J. Black Sea/Mediterranean Environment
Vol. 21, No. 2: 208-223 (2015)

RESEARCH ARTICLE

The comparison of growth with length-weight relation and artificial neural networks of crayfish, *Astacus leptodactylus*, in Mogan Lake

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Abstract

This study aimed to determine some morphological characteristics of freshwater crayfish, *Astacus leptodactylus* Eschscholtz 1823, populations in Mogan Lake, Turkey. Samplings were done between 2 July and 30 October in 2006 and 2007 with a random method. We present the relationships between total length (TL), carapace length (CL), chelae length (ChL), abdomen length (AL) and total weight (TW) for *A. leptodactylus* from Mogan Lake. Study was conducted in 112 individuals (14 female, 98 male). The research was found as 87.5 % male, 12.5 % female of crayfish thought investigation female and male ratios was of determined as to 0.14 /1.00. Avarage total length was 108.71 mm for female, 102.93 mm for male, average total weight was 28.64 g for female, 32.49 g for male. Length-weight relation equation was found for females $W=0.0022\ L^{2.01}$ for males $W=0.00095\ L^{2.23}$. The results obtained by artificial neural networks and length-weight relation equation are compared to those obtained by the growth rate of the crayfish caught from Mogan Lake. Length-weight relation and artificial neural network MAPE (mean absolute percentage error) results were examined. Artificial neural networks gives better results than length-weight relation. Artificial neural networks can be alternative as a evaluated for growth estimation.

Keywords: artificial neural networks, crayfish, estimated, length-weight relation, Mogan Lake

Introduction

The importance of crayfish in the food webs of freshwater habitats has been recognised for a long time; thus, they are regarded as a flagship species for comprehensive water protection (Füreder *et al.* 2003).

Astacus leptodactylus is a widespread species distributed throughout Europe, the eastern Russia, and the Middle East (Souty-Grosset *et al.* 2006). Freshwater crayfish has had an economic importance in Turkish markets. Recently, there has been an increase, gradually. In 1990s, the annual crayfish production was between 300 and 500 tonnes. In 2011, crayfish production in Turkish freshwater was 1681 tonnes. (TUIK 2011).

Water bodies in British Isles, Norway and Turkey remained long the last safe havens for the European crayfish (Souty-Grosset *et al.* 2006) until mid 1980's, after which many productive native narrow clawed crayfish, *A.leptodactylus* stocks collapsed in Turkey (Harlıoğlu 2004). As a result, the crayfish trapping and export ceased from Turkey to Europe. The stock collapses in Turkey were partial in some water bodies with up to 25% survival (Harlıoğlu and Harlıoğlu 2006). The collapsed narrow clawed crayfish stocks have later recovered substantially in Turkey (Güner and Harlıoğlu 2010).

The most frequently used dimensions for crustaceans are carapace length, body length, total length, body width, and wet weight (Primavera *et al.* 1998). To demonstrate the morphological differences between male and female crayfish are seen in length of individual parts of the body (Lindqvist and Lahti 1983). These differences also in the determination of the crayfish populations, relative growth, comparing the populations of the same species, the comparison of the morphology of crayfish species is used in the systematic classification of crayfish (Lindqvist and Lahti 1983; Skurdal and Qvenild 1986; Gillet and Lauren 1995). To convert into the desired length measurements may be convenient when only one of other length measurements is available and the length-weight regression may be used to estimate length from weight (Tosunoğlu *et al.* 2007).

Relationships among variables (i.e., weight-carapace length/width relationships) are often non-linear or unknown. Thus independent variables are transformed by linear regression. Despite these manipulations, however, the results often remain disappointing and offer poor predictive value. However, ANNs (Artificial Neural Networks) are nonlinear-type models. They do not necessitate the transformation of variables and can yield better results (Yanez *et al.* 2010). Traditional methods of statistical analysis (i.e., linear regression models, both single and multiple) may be inadequate for quantification (Maravelias *et al*. 2003). ANNs offer a promising alternative to traditional statistical approaches for predictive modeling when non-linear patterns exist (Joy and Death 2004). ANNs could be used to substitute for regression analyses, particularly those involving non-linear relationships (Mastrorillo *et al.* 1997).

