fulton's condition factor, 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.

The chi-squared test (x^2) was used to show whether the sex ratio deviated from expected 1 : 1 ratio (Zar, 1999). 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 at the same age groups (Zar, 1999). It was estimated by the student's t-test whether the growth of fish was isometric ($b = 3$) or allometric ($b > 3$, $b < 3$) (Zar, 1999). Difference between condition factor values of females and males were controlled by employing the student's t-test (Zar, 1999).

RESULTS

During the study period, a total of 1329 individuals were captured; 1146 (86.23%) were females and 183 (13.77%) were males. The overall sex ratio (F : M) was calculated as 1:0.16. This ratio was significantly different from 1 : 1 (x^2 = 697.79, P < 0.001). Rudd population was represented by six age groups, ranging from 2 years to 7 years. Age group IV was dominant with 33.56% (Table 1).

Table 1. Age distribution and sex ratio of rudd population in Lake Ladik

	Female		Male		Combined sex		
Age group	n	%	n	%	n	%	F : M
II	9	0.68	20	1.50	29	2.18	1 : 2.22
III	48	3.61	24	1.81	72	5.42	1 : 0.50
IV	392	29.50	54	4.06	446	33.56	1 : 0.14
V	255	19.19	37	2.78	292	21.97	1 : 0.15
VI	315	23.70	38	2.86	353	26.56	1 : 0.12
VII	127	9.56	10	0.75	137	10.31	1 : 0.08
Total	1146	86.23	183	13.77	1329	100	1 : 0.16

n, sample size; F, female; M, male

The fork lengths of females varied between 9.8 and 21.4 cm, and the mean fork length was calculated as 15.60 cm. The length group of 17 cm, on average, was dominant, and the majority of the samples (64.57%) were longer than 14.5 cm. The fork lengths of male individuals ranged from 10.0 to 20.5 cm, and the mean fork length was determined as 14.41 cm. The length group of 12 cm, on average, was dominant and more than half of the samples (51.37%) were shorter than 14.5 cm (Fig. 1a). The difference between mean fork length values of males and females was statistically significant (Mann-Whitney U test, P < 0.001). It was seen that fork length distributions of sexes were different from each other (Kolmogorov-Smirnov testi, Z = 2.970, P < 0.001).

The body weights of females varied between 13.62 and 200.68 g, and the mean weight value was obtained as 71.91 g. Most samples were in the 40 g-average-weight group. It was observed that the majority of female individuals (69.9%) were under 90 g. The weights of male specimens changed between 14.41 and 168.0 g, and the average weight was computed as 56.53 g. The highest number of male fish was in the group of 20 g, on average. Almost all male fish (81.97%) were lighter than 90 g (Fig. 1b). The weight distributions of sexes were different from each other (Kolmogorov-Smirnov test, Z = 3.252, P < 0.001).

