ARTIFICIAL NEURAL NETWORKS (A NEW STATISTICAL APPROACH) METHOD IN LENGTH-WEIGHT RELATIONSHIPS OF *ALBURNUS MOSSULENSIS* IN MURAT RIVER (PALU-ELAZIĞ) TURKEY

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(Received 24th Jan 2019; accepted 21st Mar 2019)

Abstract. Artificial Neural Networks (ANNs) is a reliable and alternative method used specially in the growth characteristics of some fish species. The purpose of this work was to compare with length-weight relationships and Artificial Neural Networks, the length-weight relation of 415 (232 female and 183 male) *Alburnus mossulensis* captured from Murat River between January 2018 and December 2018. The total length and the weight of the fish changed between 7.2-19.9 cm (12.81±0.095) and 3.24-40.6 g (13.51±0.30) respectively. The length-weight relationships were determined for females, males and all individuals as W=0.0097$L^{2.812}$ (R^2=0.95), W=0.0168$L^{2.599}$ (R^2=0.95) and W=0.0130$L^{2.701}$ (R^2=0.95), respectively. The growth type of *A. mossulensis* was negative allometric growth for female, male and all individuals. Regression analysis showed that length has high significantly correlation with weight (R = 0.97, R^2 = 0.95, $F_{1,413}$ = 79550.3, P <0.001) and 95% remain in weight was due to length remain. *t*-test results was used for the importance condition of the regression coefficients (t=89.193, P<0.01). Length-length relations were highly significant with R^2 values greater than 0.97. The condition factor values were ranged between 0.430 and 0.975 for all individuals. According to the comparison of the results obtained with MAPE (%), ANNs provided better results than the LWRs. With this study, it can be seen that ANNs can be used as an alternative useful method for population parameters prediction.
Keywords: *ANNs, MAPE (%), length-weight relation, negative allometric growth, Murat River*

Introduction

Alburnus mossulensis is a freshwater fish species from cyprinid, inhabiting the Euphrates, Tigris and Ceyhan rivers and in their near basins in Iran (Kuru, 2004; Geldiay and Balık, 2007; Coad, 2010). Ergene (1993) studied the reproduction and growth of this species in the Euphrates Basin of Turkey. Başusta (Girgin) (2000) investigation and growth and changes of in blod cells this species living in Keban Dam Lake. Turkmen and Akyurt (2000) and Yıldırım et al. (2003) studied the population structure and growth properties of the species in Karasu River. Başusta and Cicek (2006) studied the length-weight relationships for this fish in Ataturk Dam Lake in southeastern Anatolia, Turkey. Yıldırım et al. (2007) studied the reproduction and growth of this species in the Euphrates Basin of Turkey. Ghorbani (2011) studied the reproductive biology and population dynamics of the fish in Bibi-Sayyedan River of Tigris basin in Iran. Mousavi-Sabet et al. (2013, 2014) determined the length-weight relationships of the fish in Iran. Esmaeili et al. (2014) studied the LWR in this species in Iran. Abdul-Razak et al. (2015) studied some biological aspects of this species in the southern reaches of Euphrates River, Iraq. Alkan Uckun and Gokce (2015) assessed the age, growth, and reproduction of *A. mossulensis* in Karakaya Dam Lake (Turkey). Keivany et al. (2015, 2016); Radkhah (2016) and Keivany and Zamani-Faradonbeh (2017) studied the length-weight relationship and condition factor of *A. mossulensis* in Beheshtabad River, Bibi-Sayyedan River, Hamzeh-Ali Spring and Jarrahi River.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1705_1025310266

Keivany et al. (2017) studied the reproductive biology and morphological diversity of *Alburnus mossulensis* populations in Iran. Serdar et al. (2017) some population parameters of *Alburnus mossulensis* in the Karasu River.

ANNs have been used in differ branches of aquatic science and in biology more than in other sciences (Tureli Bilen et al., 2011). With ANNs models; Maravelias et al. (2003) estimated the distributions of demersal fish species, Mastrorillo et al. (1997) estimated the existences of small fish in a river, Park et al. (2003) estimated aquatic macro-invertebrate varieties, Obach et al. (2001) predicted population dynamics of aquatic insects, Joy and Death (2004) estimated and spatially mapping freshwater fish and assemblies of decapods and Benzer and Benzer (2016) fish population predicted. Benzer et al. (2015, 2017) and Benzer and Benzer (2018) predicted growth properties of crayfish (*Astacus leptodactylus*). Ozcan and Serdar (2018a) estimated some population parameters of tigris loach (*Oxynoemacheilus tigris*). Sangun et al. (2019) estimated body weight of *Sparus aurata* with artificial neural network. Many authors reported that ANNs gave better results than other methods (Tureli Bilen et al., 2011; Benzer et al., 2015, 2017; Benzer and Benzer, 2016, 2018; Ozcan and Serdar, 2018a). ANNs is an alternative method for other methods in non linear situations for predict modeling (Joy and Death, 2004).