ANNs have been used in biology and in various disciplines of aquatic ecology rather than in physical or chemical sciences (Türeli Bilen *et al.* 2011). Applications of ANNs have included predicting the distributions of demersal fish species (Maravelias *et al.* 2003), predicting the presences of small-bodied fish in a river (Mastrorillo *et al.* 199), predicting aquatic macro-invertebrate diversities (Park *et al.* 2003), modeling population dynamics of aquatic insects (Obach *et al.* 2001) and modeling and spatially mapping freshwater fish and assemblies of decapods (Joy and Death 2004).

The fact that the ANN provides a better model was highlighted by better predictions for lower values, the normality of the residuals and their independence from the predicted variable. Several authors reported greater performances of ANNs compared to linear regressions (Suryanarayana *et al.* 2008; Türeli Bilen *et al.* 2011; Sun *et al.* 2009). ANNs have another advantage in that the ANN modeling approach is fast and flexible (Brosse *et al.* 1999). In this study, the ANN demonstrated a new and alternative approach on its application in predicting the growth and weight of crayfish.

There are many literatures regarding the properties of crayfish in various water reservoirs, such as Karabatak and Tüzün (1989) in Mogan Lake, Harlıoğlu (1999) in Keban Dam Lake, Köksal *et al.* (2003) in Dikilitaş Pond, Harlıoğlu and Harlıoğlu (2005) in Eğirdir Lake, İznik Lake and Hirfanlı Dam Lake, Balık *et al.* (2005) in Demirköprü Dam Lake, Berber and Balık (2006) in Manyas Lake, Güner (2008) in Kavaklı Pond, Berber and Balık (2009) in Apolyont Lake and Deniz *et al.* (2013) inland water in Turkey.

The main purpose of the present study was to study length-weight relation and ANNs for growth in crayfish. Thus, the present study provides the properties of the crayfish in Mogan Lake in the recent years.

Materials and Methods

Mogan Lake is located about 20 km south of Ankara and lies within the coordinates of 39°44´40´´ N and 39°47´45´´ N latitudes and 32°46´30´´ E and 32°49´30´´ E longitudes (Figure 1). It is near Gölbaşı Town which has undergone considerable development by the increased population and settlement in recent years. A large number of commercial establishments such as restaurants, social clubs, tea gardens as well as summer resorts have been built around the lake which became a popular site for sports, fishing, sailing, and rowing (Anonymous 1989).

Crayfish samples were collected from Mogan Lake between 2 July and 30 October in 2006 and 2007. During the study, 112 crayfish specimens were caught. The total length (TL), total weight (TW), carapace length (CL), chelae length (ChL), chelae width (Chw) and abdomen length (AL) and abdomen width (Aw) of each specimen were measured with a digital caliper to the nearest 0.1 mm, while weighted to the nearest 0.01 g, and each specimen was sexed

(Rhodes and Holdich 1979). The crayfish obtained from the lake were immediately transported to the laboratory.

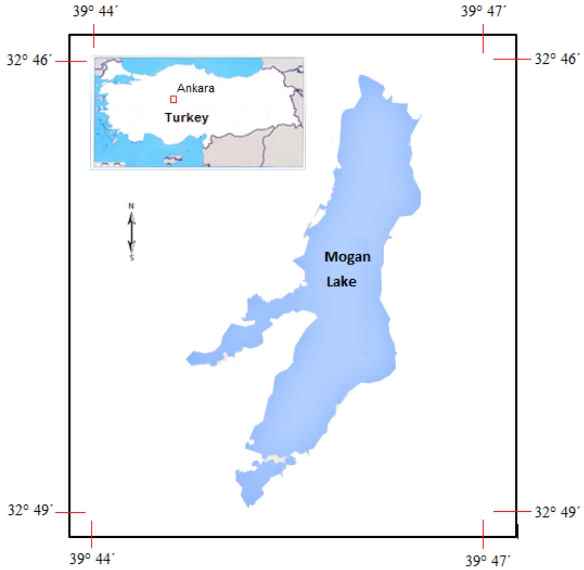

Figure 1. Map of Mogan Lake

Sex, maturity, mating, spawning and hatching statuses were recorded during the study. Sex and length composition, the average length and weight, and the length-weight relationship for each sex and combined sexes were determined.