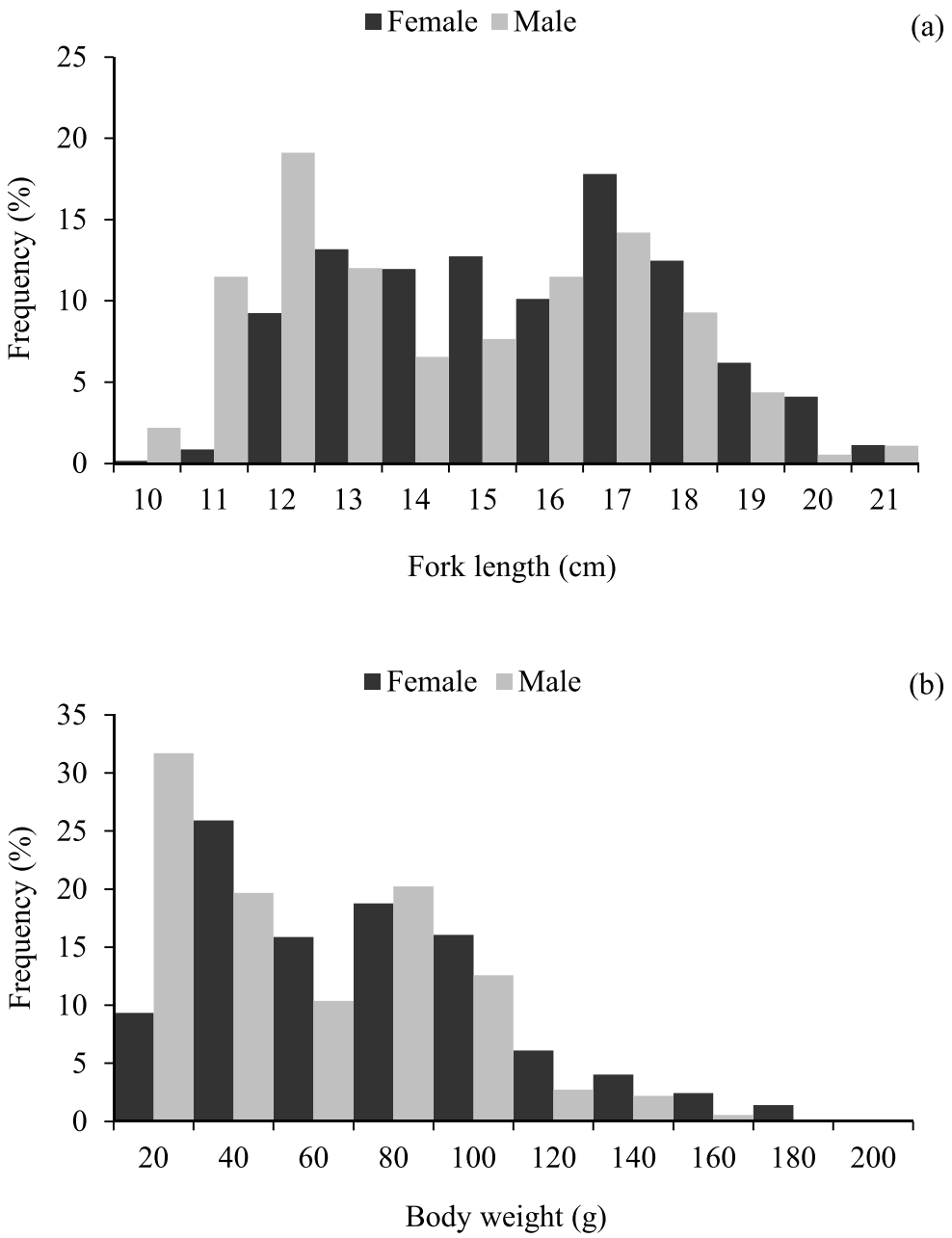

Fig 1. The fork length (a) and weight (b) distributions of rudd in Lake Ladik

Average fork lengths and weights in accordance with age and sex groups are presented in Table 2. The mean fork lengths of male and female individuals in the same age group showed statistical differences in age group IV only, whereas average weights showed differences in age group IV and VII ($P < 0.05$).

Table 2. Mean length and weight values according to sex and age groups in rudd population in Lake Ladik

Sex	Age group	*n*	Fork length (cm)		Body weight (g)	
			Min - Max	Mean ± SE	Min - Max	Mean ± SE
Female	II	9	9.8 - 11.5	10.7 ± 0.18	13.6 - 24.9	19.0 ± 1.18
	III	48	11.2 - 12.1	11.7 ± 0.03	22.0 - 28.0	26.1 ± 0.24
	IV	392	11.6 - 15.6	13.3 ± 0.04	24.0 - 63.2	39.1 ± 0.42
	V	255	14.5 - 17.5	15.7 ± 0.04	44.0 - 120.1	68.5 ± 0.80
	VI	315	15.8 - 19.2	17.4 ± 0.03	57.8 - 176.7	95.9 ± 0.74
	VII	127	17.5 - 21.4	19.4 ± 0.07	94.0 - 200.7	141.7 ± 1.97
Male	II	20	10.0 - 11.0	10.6 ± 0.07	14.4 - 22.0	18.1 ± 0.44
	III	24	11.1 - 12.0	11.7 ± 0.06	20.0 - 30.0	25.9 ± 0.51
	IV	54	12.0 - 15.2	13.1 ± 0.11	25.3 - 60.0	35.5 ± 1.07
	V	37	14.5 - 16.8	15.8 ± 0.11	48.6 - 91.2	72.2 ± 2.21
	VI	38	16.6 - 19.0	17.4 ± 0.09	72.6 - 133.3	92.2 ± 1.94
	VII	10	18.6 - 20.5	19.3 ± 0.22	103.7 - 168.0	126.7 ± 6.31
Female + Male	II	29	9.8 - 11.5	10.7 ± 0.07	13.6 - 24.9	18.4 ± 0.47
	III	72	11.1 - 12.1	11.7 ± 0.03	20.0 - 30.0	26.0 ± 0.23
	IV	446	11.6 - 15.6	13.3 ± 0.04	24.0 - 63.2	38.6 ± 0.40
	V	292	14.5 - 17.5	15.7 ± 0.04	44.0 - 120.1	69.0 ± 0.76
	VI	353	15.8 - 19.2	17.4 ± 0.03	57.8 - 176.7	95.5 ± 0.69
	VII	137	17.5 - 21.4	19.4 ± 0.06	94.0 - 200.7	140.6 ± 1.90

n, sample size; Min, minimum; Max, maximum; SE, standard error

The parameters of the von Bertalanffy growth equations and length-weight relationships are given 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 2.092, 2.014, 2.082 for females, males and all fish, respectively. Calculated b coefficient of length-weight relationship was significantly different from 3 ($P < 0.05$). This finding has shown that the growth is positive allometric. Comparisons of the observed and calculated fork length and weight values are shown in Table 4.

