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Artificial neural networks approach in length-weight relation of crayfish (*Astacus leptodactylus* Eschscholtz, 1823) in Eğirdir Lake, Isparta, Turkey

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ABSTRACT

Objective: To analyze the growth prediction results of crayfish (*Astacus leptodactylus* Eschscholtz 1823) with two methods of length-weight relation (LWR) and artificial neural networks (ANNs).
Methods: We examine the relationships between total length and total weight; carapace length and total weight; carapace length and total length for *Astacus leptodactylus* caught from Eğirdir Lake between 2013 and 2014. Length weight relation is used as a traditional method and artificial neural networks as a new approach.
Results: The research is based on a sample of 222 crayfish [34% (75 individual) female, 66% (147 individual) male]. The outcomes of the research can be summarized as follows: average total length is 128.40 mm for female and 135.50 mm for male; average total weight is 59.79 g for female and 82.95 g for male crayfish. LWR equation was found to be $W = 0.054\,251\,96\ L^{2.73}$ for females, $W = 0.052\,721\,02\ L^{2.81}$ for males, and $W = 0.035\,898\,89\ L^{2.94}$ for the entire sample, regardless of gender. The results acquired from ANNs and LWR are analyzed to those obtained by the growth rate of crayfish caught from Eğirdir Lake.
Conclutions: LWR and ANNs mean absolute percentage error results were examined. ANNs provide better results than the LWR. ANNs can be considered as an alternative for growth estimation.

1. Introduction

There is considerable interest in raising narrow clawed crayfish, *Astacus leptodactylus* (Escholtz, 1823) (*A. leptodactylus*), due to their high commercial value and limitations of current farming practices in dams and ponds[1].

Ecological roles of freshwater crayfish are reasonably well understood after a few decades of study. It is recognized as having an important and rather unique position in aquatic food webs[2]. It is known that freshwater habitats of crayfish are found in food webs. For this reason, they are often selected as flagship species for water protection[3].

Narrow-clawed crayfish is a widespread species distributed throughout Europe, Eastern Russia, and the Middle East[4]. The characteristics measured in these species are carapace length, body length, total length, body width, and wet weight[5]. Metric measures between individual body parts are used to show the morphological changes between gender of crayfish species[6]. If one of the metric measurements is known and the length-weighted regression can be used to calculate the length from the weight, it may be appropriate to be able to convert it to the desired length measurement[7].

Relationships between variables in these relationships are often non-linear or discovered. In regression, a transformation to achieve linearity is a special kind of nonlinear transformation. It is a nonlinear transformation that increases the linear relationship between two variables. Despite of these arrangements, the results are often inadequate and provide an insufficient forecast value for scientific studies. Besides all these results, artificial neural networks (ANNs) are emerging as nonlinear models. They do not require conversion of the parameters used and can give the desired good results[8].

Traditional statistical methods used in academic studies may be insufficient for quantification[9]. ANNs emerge as an alternative method to traditional statistical approaches for forecast modeling in nonlinear situations[10]. ANNs can be used in regression analysis involving nonlinear relations[11].

ANNs are used in prediction, classification, data association, data interpretation and data filtering processes in various disciplines of water ecology instead of biology and physical or chemical science[9-16]. Many studies have been carried out in forecasting studies because

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they give better results than conventional methods[14,17].

ANNs provide better estimates of predicted variable independence. There are many comparative studies with linear regressions methods in the literature[18]. Another advantage of ANNs is that they are fast and flexible[19].

In this research, ANNs have established an alternative method for its application in forecasting the growth of crayfish. The main goal of the current research is to study length-weight relation (LWR) and ANNs for growth in crayfish.

2. Materials and methods

2.1. Study area

The Eğirdir Lake is located within Turkey's South-West Mediterranean Region (Figure 1). Eğirdir Lake is geographically placed between 30°57'43" E & 30°44"30' E and 37°50"41' N & 38°16'55" N. Eğirdir Lake is 48 km long in north south direction. The widest part is 16 km, the maximum depth is 12.5 m and the average depth is 6.7 m[20].