The length-weight relationships were estimated 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 (Ricker 1973). The equation was log transformed to estimate the parameters ‘a’ and ‘b’. When b is equal to three (3), isometric pattern of growth occurs but when b is not equal to 3, allometric pattern of growth occurs, which may be positive if >3 or negative if <3.

ANNs are computational systems that simulate biological neural networks and can be defined as a specific type of parallel processing system based on distributional or connectionist methods (Hopgood 2000). ANNs can reveal the power relations between unknown and unnoticed data. ANNs are simulations of biological nervous systems using mathematical models. They are networks with simple processor units, interconnections, adaptive weights and scalar measurement functions, e.g., summation and activation functions (Rumelhart *et al.* 1986). ANN mathematical expression is seen in Figure 2. *y* is the neuron’s output, *x* is the vector of inputs, and w is the vector of synaptic weights.

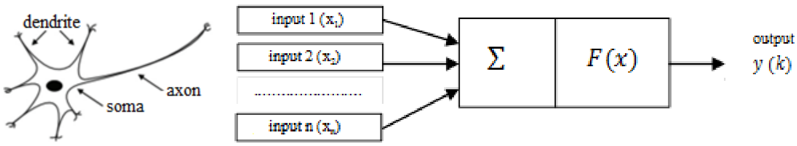

Figure 2. Biological and mathematical explanation for ANNs design

In case of biological neuron information comes into the neuron via dendrite, soma processes the information and passes it on via axon. In case of artificial neuron the information comes into the body of an artificial neuron via inputs that are weighted (each input can be individually multiplied with a weight). The body of an artificial neuron then sums the weighted inputs, bias and "processes" the sum with a transfer function. At the end an artificial neuron passes the processed information via output(s). Benefit of artificial neuron model (Krenker *et al.* 2011) simplicity can be seen in its mathematical description below:

$$y(k) = F\left(\sum_{i=0}^{m} w_i(k).x_i(k)\right) \qquad \text{(Equation 1)}$$

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

As seen from a model of an artificial neuron and its equation (1) the major unknown variable of our model is its transfer function. Transfer function defines the properties of artificial neuron and can be any mathematical function.

During the training of the network, the input data and the input-output relationship between the learning of the network is provided. This method, which is generally called supervised learning, is one of the preferred methods (Haykin 1999). The supervised learning method trained with the network structure (Back-propagation Networks) will be used to solve problems in this study.

In this study, the sum squared error (SSE) and MAPE (Mean Absolute Percentage Error) are used as the two performance criteria (Matlab 2006) SSE was used as a criterion for determine training during the training of the network. In addition, we can make comparisons involving more than one method because the MAPE of each provides information about the average relative size of their errors.

SSE and MAPE are described by equations 2 and 3, respectively.

$$SSE = \sum_{i=1}^{n} e_i^2 \qquad \text{(Equation 2)}$$

$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{e_i}{Y_i} \right| * 100 \qquad \text{(Equation 3)}$$

Where Y_i is the actual observation value, e_i is the difference between the actual value and prediction value, and n is the number of total observations.

Neural Network Toolbox of MATLAB was used for the ANN calculations. Data were divided into three equal parts: training, validation and test sets. The Matlab functions were used for “training”, “testing”, and “validation”. They were used randomly: 70% in training, 15% in testing, and 15% in the validation of the crayfishes.