Table 3. Estimated parameters of the von Bertalanffy growth equation (VBGE) and length-weight relation (LWR) of rudd population in Lake Ladik

		VBGE				LWR			
Sex	*n*	L_∞	W_∞	*k*	t_0	*a*	*b*	%95 CI of *b*	r^2
F	1146	39.32	1504.92	0.08	-1.08	0.0060	3.386	3.355-3.417	0.976
M	183	28.19	448.03	0.13	-1.19	0.0078	3.282	3.207-3.357	0.976
A	1329	31.72	713.49	0.12	-0.78	0.0062	3.371	3.343-3.399	0.976

F, female; M, male; A, all fish; *n*, sample size; L_∞, asymptotic length; W_∞, asymtotic weight; *k*, body growth coefficient; t_0, theoretical age at zero length; *a*, intercept; *b*, slope; CI, confidence interval; r^2, coefficient of determination

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting and pagination process which may lead to differences between this version and the Version of Record. Please cite this article as an 'Accepted Article' 2015 online first

Table 4. Observed and calculated fish length and weight values according to age groups of rudd in Lake Ladik

		Fork length (cm)		Body weight (g)	
Age group	Sex	Observed	Calculated	Observed	Calculated
	Female	10.7	8.6	19.0	8.7
II	Male	10.6	9.6	18.1	12.9
	All	10.7	9.0	18.4	10.2
	Female	11.7	10.9	26.1	19.8
III	Male	11.7	11.8	25.9	26.0
	All	11.7	11.6	26.0	23.8
	Female	13.3	13.1	39.1	36.7
IV	Male	13.1	13.8	35.5	43.3
	All	13.3	13.8	38.6	43.6
	Female	15.7	15.1	68.5	59.5
V	Male	15.8	15.6	72.2	64.0
	All	15.7	15.9	69.0	69.1
	Female	17.4	17.0	95.9	88.0
VI	Male	17.4	17.1	92.2	87.2
	All	17.4	17.7	95.5	99.1
	Female	19.4	18.7	141.7	121.9
VII	Male	19.3	18.5	126.7	111.8
	All	19.4	19.2	140.6	132.5

The determination coefficient values of length-length relationships for females, males and overall samples in *Scardinius erythrophthalmus* population were greater than 0.987 (Table 5) and highly significant ($P < 0.001$).

Table 5. Length-length relationships between total length, fork length and standard length of *Scardinius erythrophthalmus* in Lake Ladik

Sex	*n*	Equation	*a*	*B*	r^2
		TL = a + b FL	-0.142	1.099	0.988
Female	1146	FL = a + b SL	0.631	1.056	0.992
		SL = a + b TL	-1.30	0.853	0.988
		TL = a + b FL	-0.260	1.111	0.989
Male	183	FL = a + b SL	0.767	1.044	0.992
		SL = a + b TL	-0.315	0.850	0.990
		TL = a + b FL	-0.143	1.100	0.989
All fish	1329	FL = a + b SL	0.650	1.054	0.993
		SL = a + b TL	-0.273	0.850	0.988

n, sample size; TL, total length; FL, fork length; SL, standard length; *a* and *b*, parameters of length-length relationship; r^2, coefficient of determination

The average value of Fulton's condition factor (K) was calculated as 1.737 for females, 1.667 for males and 1.727 for all fish. K values of sexes were found to be different from each other ($P < 0.05$). K values showed an upward trend with age (Table 6). The highest mean K values of females and males were obtained in 20.5 cm (K = 1.950) and 16.5 cm (K = 1.813) groups, respectively. The mean K values of specimens displayed an increase in both sexes according to length groups (Fig. 2).

Table 6. Condition factor values depending on age groups of rudd in Lake Ladik

Age group	Female		Male		All specimens	
	n	K ± SE (Min - Max)	*n*	K ± SE (Min - Max)	*N*	K ± SE (Min-Max)
II	9	1.526 ± 0.058 (1.283 - 1.796)	20	1.498 ± 0.023 (1.301 - 1.721)	29	1.507 ± 0.024 (1.283 - 1.796)
III	48	1.623 ± 0.015 (1.374 - 1.851)	24	1.629 ± 0.028 (1.350 - 1.993)	72	1.625 ± 0.013 (1.350 - 1.993)
IV	392	1.626 ± 0.007 (1.240 - 2.546)	54	1.585 ± 0.016 (1.358 - 1.988)	446	1.621 ± 0.006 (1.240 - 2.546)
V	255	1.753 ± 0.010 (1.405 - 2.318)	37	1.808 ± 0.029 (1.460 - 2.125)	292	1.760 ± 0.009 (1.405 - 2.318)
VI	315	1.811 ± 0.008 (1.242 - 2.497)	38	1.740 ± 0.033 (1.245 - 2.273)	353	1.804 ± 0.008 (1.242 - 2.497)
VII	127	1.920 ± 0.016 (1.477 - 2.447)	10	1.750 ± 0.034 (1.593 - 1.950)	137	1.907 ± 0.015 (1.477 - 2.447)
Total	1146	1.737 ± 0.005 (1.240 - 2.546)	183	1.667 ± 0.014 (1.245 - 2.273)	1329	1.727 ± 0.005 (1.240 - 2.546)

n, sample size; K, condition factor; Min, minimum; Max, maximum; SE, standard error