2.2. Data collection

In this study, 222 crayfish individuals (75 females and 147 males) were taken between 2013 and 2014 from Eğirdir Lake. The carapace length (CL), abdomen width (Aw), abdomen length (AL), carapace width (Cw), and chela length (ChL), chela width (Chw) and total length (TL), total weight (TW) of each specimen were measured with a digital caliper to 0.1 mm, weighted to 0.01 g, and each specimen was sexed[21]. The crayfish obtained from the lake were directly moved to the laboratory for measurement taking. The length and weight (min-max) of the crayfish were 105–166 mm and 38.31–160.08 g, respectively.

2.3. LWR equation

Gender and length composition, average length and weight, and length-weight relationship for each gender and combined gender were determined from samples. LWR was forcested from the formula, $W = a L^b$, where W is total body weight (g), L the total length (mm), a and b are the coefficients of the functional regression between W and L[22].

2.4. ANNs

ANNs are modeled on the brain where neurons are connected in complex patterns to process data from the senses, establish memories and control the body. ANN is a system based on the operation of biological neural networks or it is also defined as an emulation of biological neural system[23].

ANNs biological systems are simulated with mathematical models. ANNs are normally organized into layers of processing units. Connections can be made either from units of one layer to units of another or from the units within the layer or both inter and interlayer connections[24].

Benefit of artificial neuron model's[25] simplicity can be seen in its mathematical manifestation below:

$$y(k) = F\left(\sum_{i=0}^{m} w_i(k).x_i(k)\right)$$

where $w_i(k)$ is weight value in discrete time k and i goes from 0 to m, $x_i(k)$ is input value in discrete time k and i goes from 0 to m, F is a transfer function, and $y_i(k)$ is output value in discrete time k.

Once a network has been structured for a application, it is ready to be trained. To start this operation, the initial weights are chosen randomly. Then, the training, or learning, starts. There are two approaches to training – supervised and unsupervised[26]. In this study, supervised learning method trained with the network structure (back-propagation networks) was used.

In this study, mean absolute percentage error (MAPE) and sum squared error (SSE) are used as the two performance criteria. During the training of the network, SSE was used as a criterion to determine the training of ANNs. More than one method is used in comparison. Because only MAPE results can give wrong results.

ANNs tool of matrix laboratory application is used for the ANNs operations. With these settings, the input vectors and target vectors will be randomly divided into three sets as follows: 70% will be

Figure 1. Area of study.

used for training. 15% will be used to validate that the network is generalizing and to stop training before overfitting. The last 15% will be used as a completely independent test of network generalization. The correlation coefficient was used to gauge the linear dependence between two random variables. In this research, correlation can be described using that Evans[27] suggested for the absolute values (0.00–0.19: very weak, 0.20–0.39: weak, 0.40–0.59: moderate, 0.60–0.79: strong, 0.80–1.0: very strong). The obtained values were found to be statistically significant. Statistical analyses of the present study were performed using SPSS software (SPSS Inc., USA).

3. Results

There were about 34% females, 66% males. The female: male ratio was detectedto be 0.51:1 for the all individual. The weight and length (min-max) of the crayfish were 105–166 mm and 38.31–160.08 g. The average weight and length of samples were (135.50 ± 16.00) mm and (82.95 ± 28.11) g for males, (128.40 ± 11.14) mm and (59.79 ± 15.28) g for females and (133.10 ± 10.49) mm and (75.12 ± 26.84) g for the combined sexes, respectively (Table 1).