Results

There were about 12.50 % females, 87.50 % males (14 female, 98 male). The female: male ratio was found to be 0.14:1 for the general population. The length and weight (min-max) of the crayfish were 87 – 124 mm and 18.28 – 60.76 g. The average length and weight of samples were 102.93 ± 7.65 mm and 32.49 ± 0.9 g for male, 108.71 ± 6.36 mm and 28.64 ± 4.81 g for females and 103.65 ± 7.72 mm and 32.11 ± 6.94 g for the combined sex, respectively (Table 1).

TL, Aw, AL, and CL were bigger in females than in males, while TW, ChL and Chw were bigger in males than in females (Table 1). The general difference between the TL, TW, CL, AL, Aw, ChL and Chw values of the female and males were found to significant (t-test, $p < 0.05$) (Table 1).

The CL/TL ratio of samples were 0.47 ± 0.02 for females, for 0.48 ± 0.04 males. The AL/TL ratio of samples were 0.38 ± 0.05 for female, for 0.39 ± 0.06 males. The Aw/AL ratio of samples were 0.99 ± 0.11 or female, for 0.82 ± 0.12 males.

The CL/AL ratio of samples were 0.30 ± 0.09 for females, 1.23 ± 0.16 for males. The CW /CL ratio of samples were 0.48 ± 0.05 for female, for 0.43 ± 0.07 males. (Table 2).

Table 1. Several metric characteristics for crayfish

Metric properties	Sex	Average ± S_x	Min-Max	t test
	F	108.71 ± 6.36	96.00 – 122.00	
TL	M	102.93 ± 7.65	87.00 – 124.00	P < 0.05
	FM	103.65 ± 7.72	87.00 – 124.00	
	F	28.64 ± 4.81	24.6 – 41.33	
TW	M	32.49 ± 7.09	18.28 – 60.76	P < 0.05
	FM	32.11 ± 6.94	18.28 – 60.76	
	F	51.43 ± 3.84	46.00 – 61.00	
CL	M	49.42 ± 5.85	38.00 – 67.00	P < 0.05
	FM	49.67 ± 5.66	38.00 – 67.00	
	F	39.79 ± 2.50	36.00 – 44.00	
AL	M	39.53 ± 6.53	27.00 – 54.00	P < 0.05
	FM	39.56 ± 6.17	27.00 – 54.00	
	F	40.51 ± 3.30	33.00 – 46.00	
Aw	M	32.27 ± 6.41	32.00 – 44.00	P < 0.05
	FM	33.31 ± 6.68	32.00 – 46.00	
	F	33.5 ± 4.52	26.00 – 40.00	
ChL	M	40.16 ± 7.01	24.00 – 58.00	P < 0.05
	FM	39.33 ± 7.09	24.00 – 58.00	
	F	15.43 ± 1.91	12.00 – 18.00	
Chw	M	17.05 ± 3.63	8.00 – 29.00	P < 0.05
	FM	16.85 ± 3.49	8.00 – 29.00	

S_x: Standard deviation.

Table 2. Several ratios for crayfish.

Metric ratio	Sex	Average ± S_x	Min-Max	t test
	F	0.47 ± 0.02	0.43 – 0.51	
CL/TL	M	0.48 ± 0.04	0.41 – 0.65	P < 0.05
	FM	0.48 ± 0.04	0.41 – 0.65	
	F	0.38 ± 0.05	0.33 – 0.49	
AL/TL	M	0.39 ± 0.06	0.29 – 0.50	P < 0.05
	FM	0.38 ± 0.05	0.29 - 0.50	
	F	0.99 ± 0.11	0.81 – 1.14	
Aw/AL	M	0.82 ± 0.12	0.47 – 1.15	P < 0.05
	FM	0.84 ± 0.13	0.47 – 1.15	
	F	0.30 ± 0.09	1.13 – 1.45	
CL/AL	M	1.23 ± 0.16	1.00 – 2.00	P < 0.05
	FM	1.27 ± 0.15	1.00 – 2.00	
	F	0.48 ± 0.05	0.38 – 0.55	
Chw/ChL	M	0.43 ± 0.07	0.25 – 0.63	P < 0.05
	FM	0.43 ± 0.07	0.25 – 0.63	

The general difference between the The CL/TL, AL/TL, Aw/AL, CL/AL and CW/CL ratio of females and males were found to significant (t-test, $p < 0.05$). Aw/AL, CL/AL and CW/CL of females bigger than males (Table 2).