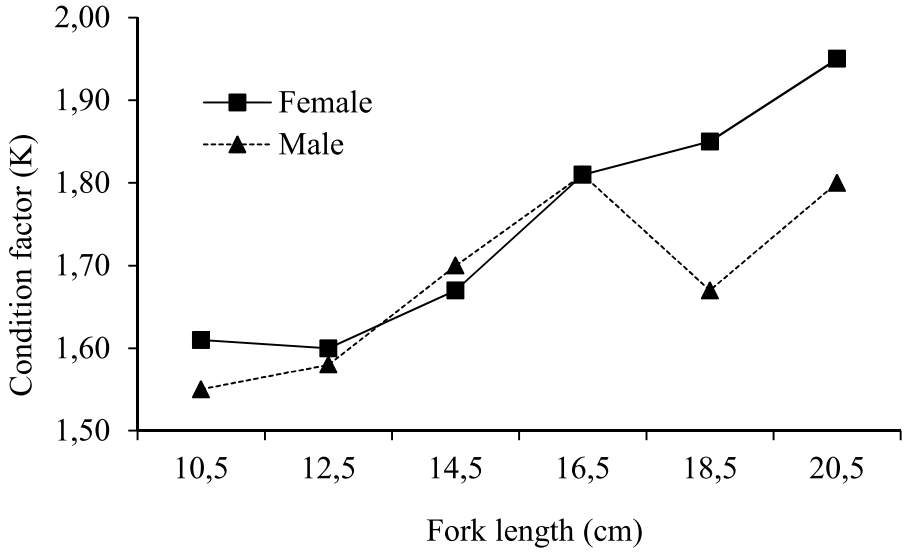

Fig 2. Mean condition factor values per fork length group for female and male individuals of rudd inhabiting Lake Ladik

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting and pagination process which may lead to differences between this version and the Version of Record. Please cite this article as an 'Accepted Article' 2015 online first

DISCUSSION

This study is the first reference on the population structure, growth features and condition of rudd living in Lake Ladik characterized as eutrophic. Ages of fish varied between 2 and 7 years. The absence of age group 0 and I in sampling can be attributed to predation of pike (*Esox lucius*) and perch (*Perca fluviatilis*), and the mesh size of fishing nets. Berka (1989) stated that the maximum age of species could be 7 years. This situation was confirmed in some studies (Tarkan, 2006; Çınar et al., 2008; Blackwell et al., 2009; Emiroğlu et al., 2010). While the maximum age was observed under 7 years at many locations (Zerunian et al., 1986; Erdem et al., 1994; Balık et al,. 1997; Gumus et al., 2007; Patimar et al., 2010; Piria et al., 2011), maximum age was determined as more than 7 years old at some other locations (Balkuvienė et al,. 2003; Nurminen et al., 2003; Blackwell et al., 2009; Horpilla and Nurminen, 2009; Kapuscinski et al., 2012). Prokeš and Řebičková (1987) stated that rudd could live up to 10–15 years.

Sex ratio of fish varies for different species, among the populations of the same species, from year to year in the same population (Nikolsky, 1963). The sex ratio of rudd in Lake Ladik was 1 : 0.16, whereas it was 1 : 0.66 in Lake Kuş (Balık et al., 1997), 1 : 0.85 in Lake Sapanca (Okgerman, 2005), 1 : 0.39 in Lake Gölhisar (Bostancı et al., 2007), 1 : 0.79 in Ömerli Dam Lake (Gürsoy, 2008), 1 : 1.08 in Anzali Lagoon (Patimar et al., 2010), 1 : 0.95 in Lake Erie (Kapuscinski et al., 2012). On the other hand, this rate in Lake Uluabat was reported as 1 : 0.53 (Koyuncu, 2007), 1 : 0.38 (Çınar et al., 2008) and 1 : 0.54 (Emiroğlu et al., 2010), respectively, in different years. It is understood from these results that the sex ratio of species shows variation and that females are generally more dominant than males.

In our study, the maximum FL and W values were 21.4 cm and 200.68 g, respectively. The longest rudd individual was reported with 35.8 cm total length in Lake Sapanca (Gürsoy, 2008). However, the heaviest rudd specimen was reported in Lake Uluabat with the weight of 478 g (Emiroğlu et al., 2010). In literature, the longest and heaviest sample of this fish was captured from Lake Vrana in 2008 and its total length and weight were measured as 61.7 cm and 3623 g, respectively (Šprem et al., 2010).

In the current work, while the asymptotic length (L_∞ = 39.32 cm FL) and weight (W_∞ = 1504.92 g) of females are greater than those of males, their growth coefficient (k = 0.08) is lower than that of males. The same result was reported for rudd populations in other habitats by different researchers (Table 7). This situation can be associated to females growing slower and having longer life spans (Ricker, 1975; Sparre and Venema, 1998). When the von Bertalanffy parameters are generally evaluated, it can be said that the species mentioned is a long-lived fish. Thus, Tarkan et al. (2010) stated that the maximum age of rudd was 17 years. The growth performance index values of rudd in Lake Ladik are slightly lower than those of the populations in other habitats (Table 7). This case can be related to slow growth due to inadequate nutrition.