This study is the first record ANNs as a new and alternative approach to predicting basic biological characteristics for *A. mossulensis* in Murat River. The results showed high proximity between the measured and predicted data. Predicted and observed values are compared by Mean Absolute Percent Error (%). The values obtained with Artificial Neural Networks are much closer to their real values. For this reason, in this study it can be concluded that ANNs model applied made a more effective and reliable analysis than other methods. The aim of this study is to show the reliability of ANNs, which is an alternative method for the calculation of length-weight relationships.

Materials and Methods

Murat River, which is born from Aladağ in the north of Lake Van, flows into the Palu and Keban Dam Lake. The coordinates of Murat River (Palu-Elazığ) sampling 1. stations (38°41'08.9"N, 39°52'51.9"E) and 2. stations (38°40'05.1"N, 39°50'59.5"E) are given in *Figure 1*.

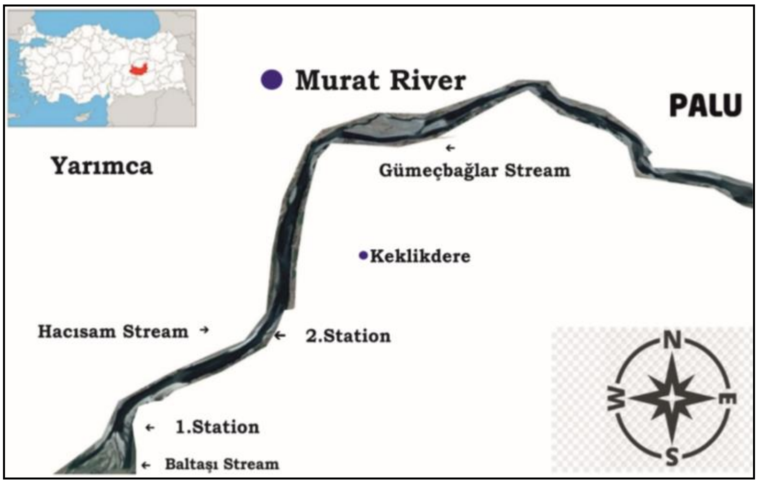

Figure 1. *Sampling stations of Murat River (Palu, Elazığ)*

APPLIED ECOLOGY AND ENVIRONMENTAL RESEARCH 17(5):10253-10266.
http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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Fishes were as monthly caught with gillnet by researcher and local fishermen during January 2018 and December 2018. Fishes were carried to the laboratory and fixed with 5% formaldehyde. Fish samples were measured for total length, fork length, standard length, weight and sexes identified by macroscopic observation of gonads; sex ratios were checked by a chi-square test (differed from 1:1).

The total length-weight relationship was determined with the below equation (*Eq. 1*) (Ricker, 1975). The degree of relation between the changeables was calculated with the determination coefficient, R^2 (King, 1995). (W is weight (W), L is total length (TL), a is the intercept, and b is the slope).

$$W = a*L^b \qquad \text{(Eq.1)}$$

Length-length relationships were calculated with linear regression analysis (*Eq. 2*) (Zar, 1999).

$$TL=a+bFL,\ FL=a+bSL,\ SL=a+bTL \qquad \text{(Eq.2)}$$

The condition factor values of fish are obtained by the below equation (*Eq. 3*) (W is weight; TL is total length and b is the coefficient of allometric of relationship) (Le Cren, 1951).

$$K=(W/TL^b)*100 \qquad \text{(Eq.3)}$$

Artificial neural networks (ANNs) are biologically computer programs designed to adapt the human brain. ANNs identify the relationships in the data and learn through experiment and add their knowledge. An ANN is comprise of hundreds of single units, artificial neurons or processing elements. Neurons in a network are interconnected by the power of neural calculations. The behavior of these neural networks is determined by the transmission process and learning rule of their neurons. The activation signal is taked place transfer function to generate a single output of the neuron. Transmission process introduces non-linearity to the network. Throughout the course of the training, the connections are optimized until you reach the minimum and the best accuracy of the error. After the network is trained and tested, new data for output can be displayed (Agatonovic-Kustrin and Beresford, 2000). This model is an interrelatedness group of artificial neurons that process information in parallel. In general, an ANN is a system that varies according to internal and external information flowing through the network. Briefly summarized, neural networks are regression analysis, statistical, data-modelling tools used for modelling sophisticate relationships between inputs and outputs in data (Cabreira et al., 2009). Basically, there are 3 different layers in a neural network:

1. Input Layer (All the inputs are fed in the model through this layer (Length/weight, sex)).
2. Hidden Layers (There can be more than one hidden layers which are used for processing the inputs received from the input layers).
3. Output Layer (The data after processing is made available at the output layer (Weight/length)) (URL, 1); (*Fig. 2*).