In the present study, Table 3 showed that there is negative pearson correlation between Aw and TW, ChL and Aw. Apart from these results, CL and TL; AL and TW have a high correlation.

Table 3. Pearson correlation coefficients between metric characteristics

	TL	TW	CL	AL	Aw	ChL	Chw
TL	1.000						
TW	0.462**	1.000					
CL	0.716**	0.213*	1.000				
AL	0.605**	0.93	0.692**	1.000			
Aw	0.556**	-0.129	0.641**	0.679**	1.000		
ChL	0.337**	0.563**	0.323**	0.343**	-0.032	1.000	
Chw	0.244**	0.345**	0.272**	0.380**	0.126	0.664**	1.000

**Correlation is significant at the 0.01 level. *Correlation is significant at the 0.05 level.

The length-weight relations and the chelae length-weight relations for the crayfish in Mogan Lake were shown in Table 4.

Table 4. Length-weight relation parameters, equations and coefficient of determination

Species	Sex	Regression equations	r^2
TW - TL	F	$W = 0.00220024\ L^{2.0221}$	0.994
	M	$W = 0.00095247\ L^{2.2196}$	0.990
	FM	$W = 0.00162688\ L^{2.101}$	0.991
CL - TW	F	$W = 0.02005470\ L^{1.8418}$	0.995
	M	$W = 0.35673492\ L^{1.1197}$	0.988
	FM	$W = 0.20255878\ L^{1.261}$	0.989

A multilayer feed-forward neural network was used for ANN. A schematic representation of a typical ANN is shown in Figure 3 and consists of 4 interconnected layers of ‘nodes’ or ‘neurons’, including an input layer containing 1 node per independent variable (i.e., length, weight and sex of crayfish), hidden layer, and finally, an ‘output layer’ with 1 node (i.e., the weight or length of the crayfish samples). Figure 4 illustrate graphical presentation of the fit between the actual and predicted values.

The observed values, ANNs and length-weight relation data are shown in Table 5. The observed data collected from Mogan Lake were presented according to the gender of group with length and weight. The calculated data observed from the ANNs, length-weight relations. Table 5 were prepared for comparison of data of the crayfish in Lake Mogan with length-weight relation and ANNs method.

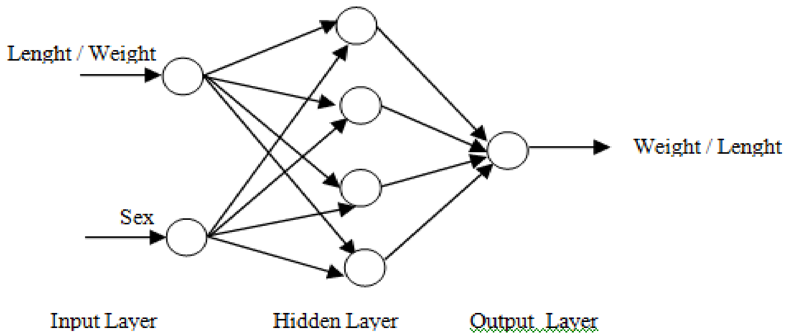

Figure 3. The ANN consisted of an input layer with 2 nodes, hidden layer, and an output layer with 1 node to be predicted for crayfish