Table 7. Von Bertalanffy growth parameters and growth performance index values for rudd populations in different localities

Locality	Sex	L_∞	W_∞	k	t_0	Φ'	References
Lake Kuş	All	18.07	146.30	0.496	-0.098	2.210	Balık et al., 1997
Bafra Fish Lakes	All	63.20	-	0.040	-	3.203	Gumus et al., 2007
Lake Wegorzewo	All	62.46^{+}	-	0.117	-0.277	2.660	Szypula, 2005
Lake Uluabat	Female	28.13^{++}	391.92	0.360	-0.400	2.455	Koyuncu, 2007
	Male	26.48	381.12	0.380	-0.380	2.426	
Lake Uluabat	Female	24.39	287.77	0.250	-1.148	2.172	Çınar et al., 2008
	Male	23.83	249.49	0.270	-1.017	2.186	
	All	24.54	293.57	0.241	-1.205	2.161	
Ömerli Reservoir	Female	37.43^{++}	847.58	0.153	-1.371	2.331	Gürsoy, 2008
	Male	34.63	574.31	0.170	-1.327	2.309	
	All	37.55	819.23	0.153	-1.389	2.334	
Lake Uluabat	Female	38.47^{++}	945.01	0.191	-1.155	2.451	Emiroğlu et al., 2010
	Male	37.72	506.84	0.310	-0.583	2.644	
	All	37.47	-	0.213	-0.780	2.475	
Lake Erie	Female	41.72^{++}	-	0.459	-0.109	2.902	Kapunscinski et al., 2012
	Male	39.71	-	0.303	-1.326	2.680	
Lake Ladik	Female	39.32	1504.92	0.080	-1.080	2.092	This study
	Male	28.19	448.03	0.130	-1.190	2.014	
	All	31.72	713.49	0.120	-0.780	2.082	

$^{+}$Standard length; $^{++}$Total length; L_∞, asymptotic length; W_∞, asymtotic weight; k, body growth coefficient; t_0, theoretical age at zero length; Φ', growth performance index

The strong relationships between fork length and weight were determined ($P < 0.001$, $r^2 > 0.97$). The values of *b* parameter of length-weight relationships were observed as expected, between the ranges of 2.5 to 3.5. On the other side, *b* values in fish changes between 2 and 4 (Bagenal and Tesch, 1978). Calculated *b* parameters of length-weight relationship for females, males and all fish were higher than 3, which is an isometric growth indicator. This conclusion shows that species growth is positive allometric. Our findings of length-weight relationship parameters highly correspond to conclusions of studies at other habitats. However, there are some differences (Table 8). The number of samples, length-weight distributions, sampling time, used length type and ecological conditions of habitats may have led to these differences. Length-weight relationship in fish is not stable. It changes depending on food sufficiency, feeding ratio, gonad development and reproduction period (Bagenal and Tesch, 1978).

Table 8. Parameters of length-weight relation for rudd from different study areas

Locality	Sex	*a*	*b*	r^2	Reference
Lake Hamam	All	0.7252	4.267	-	Erdem et al., 1994
Lake Kuş	All	0.0066	3.460	0.99	Balık et al., 1997
Lake Volvi[+]	All	0.0036	3.480	0.99	Kleanthidis et al., 1999
Lake Hiidenvesi[+]	All	0.00003	3.305	0.99	Nurminen et al., 2003
Lake Sapanca[+]	All	0.0040	3.373	-	Okgerman, 2005
Ter River[+]	All	0.0030	3.459	0.98	Miranda et al., 2006
Büyük Çekmece Res.[+]	All	0.0078	3.210	0.99	Tarkan et al., 2006
Ömerli Res.[+]	All	0.0059	3.280	0.99	
Lake Sapanca[+]	All	0.0116	3.020	0.99	
Terkos Res.[+]	All	0.0035	3.450	0.98	
Lake Uluabat[+]	Female	0.0039	2.926	-	Koyuncu, 2007
	Male	0.0026	3.150	-	
Lake Gölhisar	Female	0.0141	3.107	0.90	Bostancı et al., 2007
	Male	0.0195	2.983	0.91	
	All	0.0146	3.093	0.92	
Bafra Fish Lakes	All	0.0105	3.230	0.98	Gumus et al., 2007
Lake Uluabat	All	0.0099	3.217	0.98	Çınar et al., 2008
Ömerli Res.[+]	Female	0.0059	3.280	0.99	Gürsoy, 2008
	Male	0.0081	3.150	0.99	
	All	0.0066	3.240	0.99	
Lake Uluabat[+]	Female	0.0087	3.178	0.94	Emiroğlu et al., 2010
	Male	0.0091	3.159	0.93	
	All	0.0064	3.273	0.97	
Anzali Lagoon[+]	Female	0.0145	2.930	0.84	Patimar et al., 2010
	Male	0.0933	3.060	0.86	
	All	0.0490	3.010	0.86	
Anzali Lagoon[+]	All	0.0055	3.361	0.96	Moradinasab et al., 2012
Lake Ladik	Female	0.0060	3.386	0.98	This study
	Male	0.0078	3.282	0.98	
	All	0.0062	3.371	0.98	

[+]Total length; *a*, intercept; *b*, slope; r^2, coefficient of determination

Condition factor, also named as condition coefficient or length-weight factor, is a parameter that shows how healthy fish is or how well it feeds. Changes in condition factor firstly indicate gonad development and feeding level (Wootton, 1990). Furthermore, condition factor is known to change in accordance with habitat, year, season, age group, sex and spawning period (Erkoyuncu, 1995). In this study, condition factor was analysed with reference to sex, age and length groups. Statistical analyses indicated that the mean condition factor of males was different from females. In other words, condition of females is better than that of males. This conclusion coincides with the findings of Tarkan (2006) and Bostancı et al. (2007). Also, condition factor value goes up in parallel with increasing age. Calculations conducted with regard to length groups have supported this outcome. Balık et al. (1997), Çınar et al. (2008) and Gürsoy (2008) stated that condition of rudd went up depending on age, and Okgerman (2005) indicated that the condition showed an upward trend depending on length groups.