The mathematical equation of the neuron model is as follows (*Eq.4*) (Krenkel et al., 2011). ($yi(k)$ is output value in discrete time k, F is a transfer function, $wi(k)$ is weight

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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value in discrete time *k* where i goes from *0* to *m*, *xi*(*k*) is input value in discrete time *k* where *i* goes from *0* to *m*, *b* is bias).

$$y(k) = F(\sum_{i=0}^{m} wi(k).xi(k) + b) \quad \text{(Eq.4)}$$

MAPE was used to compare ANNs and other methods. The smaller the MAPE values, the closer are the predicted values to the actual values (Benzer et al., 2017). MAPE is as follows equality (*Eq.5*). Yi is actual observation value, ei is difference between the actual value and the prediction value, n is number of total observations.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{ei}{Yi}\right| x100 \ldots\ldots\ldots\ldots \quad \text{(Eq.5)}$$

Neural Network Toolbox of MATLAB (Ver R2016a) was used for ANNs. Created in MATLAB software are made up of three parts. These are “training”, “testing”, and “validation”. In this study, for ANN model, 70% for training step, 15% for validation step and 15% for test step.

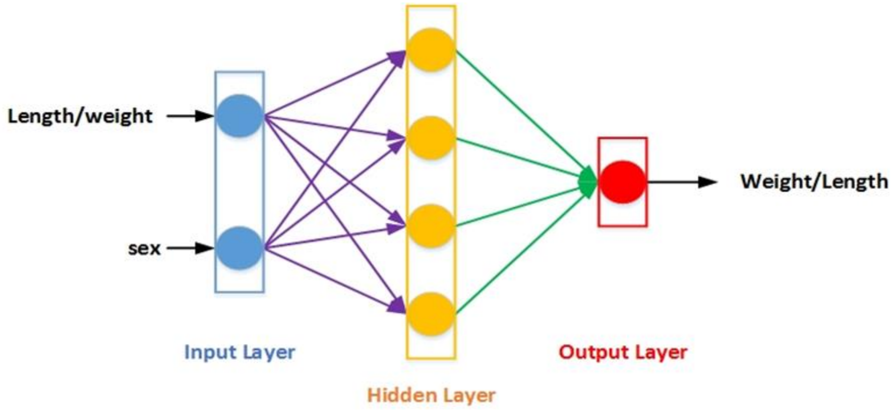

Figure 2. *Representation an ANN formed of 2 input layers, a hidden layer and an output layer to be estimated*

Results

A total of 415 (232 female and 183 male) specimens were caught in this study, the length and weight of females ranged from 8.7 to 19.9 cm (12.76 ± 0.12) and 5.0 to 40.60 g (13.32 ± 0.38) and those of males from 7.2 to 19.6 cm (12.82 ± 0.14) and 3.24 to 38.70 g (13.53 ± 0.45), respectively. The specimens were composed of 56% females and 44% males. The sex ratio of female to male was 1:0.79, chi-square test showed that significantly different from the expected 1:1 ratio ($P<0.05$). The difference in the lengths of females and males were not statistically important (*t*-test, $p>0.05$). The total length, weight-frequency is presented in *Figure 3*. The length group interval 11.0-12.9 cm (43.61%) and weight group 10.0-16.9 g (55.66%) were the most aboundant for all specimens. The females were larger in length and weight.

Length-weight relationships of *A. mossulensis* were found as $W=0.0097*L^{2.812}$, $R^2=0.95$, SE of $b=0.0025$ and 95% confidence intervals of $b=2.557\text{-}2.836$, *t*-test $P<0.05$ for females; $W=0.0168*L^{2.599}$, $R^2=0.95$ SE of $b=0.0028$ and 95% confidence intervals of $b=2.575\text{-}2.865$, *t*-test $P<0.05$ for males and $W=0.0130*L^{2.701}$, $R^2=0.95$ SE of $b=0.0019$

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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and 95% confidence intervals of b=2.557-2.865, t-test P<0.05 for all individuals (*Fig. 4*); (*Table 1*). The growth type of *A. mossulensis* was negative allometric growth for female, male and all individuals. Regression analysis showed that length has high significantly correlation with weight (R = 0.97, R^2 = 0.95, $F_{1,413}$ = 79550.3, P<0.001) and 95% remain in weight was due to length remain. t-test results was used for the importance condition of the regression coefficients (t=89.193, P<0.01).