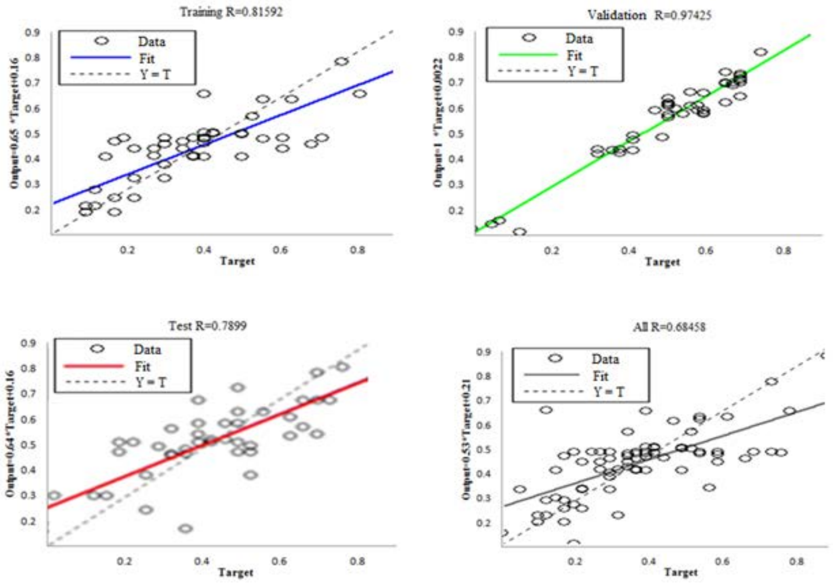

Figure 4. Relationship between observed and predicted values for TL and TW

Table 5. Observed and calculated values for ANNs, length-weight relation

Type (1) - (2)	Sex	Observed data 1	Observed data 2	Prediction 1	Prediction 2	MAPE (%) 1	MAPE (%) 2	L - W Relation 1	L - W Relation 2	MAPE (%) 1	MAPE (%) 2
TL (1) TW (2)	F	10.871	28.637	10.737	31.945	1.234	11.552	10.924	28.389	0.482	0.866
	M	10.293	32.494	9.288	30.182	9.763	7.114	10.420	31.937	1.237	1.713
	FM	10.363	32.012	10.352	32.556	0.108	1.703	10.545	31.459	1.750	1.727
CL (1) TL (2)	F	5.142	10.871	5.269	11.122	2.468	2.307	5.162	10.924	0.383	0.482
	M	4.941	10.293	4.654	9.752	5.822	5.256	5.227	10.420	5.779	1.237
	FM	4.966	10.363	4.983	10.543	0.316	1.736	5.232	10.545	5.341	1.750
CL (1) TL (2)	F	3.350	10.871	3.680	11.200	9.851	3.023	3.470	10.924	3.582	0.482
	M	4.016	10.293	3.652	9.284	9.080	9.803	4.096	10.420	1.982	1.237
	FM	3.933	10.363	3.988	10.418	1.396	0.532	4.009	10.545	1.927	1.750
MAPE (%)						0.607	1.323			3.006	1.742

Discussion

Males were more than females in Mogan Lake. Some studies reported that the males than emales (Balık *et al.* 2005 - Demirköprü Dam Lake; Berber and Balık 2006 - Mogan Lake; Güner 2008 - Kavaklı Pond; Berber and Balık 2009 - Apolyont Lake; Deniz *et al.* 2013 - different inland waters) while others reported that females were greater than males (Karabatak and Tüzün 1989 - Mogan Lake; Harlıoğlu 1999 - Keban Dam Lake; Köksal *et al.* 2003 - Dikilitaş Pond; Harlıoğlu and Harlıoğlu 2005 - Eğirdir Lake, İznik Lake and Hirfanlı Dam Lake). The reason for this difference in different regions of different ecological characteristics, may be due to biological causes and the catch method. However, females are not as active as males in the reproductive period as they carry eggs under abdomen. Female crayfish can show as much interest as males (Ateş and Aksu 2013).

Although the average lengths of both sexes were nearly the same, the average weight of males was higher than that of females. TL of crayfish in Mogan Lake is greater than those in Demirköprü Dam Lake (Balık *et al.* 2005); in Manyas Lake (Berber and Balık 2006). Some researchers found that TL of males and females was shorter than Mogan Lake. The present study was also found that TW was greater than those from Apolyont Lake (Berber and Balık 2009) (Table 6).