In this study, relationships among total, fork and standart lengths of species were determined and an opportunity was provided for length types to convert each other. Employing different length measurements at different studies has made it difficult for studies to be compared with each other and to interpret the results. In some studies related to the species, fork length was employed, in others total length, and in some of the studies standard length was used. Despite the importance of length transformation, these equations were only given in few studies (Gürsoy, 2008; Moradinasab et al., 2012).

Consequently, when both length and weight distributions and age data were taken into account, it can be said that Lake Ladik population of the species is composed of young fish. Even though rudd has less economical value compared to pike (*Esox lucius*), perch (*Perca fluviatilis*) and bream (*Abramis brama*) in this lake, it is caught by local fisherman and marketed to people in the region. For this reason, hunting pressure is higher on big individuals. In addition to this, it is tought that preferring large bodied rudd individuals of pike, characterized as piscivorous (Yazıcıoğlu, 2014), can be contributed to the present situation. On the other hand, fecundity and biomass of the fish should be determined in order to gain more precise data on density and stock structure of rudd. Growth parameters, length-weight relation and condition factor values have indicated that growth of rudd is slow in Lake Ladik conditions. This situation can be attributed to the species being slow-growing and long-living, and nutrition competition due to fish density (especially Cyprinidae members) in the lake. To test the present perspective, it is necessary to study feeding features of rudd and other fish species in Lake Ladik.

ACKNOWLEDGEMENTS

We would like to thank the local fishermen for their help during sampling.

Sažetak

STRUKTURA POPULACIJE I RAST CRVENPERKE, *Scardinius erythrophthalmus* (L., 1758), IZ EUTROFNOG JEZERA U JUŽNOJ ANATOLIJI

Prikupljeno je ukupno 1329 uzoraka mjesečnim uzorkovanjem između studenog 2009. i listopada 2010. radi analize mogućnosti rasta i strukture populacije crvenperke, *Scardinius erythrophthalmus,* koja obitava u eutrofnom jezeru Ladik. Dužina do vilice (FL) kretala se u rasponu od 9,8 do 21,4 cm, a tjelesna težina (W) u rasponu 13,62-200,68 g. Na temelju čitanja otolita (lapillus), maksimalna dob iznosila je sedam godina. Ukupni omjer ženki i mužjaka je iznosio 1: 0,16. Von Bertalanffy-evi parametri rasta su izračunati kao L_∞ = 39,32 cm, W_∞ = 1504,92 g, k = 0,08, t_0 = -1,08 za ženke i L_∞ = 28,19 cm W_∞ = 448,03 g, k = 0,13, t_0 = -1,19 za mužjake. Dužinsko maseni odnos prikazan je jednadžbom $W = 0{,}0060\ FL^{3{,}386}$ za ženke i $W = 0{,}0078\ FL^{3{,}282}$za mužjake. Fultonovim kondicijskim faktorom (K) prikazan je uzlazni trend s obzirom na dob i duljinu skupina u oba spola. Srednja vrijednost K iznosila je 1,737 za ženke, 1,667 za mužjake i 1,727 za oba spola. Ova studija daje podatke o strukturi populacija, mogućnosti rasta i kondicije crvenperke iz jezera Ladik. Dobiveni podaci pokazali su da se populacije sastoje od mlađih individua, a stopa rasta vrste je spora.

Ključne riječi: dob, parametri rasta, faktor kondicije, lapillus, Jezero Ladik

REFERENCES

Bagenal, T. B., Tesch, F. W. (1978): Age and growth. pp. 101-136. In: Bagenal T. B. (eds). Methods for Assessment of Fish Production in Freshwaters. Blackwell Scientific Publications, Oxford, UK. 365pp.

Balık, S., Ustaoğlu, M. R., Sarı, H. M. (1997): Kuş Gölü'ndeki (Bandırma) kızılkanat (*Scardinius erythrophthalmus* (L., 1758)) populasyonunun büyüme ve üreme özellikleri. In: IX. Ulusal Su Ürünleri Sempozyumu; 1997 September 17-19, Turkey. Isparta, p. 8-12.

Balkuvienė, G., Kesminas, V., Virbickas, T. (2003): Fish diversity and growth in Lakes of Aukštaitija National Park. Acta Zoologica Lituanica 13, 4, 355-371.

Beklioglu, M., Meerfhoff, M., Søndergaard, M., Jeppesen, E. (2011): Eutrophication and restoration of shallow lakes from a cold temperate to a warm Mediterranean and a (sub) tropical climate. pp. 91-108. In: Ansari, A. A., Sarvajeet, S. G., Lanza, G. R., Rast, W. (eds). Eutrophication: Causes, Consequences and Control. Springer, New York, USA. 394pp.

Berka, R. (1989): Inland Capture Fisheries of the USSR. FAO Fisheries Technical Paper, No. 311, Roma, 143 pp.