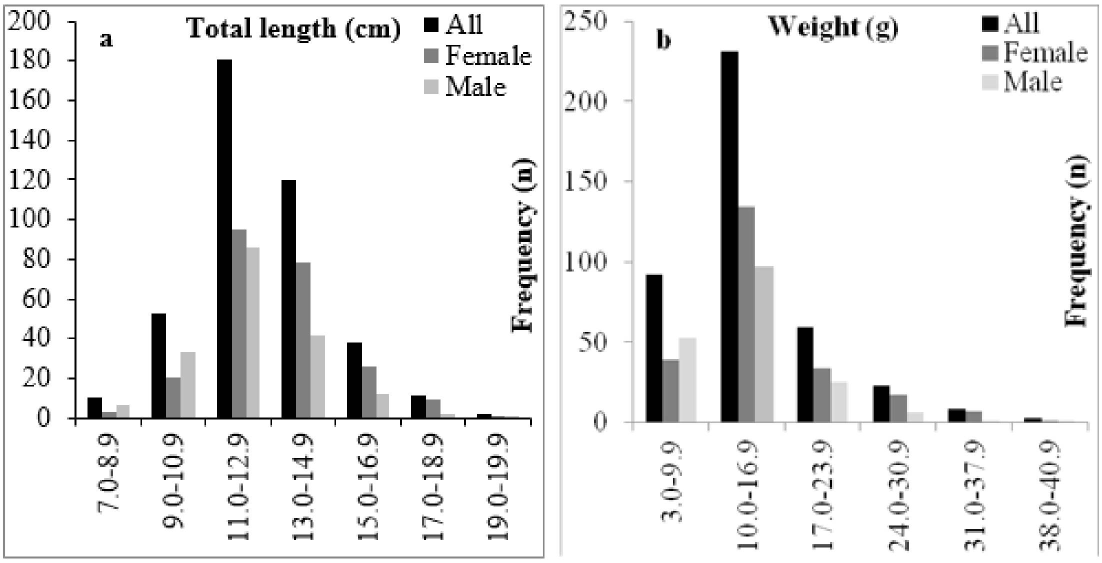

Figure 3. *Total-length (a) and weight (b) frequency of Alburnus mossulensis in Murat River*

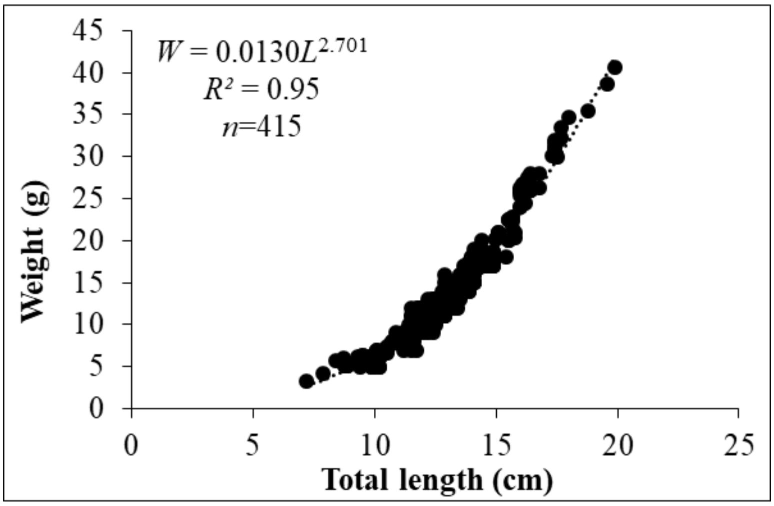

Figure 4. *Length-weight relationships of A. mossulensis for all individuals from Murat River*

The length and weight measurements, number of individuals (n), regression parameters a and b of the LWRs, 95% confidence intervals of b, coefficients of determination (R^2) and condition factor (CF) of the *A. mossulensis* were given in *Table 1*.