The mean CL and TW of the male individuals was greater than those of the females. On the other hand, TL, CL, AL and Aw of females was greater than that of males in Mogan Lake (Table 1). Variation in morphometric characteristics may also be largely affected by environmental factors such as feeding, behavior, foraging efficiency, and the availability and quality of food resources (Lindqvist and Lathi 1983). Environmental conditions influence crustacean growth by effecting molt intervals and incremental increases in length and weight.

The relationship between body length and weight is an important and widely used equation in fishery studies, fish length being the easiest parameter to measure, particularly in the field. During their development, crustaceans are known to pass through stages in their life history which are defined by different length-weight relationships.

Table 6. Comparison of growth parameters in different locations

Locality	Sex	TL	TW	Regression parameters			Sex ratio (F/M)
				a	b	r^2	
Mogan Lake (Karabatak and Tüzün 1989)	F	104.45	31.92	0.00002	3.05	-	1.22/1
	M	105.44	36.98	0.00001	3.18		
Keban Dam Lake (Harlıoğlu 1999)	F	106.79	-	0.00159	2.52	0.88	1.16/1
	M	108.14		0.00093	2.67	0.92	
Dikilitaş Pond (Köksal *et al.* 2003)	F	102.04	32.24	0.00002	3.08	0.99	1.08/1
	M	102.50	33.11	0.00005	3.01	0.99	
	F	103.29	32.17	-	2.11	0.82	1.14/1
Eğirdir Lake	M	101.81	33.07		2.51	0.92	
İznik Lake	F	104.54	29.19	-	2.66	0.94	1.15/1
Hirfanlı Dam Lake	M	100.47	29.34		2.72	0.94	
(Harlıoğlu and Harlıoğlu 2005)	F	105.93	19.36	-	2.22	0.78	0.82/1
	M	104.76	20.17		3.66	0.89	
Demirköprü Dam Lake (Balık *et al.* 2005)	F	92.88	24.19	0.00002	3.06	0.97	0.49/1
	M	90.18	25.43	0.00001	3.27	0.98	
Manyas Lake (Berber and Balık 2006)	F	89.07	21.85	0.0003	2.94	0.99	0.53/1
	M	82.12	19.57	0.0003	2.98	0.97	
Kavaklı Pond (Güner 2008)	F	107.314	31.83	-	-	-	0.68/1
	M	105.143	42.83				
Apolyont Lake (Berber and Balık 2009)	F	-	20.62	0.0003	2.96	0.94	0.68/1
	M		21.92	0.0002	3.03	0.95	
Inland water in Turkey	F	-	-	0.00003	2.96	0.87	0.84/1
	M			0.00003	2.97	0.88	
Eğirdir Lake	F	-	-	0.00007	2.78	0.88	0.91/1
Hirfanlı Dam Lake	M			0.00001	3.21	0.93	
Keban Dam Lake	F	-	-	0.0001	2.71	0.90	0.57/1
Porsuk Dam Lake	M			0.000008	3.28	0.92	
	F	-	-	0.0001	2.42	0.75	0.87/1
(Berber and Balık 2009)	M			0.000005	3.38	0.83	
Mogan Lake (This study)	F	108.71	28.64	0.0022	2.02	0.99	
	M	102.93	32.49	0.0009	2.22	0.99	0.14/1
	F+M	103.65	32.11	0.0016	2.10	0.99	

The variables b is characteristic of species and generally does not vary significantly throughout the year, unlike the parameter, which may vary daily, seasonally, between different habitats, water temperature and salinity, sex, food availability, differences in the number of specimens examined, as well as in the observed length ranges of the species caught (Tesch 1971).