Blackwell, B. G., Kaufman, T. M., Miller, W. H. (2009): Occurrence of rudd (*Scardinius erythrophthalmus*) and dynamics of three populations in South Dakota. Journal of Freshwater Ecology, 24, 2, 285-291.

Bostancı, D., Yılmaz, S., Polat, N. (2007): Gölhisar Gölü (Burdur)'ndeki kızılkanat (*Scardinius erythrophthalmus* Linnaeus, 1758) populasyonunda yaş belirleme, boy-ağırlık ilişkisi ve kondisyon faktörü üzerine bir araştırma. Türk Sucul Yaşam Dergisi, 5-8, 99-107.

Çınar, Ş., Küçükkara, R., Ceylan, M., Çubuk, H., Erol, G. K., Akçimen, U., Savaşer, S. (2008): Uluabat Gölü'ndeki kızılkanat (*Scardinius erythrophthalmus* L., 1758) populasyonunun büyüme parametrelerinin araştırılması. Ege Üniversitesi Su Ürünleri Dergisi, 25, 4, 289-293.

Emiroğlu, Ö., Sarı, H. M., Şahin, Y. (2010): Growth parameters research of the rudd, *Scardinius erythrophthalmus*, in Lake Uluabat. Journal Applied Biological Sciences, 4, 1, 23-28.

Erdem, Ü., Kırgız, T., Güher, H., Türeli, C. (1994): Hamam Gölünde (Kırklareli-İğneada) yaşayan kızılkanat (*Scardinius erythrophthalmus* L., 1758) ve havuz balığı (*Carassius carassius* L., 1758) türlerinin bazı biyolojik özellikleri. In: XII. Ulusal Biyoloji Kongresi; 1994 July 6-8, Turkey. Edirne, p. 122-128.

Erkoyuncu, İ. (1995): Balıkçılık Biyolojisi ve Populasyon Dinamiği. Sinop (Turkey), Ondokuz Mayıs Üniversitesi Basımevi, 265pp.

Gayanilo, P. C., Sparre, P., Pauly, D. (2005): FAO-ICLARM Stock Assessment Tools II (FISAT II) Revised Version User's Guide. Rome, FAO. 168pp.

Gumus, A., Bostanci, D., Yilmaz, S., Polat, N. (2007): Age determination of *Scardinius erythrophthalmus* (Cyprinidae) inhabiting Bafra Fish Lakes (Samsun, Turkey) based on otolith readings and marginal increment analysis. Cybium, 31, 1, 59-66.

Gürsoy, Ç. (2008): Ömerli Baraj Gölünde (İstanbul) kızılkanat balığının (*Scardinius erythrophthalmus* (Linnaeus, 1758)) bazı biyolojik özelliklerinin tespiti. Çanakkale (Turkey): Çanakkale Onsekiz Mart University. 97p.

Hicks, B. J. (2003): Biology and potential impacts of rudd (*Scardinius erythrophthalmus* L.) in New Zealand. In: Munro R, editor, Managing Invasive Freshwater Fish in New Zealand. Proceedings of a Workshop Hosted by Department of Conservation; 2001 May 10-12, New Zealand. Wellington, Department of Conservation, p. 49-58.

Horpilla, J., Nurminen, L. (2009): Food niche segregation between two herbivorous Cyprinid species in a turbid lake. Journal of Biology, 75, 6, 1230-1243.

Jokinen, H., Reinikainen, M. (2011): Potential ecological effects of cyprinid reduction fishery in Pikkala Bay. Project Report, University of Helsinki, Helsinki, Finland.

Kapuscinski, K. L., Farrell, J. M., Wilkinson, M. A. (2012): Feeding patterns and population structure of an invasive Cyprinid, the rudd *Scardinius*

erythrophthalmus (Cypriniformes, Cyprinidae), in Buffalo Harbor (Lake Erie) and the Upper Niagara River. Hydrobiologia, 693, 1, 169-181.

Kleanthidis, P. K., Sinis, A. I., Stergiou, K. I. (1999): Length-weight relationships of freshwater fishes in Greece. Naga The ICLARM Quarterly, 22, 4, 37-41.

Kottelat, M., Freyhof, J. (2007): Handbook of European Freshwater Fishes. Kottelat, Cornol, Switzerland and Freyhof, Berlin, Germany. 423pp.

Koyuncu, V. (2007): Uluabat Gölünde (Bursa) yaşayan *Scardinius erythrophthalmus* L.,1758 (kızılkanat balığı) populasyonunun büyüme parametrelerinin araştırılması. Eskişehir (Turkey): Osmangazi University, 19p.

Maraşlıoğlu, F. (2001): Ladik Gölü'nün (Ladik-Samsun-Türkiye) fitoplanktonu ve kıyı bölgesi algleri üzerine bir araştırma. Samsun (Turkey): Ondokuz Mayıs University, 61p.

Miranda, R., Oscoz, P., Leunda, M., Escala, M. C. (2006): Weight-length relationships of Cyprinid fishes of the Iberian Peninsula. J Appl Ichthyol 22, 4, 297-298.