Regression analysis between the total, fork, standard length measurements for *A. mossulensis* sexes separately are shown in *Table 2*. Length- length relationships were highly significant with R^2 values greater than 0.97.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1705_1025310266

Table 1. *Length-weight relationships of A. mossulensis in Murat River*

Sex	*n*	Length range (cm)	Weight Range (g)	*a*	*b*	*95% CI of b*	R^2	*CF*
Female	232	8.7-19.9	5.0-40.6	0.0097	2.812	2.557-2.836	0.95	0.430-0.911
Male	183	7.2-19.6	3.24-38.7	0.0168	2.599	2.575-2.865	0.95	0.460-0.975
All	415	7.2-19.9	3.24-40.6	0.0130	2.701	2.557-2.865	0.95	0.430-0.975

n: number of individuals, *a*: intercept, *b*: slope, *CI*: confidence limits, R^2: coefficient of determination, CF: condition factor

Table 2. *Length–length relationships of A. mossulensis in Murat River*

Sex	Equation	*a*	*b*	R^2
Female	*TL= a + bFL*	1.0685	0.2454	0.98
	FL= a + bSL	1.0248	0.7082	0.98
	SL= a + bTL	0.8828	-0.5386	0.97
Male	*TL= a + bFL*	1.0958	-0.0541	0.98
	FL= a + bSL	1.0297	0.6071	0.99
	SL= a + bTL	0.8692	-0.3433	0.99
All	*TL= a + bFL*	1.0822	0.0916	0.98
	FL= a + bSL	1.0298	0.6258	0.99
	SL= a + bTL	0.8742	-0.4125	0.98

TL: Total length, *FL*: fork length, *SL*: Standard length

Figure 5 shows the coefficients of regression. The linear regression line, which is most appropriate between targets and outputs, is determined with a durable line.

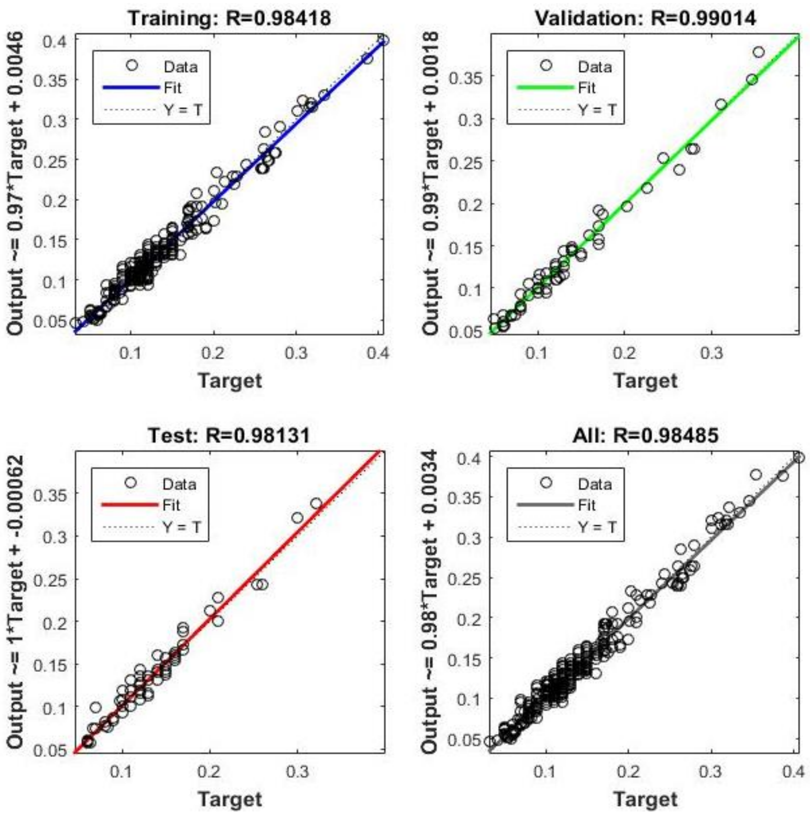

Figure 5. *Coefficients of regression in artificial neural networks model*

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DOI: http://dx.doi.org/10.15666/aeer/1705_1025310266

R value shows the relationship between outputs and targets. According to *Figure 5*, the targeted output *R* value was 0.98418 for training, 0.99014 for validation, 0.98131 for testing and 0.98485 for corresponding all response. *R*=0.98485 value confirmes that the ANN output precise linear relevance with the target (excellently match). All these results confirm that the training gives the best results. Because all of the coefficients are close to 1, the accuracy of the training is highly acceptable and gave better predictions than regression relationship (0.98485) (*Fig. 5*).

Figure 6 shows the best validation performance. The mean squared error of all data (performance chart) is occurred on a logarithmically. The training mean squared error must have a declining trend in order for the training plot to shows an excellent training.