LWR (TL-TW) for the crayfish in Eğirdir Lake were found as $W = 0.054\,251\,96\ L^{2.74}$ for females, $W = 0.052\,721\,02\ L^{2.81}$ for males and $W = 0.035\,898\,89\ L^{2.94}$ for both sexes. The carapace length-weight relations (CL-TW) were found as $W = 2.920\,608\,75\ L^{1.63}$ for females, $W = 2.892\,498\,03\ L^{1.72}$ for males and $W = 2.350\,844\,74\ L^{1.80}$ for both sexes. The carapace length-length relations (CL-TL) for the crayfish in Eğirdir Lake were found as $W = 2.807\,181\,47\ L^{0.82}$ for females, $W = 2.528\,516\,70\ L^{0.87}$ for males and $W = 2.615\,067\,72\ L^{0.85}$ for both sexes. The abdomen lenght-total weight (AL-TW) were found as $W = 7.439\,736\,95\ L^{1.12}$ for females, $W = 7.186\,800\,36\ L^{1.26}$ for males and $W = 6.456\,363\,28\ L^{1.28}$ for both sexes. The chela width-abdomen width (Chw-Aw) for the crayfish in Eğirdir Lake were found as $W = 2.303\,537\,56\ L^{0.47}$ for females, $W = 2.412\,022\,75\ L^{0.26}$ for males and $W = 2.463\,280\,67\ L^{0.28}$ for both sexes (Table 2 and Figure 2).

Table 1

Some metric properties for crayfish.

Metric species	Sex	Median ± S_x	Min–Max	*t* test
TL	F	128.40 ± 11.14	110–150	$P < 0.05$
	M	135.50 ± 16.00	105–166	
	F + M	133.10 ± 10.49	105–166	
TW	F	59.79 ± 15.28	38.31–91.0	$P < 0.05$
	M	82.95 ± 28.11	42–160.08	
	F + M	75.12 ± 26.84	38.31–160.08	
CL	F	63.60 ± 7.00	50–75	$P < 0.05$
	M	67.30 ± 9.90	45–80	
	F + M	65.90 ± 9.10	45–80	
Cw	F	65.60 ± 8.10	45–80	$P < 0.05$
	M	64.70 ± 10.90	25–80	
	F + M	65.00 ± 9.90	25–80	
AL	F	63.90 ± 7.40	45–80	$P < 0.05$
	M	65.80 ± 11.90	45–103	
	F + M	65.10 ± 10.49	45–103	
Aw	F	37.40 ± 19.50	15–85	$P < 0.05$
	M	33.80 ± 16.00	15–75	
	F + M	35.10 ± 17.30	15–85	
ChL	F	80.90 ± 21.20	50–135	$P < 0.05$
	M	104.50 ± 31.50	55–173	
	F + M	95.90 ± 30.20	50–173	
Chw	F	23.30 ± 10.10	13–49	$P < 0.05$
	M	30.20 ± 19.00	10–75	
	F + M	27.70 ± 16.60	10–75	

F: Female; M: Male.

The multilayer feed-forward neural network was used during ANNs operations. A simple typical ANNs is also seen in the Figure 3.

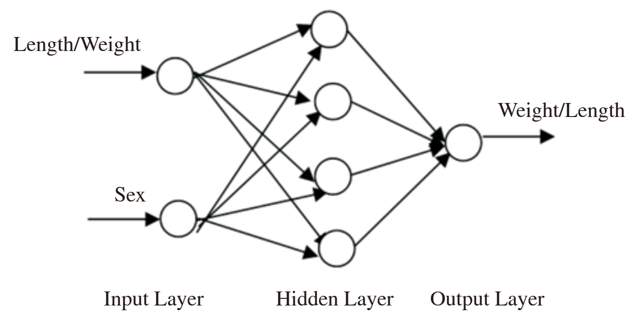

Figure 3. The ANNs model.