Moradinasab, G. H., Daliri, M., Ghorbani, R., Paighambari, S. Y., Davoodi, R. (2012): Length-weight and length-length relationships, relative condition factor and Fulton's condition factor of five Cyprinid species in Anzali Wetland, Southwest of the Caspian Sea. Caspian Journal of Environmental Sciences, 10, 1, 25-31.

Munro, J. L., Pauly, D. (1983): A simple method for comparing growth of fishes and invertebrates. ICLARM Fishbyte, 1, 5-6.

Nikolsky, G. V. (1963): The Ecology of Fishes. London (UK), Academic Press. 352pp.

Nurminen, L., Horppila, J., Lappalainen, J., Malinen, T. (2003): Implications of rudd (*Scardinius erythrophthalmus*) herbivory on submerged macrophytes in a shallow eutrophic lake. Hydrobiologia, 506, 1-3, 511–518.

Okgerman, H. (2005): Seasonal variations in the length-weight relationship and condition factor of rudd (*Scardinius erythrophthalmus* L.) in Sapanca Lake. International Journal of Zoological Research, 1, 1, 6-10.

Patimar, R., Nadjafypour, E., Yaghouby, M., Nadjafy, M. (2010): Reproduction characteristics of a stunted population of rudd, *Scardinius erythrophthalmus* (Linnaeus, 1758) living in the Anzali Lagoon (the Southwest Caspian Sea, Iran). Journal of Ichthyology, 50, 11, 1060-1065.

Piria, M., Vrbanec, D., Đurđević, G. (2011): Von Bertalanffy growth curve of the rudd (*Scardinius erythrophthalmus* L.) from the Lake Ključić Brdo, Central Croatia. Ribarstvo, 69, 4, 127-136.

Prokeš, R., Řebičková, M. (1987): Seasonal growth of the fry rudd (*Scardinius erythrophthalmus*) in the Mušov Reservoir. Folia Zool, 36, 1, 73-83.

Quist, M. C., Pegg, M. A., DeVries, D. R. (2012): Age and growth. pp. 677-731. In: Zale, A., Parrish, D., Sutton, T. (eds), Fisheries Techniques. American Fisheries Society, Bethesda, Maryland, USA. 1009pp.

Ricker, W. E. (1975): Computation and interpretation of biological statistics of fish populations. Bulletin. Fisheries Research Board of Canada. 191, 1–382.

Sparre, P., Venema, S. C. (1998): Introduction to tropical fish stock assessment-Part 1. FAO Fisheries Technical Paper N 306. 1, 377p.

Šprem, N., Matulić, D., Treer, T., Aničić, I. (2010): A new maximum length and weight for *Scardinius erythrophthalmus*. J Appl Ichthyol, 26, 618-619.

Szypula, J. (2005): Scale radius growth versus standard length growth in some fish species. Arch Pol Fish, 13, 2, 235-249.

Tarkan, A. S. (2006): Reproductive ecology of two Cyprinid fishes in an oligotrophic lake near the Southern limits of their distribution range. Ecol Freshw Fish, 15, 2, 131-138.

Tarkan, A. S., Gaygusuz, Ö., Acıpınar, H., Gürsoy, Ç., Özuluğ, M. (2006): Length-weight relationship of fishes from the Marmara region (NW-Turkey). J Appl Ichthyol, 22, 4, 271-273.

Tarkan, A. S., Lappalainen, J., Nurminen, L., Horppila, J. (2010): Life history strategies of fish: patterns in growth and lifespan of rudd *Scardinius erytrophthalmus* (L.) in Europe. Pol J Ecol, 58, 1, 191-196.

Uğurlu, S., Polat, N., Kandemir, Ş. (2009): Changes in the Ladik fish community (1972-2004) and ichthyofauna of its inlet and outlet streams (Samsun-Turkey). Turk J Zool, 33, 4, 393-401.

Wootton, R. J. (1990): Ecology of Teleost Fishes. Kluwer Academic Publisher, Dordrecht, Netherlands. 404pp.

Yazıcı, R., Yılmaz, S., Yazıcıoğlu, O., Polat, N. (2014): Ladik Gölü (Samsun, Türkiye)'ndeki kızılkanat balığı (*Scardinius erythrophthalmus* L., 1758) populasyonunda en güvenilir yaş tayini yönteminin belirlenmesi. Ege Journal of Fisheries and Aquatic Sciences, 31, 1, 27-33.

Yazıcıoğlu, O. (2014): Ladik Gölü (Samsun)'ndeki turna balığı (*Esox lucius* L., 1758)'nın biyolojik özellikleri. Samsun (Turkey): Ondokuz Mayıs University. 133p.

Yılmaz, S., Yazıcıoğlu, O., Erbaşaran, M., Esen, S., Zengin, M., Polat, N. (2012): Length-weight relationship and relative condition factor of white bream, *Blicca bjoerkna* (L., 1758), from Lake Ladik. Turkey. J Black Sea/Mediterranean Environment, 18, 3, 380-387.

Zar, J. H. (1999): Biostatistical Analysis 4th edition. Prentice Hall, New Jersey, USA. 663pp.

Zerunian, S., Valentini, L., Gibertini, G. (1986): Growth and reproduction of rudd and red-eye roach (Pisces, Cyprinidae) in Lake Bracciano. Boll Zool, 53, 1, 91-95.