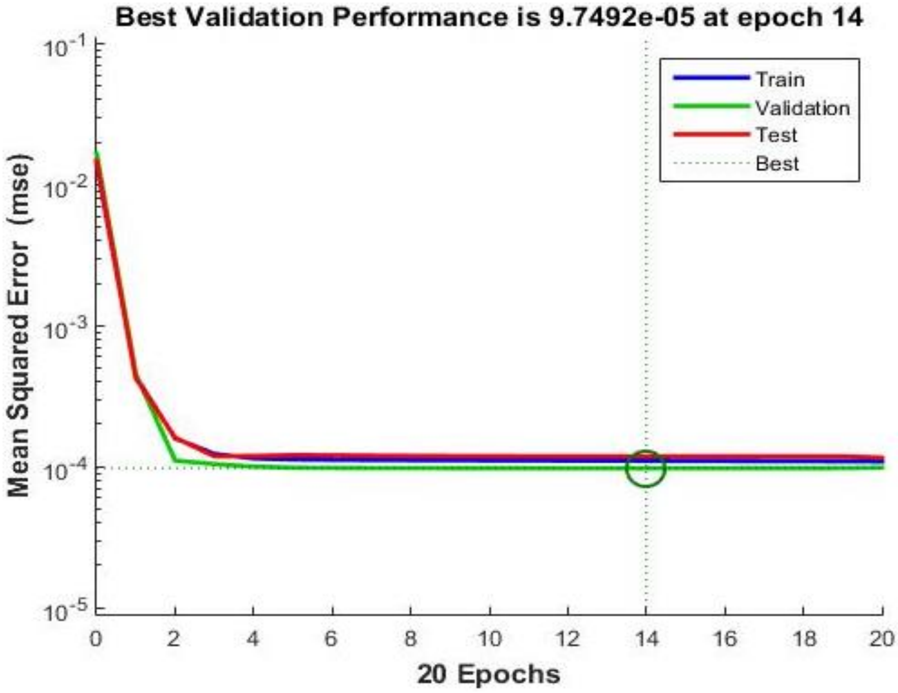

Figure 6. *Best validation performance of artificial neural networks*

In *Figure 6*, when the validation error increased to 20 epochs, the training was ended and the best validation performance was seen as 9.7492e-05 at 14th epoch. The optimum epoch is 20 for *A. mossulensis* there is no benefit to the system of increasing epoch after that.

Figure 7 shows the corresponding validation checks and the gradient of epochs. For the training state of artificial neural networks model, the validation checks was attained as 6, at epoch 20 and gradient=0.00032946, at epoch 20.

Actual values, ANNs and LWRs data of *A. mossulensis* are shown in *Table 3*. All values were classified by length groups and sexes. *Table 3* was obtained by comparison with ANNs and LWRs of *A. mossulensis*. The values we obtained with ANNs and LWRs were calculated one by one. It was determined that the ANNs MAPE (%) values were better than MAPE values calculated in length-weight relation.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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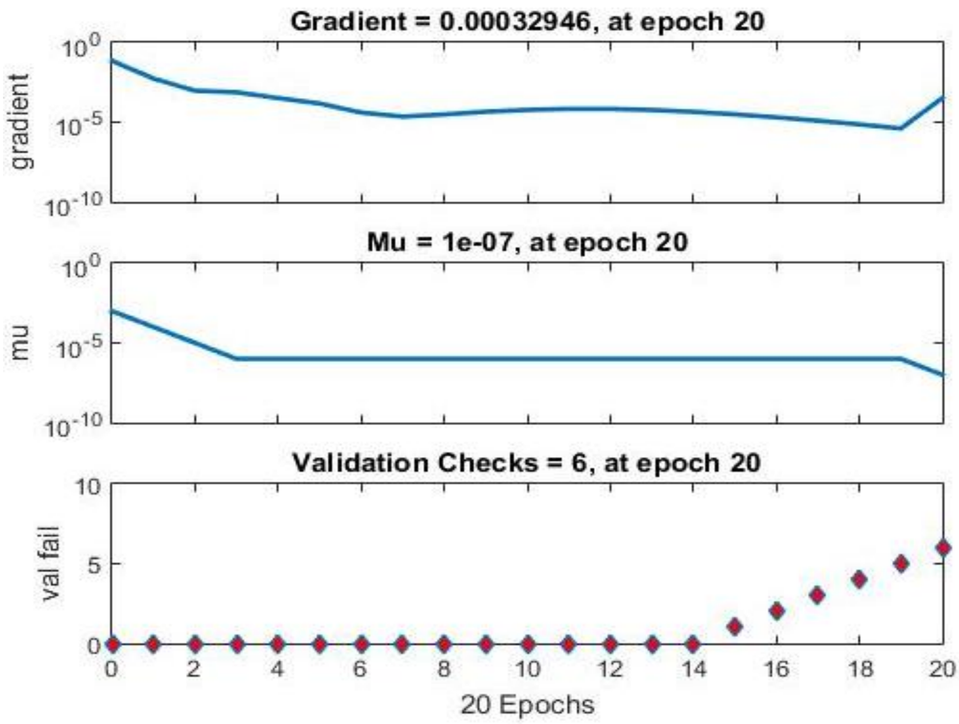