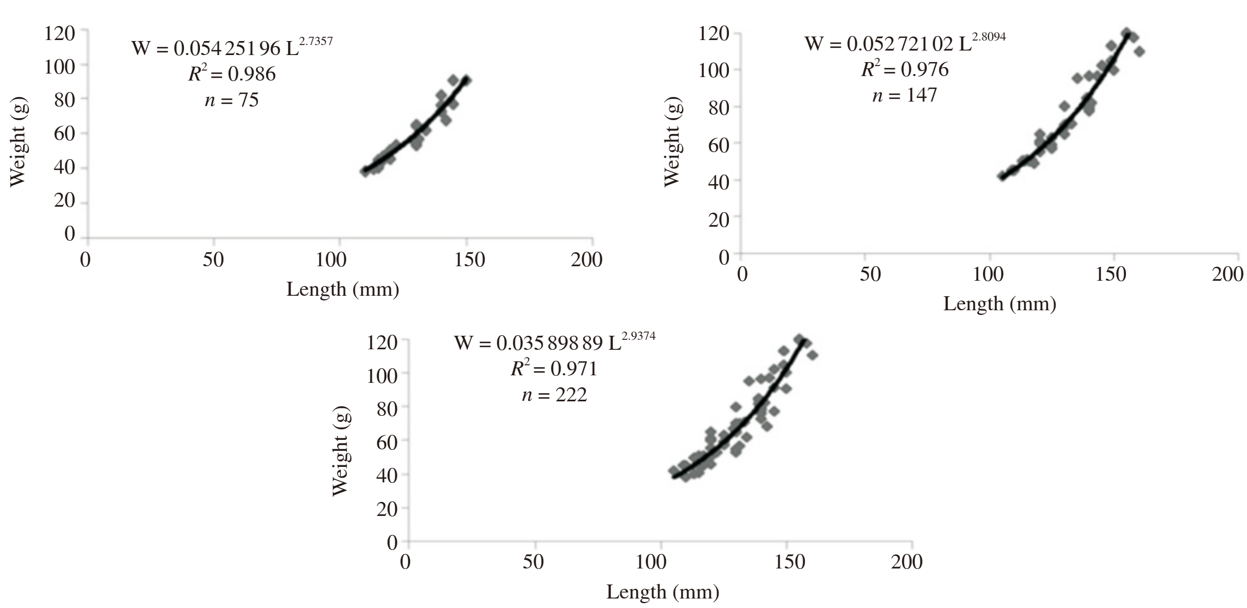

Figure 2. Length-weight relationships in female (a), male (b) and all genders (c).