The slope (b) values of the length–weight relationship in both gender is found as 2.101. It was found intercept of the relationship (a) as 0.00162688. It is found that b values are smaller than in all other researches (Table 6). In the present study, growth showed a negative allometry. Similar results were reported for Harlıoğlu (1999) in Keban Dam Lake and Harlıoğlu and Harlıoğlu (2005) in Eğirdir and İznik Lake. The reason for these differences may be factors such as the environmental, food, population density and the selectivity of the traps or fyke nets used in the studies. In addition, male crayfish specimens were heavier than females. This disparity is due primarily to the accelerated development of the male chelae with the onset of sexual maturity, while the chelae of the females remain isometric throughout their life (Romaire *et al.* 1977). Furthermore, males are rougher and more thick-set than females (Skurdal and Quvenild 1986). Lengths of both male and female crayfish ranged from 40 to

150 mm. The catching of crayfish smaller than 90 mm in total length is prohibited in all Turkish lakes (TKB 2002).

The relationships between carapace length and weight can be used for many purposes. They are, for example, indicators of condition and can be used to calculate biomass and to estimate the recovery of edible meat from crayfish of various sizes. On the other hand, body weight and total length, carapace length and carapace width are the most frequently used dimensions in studies of crustaceans (Atar and Seçer 2003).

The estimated length-weight relation is model dependent. The estimated length-weight relation is model dependent. If the number of inadequate data and the confidence intervals of the parameters below the nominal level may be difficulties in the evaluation of the data set. In this situation, it may be cause problems in comparing the between length-weight relations and ANN.

Length-weight relation and ANN MAPE results were examined. Table 3 shows that ANN gave better results than length-weight relation. ANNs can be alternative as a forecasting tool for various parameters.

The morphometric characters could be helpful in comparing the same species in different locations. It can be showed that the study of morphometric characters could be used to describe populations. This study also provides some information on the length-weight relationships that would be useful for sustainable fisheries management in Mogan Lake. In addition, for sustainable economic yield, the crayfish population should be carefully monitored in the future as well.

Mogan Gölü'ndeki kerevit (*Astacus leptodactylus*)'lerde büyümenin boy ağırlık ilişkisi ve yapay sinir ağları ile karşılaştırılması

Özet

Bu çalışmanın amacı Manyas Gölü'nde yaşayan kerevit (*Astacus leptodactylus* Eschscholtz, 1823) populasyonlarının bazı morfometrik özelliklerini belirlemektir. Örneklemeler 2006 ve 2007 yılında 02 Temmuz ile 30 Ekim tarihleri arasında yapılmıştır. Mogan Gölü'ndeki *Astacus leptodactylus* bireylerinin toplam uzunluğu (TL), karapas uzunluğu (CL), chelae uzunluğu (ChL), karın uzunluğu (AL) ve toplam ağırlığı (TW) arasındaki ilişkiler sunulmuştur. Araştırmada 112 (14 dişi, 98 erkek) birey kullanılmıştır. Araştırma boyunca yakalanan kerevitlerin %87,5'i erkek, %12,5'i dişi birey olarak tespit edilmiş ve dişi/erkek oranı 0,14/1,00 olarak hesaplanmıştır. Araştırma sonuçlarına göre, ortama tam boy dişiler için 108,71 mm, erkekler için 102,93 mm; tam ağırlık dişi bireyler için 28,64 g, erkek bireyler için 32,49 g tespit edilmiştir. Boy ağırlık ilişkisi eşitlikleri dişiler için $W=0,0022\ L^{2,01}$; erkekler için $W=0,00095\ L^{2,23}$ olarak bulunmuştur. Doğadan toplanan kerevitlerin büyüme oranları boy ağırlık ilişkisi

eşitlikleri ve yapay sinir ağları ile hesaplanmıştır. Boy ağırlık ilişkisi ve yapay sinir ağları ortalama mutlak yüzde hata (MAPE) değerleri incelenmiştir. Yapay sinir ağları boy ağırlık ilişkisine göre daha iyi sonuçlar verdiği tespit edilmiştir. Yapay sinir ağları büyüme tahmini için alternatif bir yöntem olarak değerlendirebilir.

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Received: 05.01.2015
Accepted: 08.04.2015