Figure 7. *Training state of artificial neural networks*

Table 3. *Comparison of real and calculated values by sex for A. mossulensis ANNs and LWRs*

Length groups (cm)	Sex	Real Data		ANNs		MAPE(%)		LWRs		MAPE (%)	
		TL	***W***	***TL***	***W***	***TL***	***W***	***TL***	***W***	***TL***	***W***
7.0-8.9	Female	8.77	5.373	9.005	5.353	2.680	0.372	9.294	4.577	5.975	14.815
	Male	8.40	4.917	8.875	4.893	5.655	0.488	8.968	4.123	6.762	16.148
	All	8.51	5.054	8.900	5.031	4.582	0.455	9.066	4.259	6.533	15.730
9.0-10.9	Female	10.305	6.870	10.424	6.716	1.555	2.242	10.153	7.124	1.475	3.697
	Male	10.110	6.682	10.068	6.754	0.415	10.078	10.060	6.769	0.495	1.302
	All	10.183	6.753	10.202	6.739	0.187	0.207	10.095	6.903	0.864	2.221
11.0-12.9	Female	12.216	11.142	12.246	11.256	0.246	1.023	12.151	11.252	0.532	0.987
	Male	12.121	11.009	12.151	10.994	0.248	0.136	12.104	11.025	0.140	0.145
	All	12.171	11.079	12.201	11.132	0.246	0.478	12.129	11.144	0.345	0.587
13.0-14.9	Female	13.742	15.296	13.696	15.427	0.335	0.856	13.677	15.478	0.473	1.189
	Male	13.386	14.800	13.478	15.763	0.687	6.507	13.848	15.765	3.451	6.520
	All	13.776	15.470	13.659	15.544	0.849	0.478	13.737	15.579	0.283	0.705
15.0-16.9	Female	15.888	24.208	15.909	23.823	0.132	1.590	16.218	22.855	2.077	5.589
	Male	15.742	22.867	15.655	22.710	0.553	0.687	15.865	22.284	0.781	2.550
	All	15.842	23.784	15.829	23.472	0.082	1.311	16.106	22.675	1.667	4.662
17.0-18.9	Female	17.670	32.233	17.627	32.773	0.243	1.675	18.046	30.420	2.128	5.625
	Male	17.550	31.500	18.015	32.697	2.650	3.800	17.900	29.840	1.994	5.270
	All	17.645	32.100	17.698	32.759	0.300	2.052	18.021	30.314	2.131	5.563
19.0-19.9	Female	19.900	40.600	19.802	39.793	0.492	1.988	19.665	41.893	1.181	3.184
	Male	19.600	38.700	19.458	38.247	0.724	1.170	19.319	40.209	1.434	3.899
	All	19.750	39.650	19.630	39.020	0.608	1.589	19.492	41.051	1.306	3.533
Average MAPE (%)						**1.118**	**1.866**			2.001	4.949

TL: Total length, *W*: Weight

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Discussion

In this study, the maximum length for females was 19.90 cm and that for males was 19.60 cm; females are longer and heavier than males as seen in other fish species. The maximum total length reported for this fish from Ataturk reservoir was 38.20 cm (Başusta and Cicek, 2006), from Karakaya Dam Lake was 20.4 cm (Alkan Uckun and Gokce, 2015) and from Karasu River was 21.4 cm (Serdar et al., 2017).