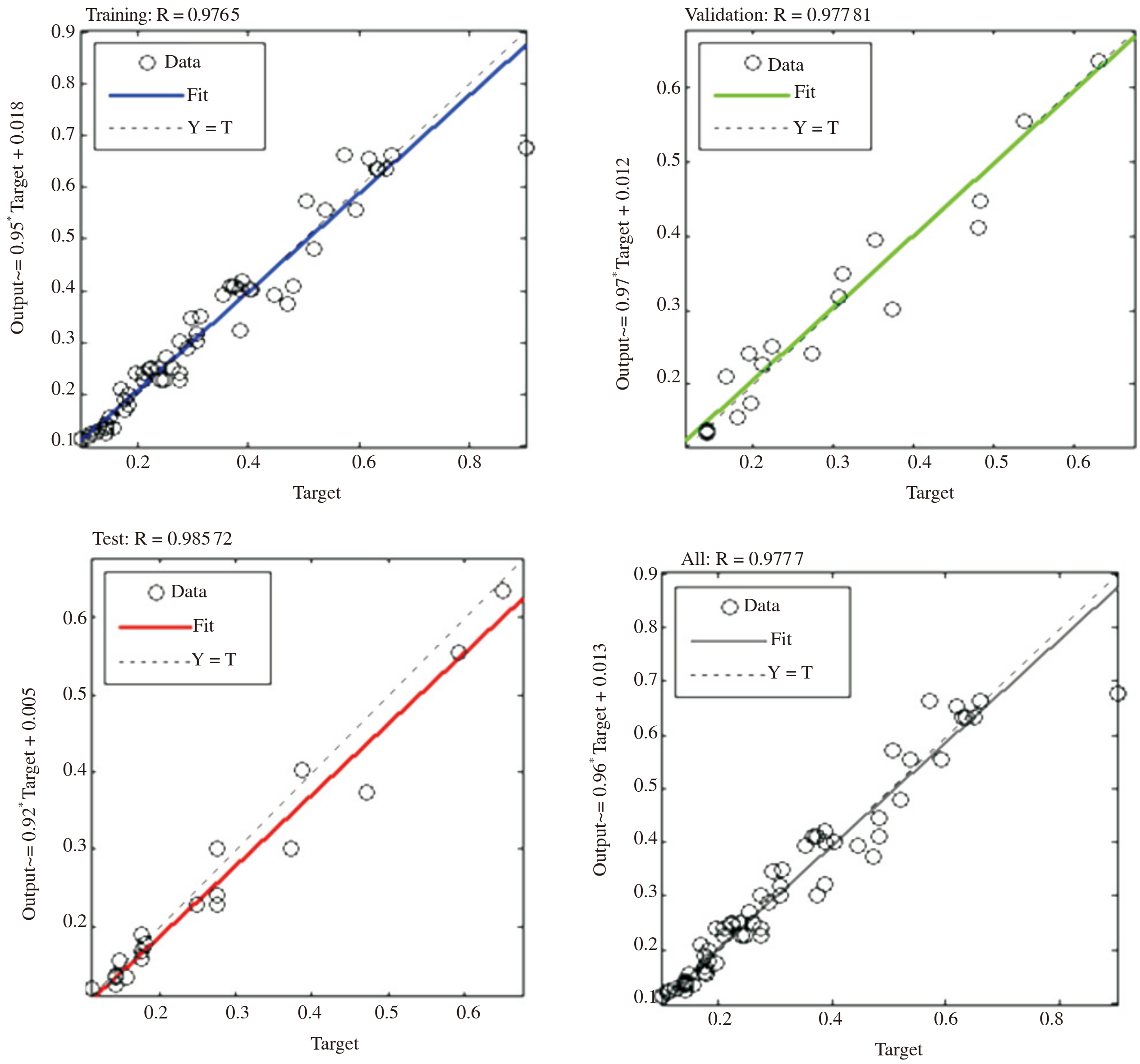

Figure 4. Relationship between observed, forecast values of ANNs for TL-TW.

Table 2
Length-weight relation parameters, equations and correlation coefficients.

Species	Sex	Relationship	R^2
TL-TW	F	$W = 0.054\,251\,96\ L^{2.7357}$	0.986
	M	$W = 0.052\,721\,02\ L^{2.8094}$	0.976
	F + M	$W = 0.035\,898\,89\ L^{2.9374}$	0.971
CL-TW	F	$W = 2.920\,608\,75\ L^{1.6308}$	0.981
	M	$W = 2.892\,498\,03\ L^{1.7254}$	0.968
	F + M	$W = 2.350\,844\,74\ L^{1.8041}$	0.967
CL-TL	F	$W = 2.807\,181\,47\ L^{0.8181}$	0.998
	M	$W = 2.528\,516\,70\ L^{0.8708}$	0.997
	F + M	$W = 2.615\,067\,72\ L^{0.8543}$	0.988
AL-TW	F	$W = 7.439\,736\,95\ L^{1.1205}$	0.976
	M	$W = 7.186\,800\,36\ L^{1.2635}$	0.962
	F + M	$W = 6.456\,363\,28\ L^{1.2764}$	0.960
Chw-Aw	F	$W = 2.303\,537\,56\ L^{0.4661}$	0.877
	M	$W = 2.412\,022\,75\ L^{0.2552}$	0.813
	F + M	$W = 2.463\,280\,67\ L^{0.2795}$	0.814

F: Female; M: Male.

Figure 4 shows that the values between forecast values for TL-TW forecasted by the models established by ANNs are significantly close to the observed values, while the values estimated by the models established by multiple linear regression are well below the values observed.

Measured values, ANNs and LWR data are shown in Table 3. Measured values of length and weight were classified by gender of the group. Calculated data observed from the ANNs and LWR. Table 3 is provided for comparison of data of the crayfish in Eğirdir Lake with LWR and ANNs approach. It was found that the ANNs MAPE values in TL-TW, CL-TW, AL-TW and ChL-TW were better than MAPE values calculated in relation with regression. In the CL-TL relationship, the MAPE values of the regression relation were found to be better than the ANNs MAPE values (Table 3).

Table 3

Calculated values for ANNs and LWR with MAPE.