Many researchers have found in different estimates for the length-weight relationship in fish. Le Cren (1951) because the oil and water content of the fish may vary depending on the temperature, stated that the length-weight relationship of the fish depends on the seasonal changes. It may also affect the *b* value in geographic location and environmental conditions such as and water temperature, which is the determining factor of feeding capacity, stomach fullness, disease and parasite loads (Bagenal and Tesch, 1978; Froese, 2006). Also, if the value of *b* is less than 3, the fish indicates negative allometric growth, and if the value of *b* is greater than 3, the fish indicates positive allometric growth (Weatherley and Gill, 1987). The *b* values reported for differ fish species ranged from 2.5 to 4.0 (Hile, 1936; Martin, 1949), 2 to 4 (Bagenal and Tesch, 1978) and 2.5 to 3.5 (Froese, 2006). In addition, high values of R^2 show that the length-weight relationships are linear observed range of values (*Table 4*). In the present study, length and weight relations of *A. mossulensis* were similar to those of Alkan Uckun and Gokce (2014) and Serdar et al. (2017).

Table 4. *Total length-weight relationship values for A. mossulensis from different regions*

Habitat	Sex	*a*	*b*	R^2	Author
Askale region of River Karasu	Female	0.0080	3.082	0.95	Turkmen and Akyurt, 2000
	Male	0.0100	2.828	0.94	
Karasu River	Female	0.0073	3.136	0.96	Yıldırım et al., 2003
	Male	0.0129	2.913	0.99	
Karakaya Dam Lake	Female	0.2060	2.065	0.95	Alkan Uckun and Gokce, 2015
	Male	0.1190	2.138	0.93	
	All	0.1350	2.120	0.94	
Karasu River (Erzincan-Erzurum)	Female	0.0131	2.800	0.93	Serdar et al., 2017
	Male	0.0125	2.820	0.92	
	All	0.0128	2.810	0.93	
Fırat River	All	0.0080	3.030	0.97	Keskin, 2016
Murat River	Female	0.0097	2.812	0.95	In this study
	Male	0.0168	2.599	0.95	
	All	0.0130	2.701	0.95	

Length-length relationships are generally used for population parameters of fish species (Başusta et al., 2013; Ozcan and Serdar, 2018a, 2018b). LLRs were significant ($P<0.001$) for all individuals with all R^2 values greater than 0.97. These results are in agreement with those of Serdar et al. (2017) work done in the Karasu River.

Ergene, (1993) reported the mean condition factor as 0.86. Turkmen and Akyurt, (2000) reported it as 1.023 in males and as 1.047 in females. In this study, the max-min condition factors were 0.430-0.911 for females and 0.460-0.975 for males. The condition factor allows us to be informed about the physiological status of fish in relation to health (Kumolu and Ndimele, 2010). The fact that the condition factor is high shows that the environmental conditions are quite suitable for population dynamics studies (Blackwell et al., 2000). In this study, it can be said that the environmental

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conditions are not suitable for *A. mossulensis* in this region since the condition factor value is less than 1.

The values obtained with Artificial Neural Networks are much closer to their real values (*Table 3*). ANNs is required for future predictions along with other methods. However, in the majority of these studies it is seen that the ANNs results are better than the results of other conventional methods (Brosse et al., 1999). In this study, according to results of *Table 3*, ANNs provided very good results compared to LWRs. Thus, ANNs can be used as an alternative and reliable method in fisheries for length-weight relation. MAPE values of the predict of ANNs for length and weight were 1.118 and 1.866 and the value of LWRs were 2.001 and 4.949. Lewis (1982) categorized models with a MAPE value of less than 10% as "very good" in predicting, 10%-20% as "good", 20%-50% as "acceptable" and over 50% are classified as "wrong and faulty" models. In many studies are determined that MAPE of ANNs values are quite low (Benzer and Benzer, 2016, 2018; Benzer et al., 2017; Ozcan and Serdar, 2018a).

According to Ekici and Aksoy (1993), R is successful when the values are between 0.95-1. In addition, Saleem et al. (2017), for a very good fit, the distribution of data should be along a 45° line indicating that the network outputs are equal to the targets. The forecasting of length-weight relation using artificial neural network was found to be 0.98485 as the R values for all individuals. With ANNs seen that the output tracks are very good targets for training (R-value = 0.98418), validation (R-value = 0.99014), and testing (R-value = 0.98131). These results show the success of the relationship between length-weight. With this study obtained high correlation coefficient (R) between the measured and predicted output variables, reaching up to 0.99 (validation).

Conclusions

The results of this study showed high proximity between the measured and predicted data. The values obtained with Artificial Neural Networks are much closer to their real values. For this reason, the ANNs model used in this study has a highly acceptable accuracy and reliability.

Acknowledgements. Author thank Dr. Ibrahim MAKINIST and Mustafa AKDENIZ for helping collecting the fish samples; Prof. Dr. Ahmet Bedri OZER and Arş. Gör. Canan TASTIMUR for helping Artificial Neural Networks (ANNs); (MATLAB; Ver R2016a) calculations.

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