Type (1) - (2)	ANNs		MAPE (%)		LWR		MAPE (%)	
	1	2	1	2	1	2	1	2
TL (1)	130.080	62.127	1.277	3.909	129.430	58.550	0.771	2.074
TW (2)	135.340	81.950	0.140	1.206	137.380	79.860	1.365	3.725
	133.720	73.310	0.436	2.409	135.050	72.050	1.435	4.087
CL (1)	64.022	59.670	0.727	2.036	64.400	59.610	1.322	2.134
TW (2)	68.510	87.150	0.175	2.409	69.900	81.720	2.208	3.972
	66.340	74.770	0.629	2.808	68.300	73.640	2.307	4.277
CL (1)	64.029	124.910	0.738	2.047	63.600	127.450	0.063	0.055
TL (2)	67.950	137.350	0.643	1.892	68.500	134.680	0.161	0.089
	66.250	131.230	0.764	0.839	66.810	132.250	0.075	0.068
AL (1)	63.590	59.270	0.516	2.692	65.300	59.470	2.159	2.364
TW (2)	66.530	82.910	0.498	2.573	68.350	81.610	3.248	4.101
	65.110	74.880	0.489	2.665	67.750	73.410	3.546	4.576
ChL (1)	93.700	59.120	6.477	2.939	81.650	60.460	7.216	0.739
TW (2)	101.780	79.720	1.415	6.322	108.630	82.450	8.240	3.114
	98.030	73.990	1.913	3.822	99.410	74.890	3.348	2.652
MAPE (%)		0.846	2.508		2.142	3.132		

4. Discussion

Morphometric characteristics are greatly influenced by environmental factors such as nutrition, behavior, nutrition efficiency and availability and quality of food resources[6]. Environmental factors may impact crayfish growth by affecting foraging efficiency, feeding behavior, and the availability and quality of food resources. The relationship has been used to describe growth and the effects of environmental conditions on growth patterns, but the functional relationships vary among species. Furthermore, simple length-weight patterns may have the potential for indicating differential growth that may be associated with the severity of environmental stress across the range of the species. Even though the change of b value depends primarily on the shape and fatness (size) of the species, various factors may be responsible for the differences in parameters of the length-weight relationships among seasons and years, including temperature, sex, food, salinity, time of year, and stage of maturity. The parameter b, unlike the parameter a, may vary seasonally, even daily, and between habitats[28].

The calculated LWR is model dependent; as a result, model selection uncertainty may be quite higher in certain data sets. Ignoring model selection uncertainty may cause substantial overestimation of the precision and estimation of the confidence intervals of the parameters below the nominal level. This uncertainty has serious implications, *e.g.*, in the case of comparing the growth parameters of different crayfish populations.

The MAPE benchmark refers to forecast errors as a percentage, and can therefore negate the disadvantages that may arise when correlating models developed for examines with different values. These features of MAPE are considered to be superior to those of other evaluation statistics. The MAPE results were assessed according to literature (0%–10%: Very Good, 10%–20%: Good, 20%–50%: Acceptable, 50%–100%: Wrong and Faulty)[29,30].

The TL-TW relationship, which displayed the estimate power of the developed ANNs, was found to be 0.977 as the R^2 (for all individuals) values.

When the R^2 is 0.95–1.0, the success rate is considered to be high[31].

The coefficient correlation (R^2) calculated by the LWR regression model was 0.971. When the coefficient correlation (R^2) was evaluated in both ANNs and LWR model, the results of ANNs were better, although they did not seem close to each other. It is evaluated that comparing the MAPE values together with R^2 values can give a healthy result[32].

LWR and ANNs MAPE results were examined. MAPE value of the predict of ANNs is found to be 0.846 and 2.508, while MAPE value of relationship results is 2.142 and 3.132 for length-weight of both genders. According to Table 3; ANNs give better results than LWR. It is reported in the literature that the ANNs MAPE values are low[14,33-36].

In conclusion, the study found the use of ANNs as a forecasting tool to provide good results. ANNs can be considered as an alternative for growth estimation. The morphometric characteristics can be helpful in comparing the same species in different locations. We have demonstrated that the study of crayfish properties could be used to describe populations. This study also supports some information on the LWR that would be beneficial for management of fisheries in Eğirdir Lake. Finally, the crayfish population should be watched carefully in the coming years to ensure sustainable economic yield.

Conflict of interest statement

We declare that we have no conflict of interest.

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