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Original article

Alternative growth models in fisheries: Artificial Neural Networks

Semra Benzer[1] • Recep Benzer[2]

[1] *Gazi University, Gazi Faculty of Education, 06500, Teknikokullar, Ankara, Turkey*
[2] *ETCOP (Education Training Consulting Organisation and Process Management), Cyber Security, Switzerland*

Correspondence
Dr Semra Benzer; Gazi University, Gazi Faculty of Education, 06500, Teknikokullar, Ankara, Turkey

sbenzer@gazi.edu.tr and sbenzer@gmail.com

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Abstract
In this study growth of *Atherina boyeri*, collected from Süreyyabey Dam Lake, was determination by Artificial Neural Networks (ANNs) along with study of length weight relationships (LWRs). A total of 394 individuals including 32.5% female and 67.5% male specimens were studied collected during the fishing season between May 2015 and May 2016 from the local fisherman. The total length and weight of the specimens were 32–90 mm and 0.225–4.062 g respectively. The relationships were $W = 0.01285708\ L^{2.67}$ ($R^2 = 0.983$) for females, $W = 0.00678019\ L^{2.95}$ ($R^2 = 0.969$) for males and $W = 0.00641527\ L^{2.87}$ ($R^2 = 0.970$) for pooled individuals. Mean Absolute Percentage Error (MAPE) of ANNs (0.182) for all specimens was lower than MAPE value of LWR (1.763). The results of study show that ANNs are superior tool to LWRs for fishes of Süreyyabey Dam Lake.

Key words: *Atherina boyeri*; artificial neural networks; ANNs; LWR; big-scale sand smelt; Süreyyabey Dam Lake

1 | INTRODUCTION

Traditionally fishermen, fisheries administrators and fisheries biologists used length and weight values to study the length weight relationship of fishes. However, in the population studies conducted in fisheries science, the [illegible] the variability in weight increases as the length of the fish increases are the two most important features (Le Cren 1951).

Artificial Neural Networks (ANNs), inspired by biological neural networks and revealed some performance characteristics similar to biological neural networks is an information processing system (Fausett 1994; Ramos-Nino *et al.* 1997; Sivanondom *et al.* 2006). ANNs, which have the ability to identify complex and nonlinear problems, have been used in many disciplines as an alternative to regression models in recent years (Türeli *et al.* 2011; Benzer 2015; Özcan and Serdar 2018; Benzer and Benzer 2019). ANNs investigate the parameters of the relationships between the non-linear growth by adjusting the input-output patterns. ANNs, which use the error backpropagation procedure, is the basis of methodology that could be [illegible] ion analysis, particularly with the non-linear relations (Rumelhart *et al.* 1986).

Atherina boyeri Risso, 1810, known as big-scale and smelt occurs throughout the Mediterranean and adjacent seas, is a commercially important fish. It is an euryhaline species mostly inhabiting coastal and shallow brackish waters including coastal lagoons, salt marshes and inland waters (Leonardos and Sinis 2000; Pallaoro *et al.* 2002; Andreu-Soler *et al.* 2003; Bartulović *et al.* 2006). The Adult *A. boyeri* migrate to sea in autumn and enter the lagoons in spring for reproduction (Congiu *et al.* 2002). This species is categorised as Least Concerned on the IUCN Red List database (Freyhof and Kottelat 2008).

Although several studies on the age and growth of *A. boyeri* were conducted to date, only a few have focused on growth parameters (Sezen 2005; Tarkan *et al.* 2007, 2012; Çetinkaya *et al.* 2011; Küçük *et al.* 2012; Taskavak *et al.* 2012; Kırankaya *et al.* 2014; Apaydın *et al.* 2015; İlhan and Sari 2015; Gençoğlu and Ekmekçi 2016; Saç *et al.* 2016; Ünlü *et al.* 2017; Benzer and Benzer 2017; Benzer 2018; Çevik *et al.* 2018). Many studies considered ANNs for the determination of growth due to better results than LWRs (Suryanarayana *et al.* 2008; Türeli Bilen *et al.* 2011; Christiansen *et al.* 2015; Benzer 2015, Benzer *et al.* 2015, 2016, 2017; Benzer and Benzer 2016, 2017, 2019; Özcan and Serdar 2018). It has been showed that neural network models are significantly better than LWRs. In this paper, ANNs and LWRs were employed to *Atherina boyeri* to determine the best estimate for its length and weight.

2 | METHODOLOGY

2.1 | Study site

Süreyyabey Dam, also known as Çekerek Dam, is a dam located 6 km southeast of Çekerek of Yozgat built on Çekerek Creek for irrigation, energy generation and flood control. The height of the dam from the river bed is 103 m and the lake area is 41.34 km^2, lake volume is 1310 hm^3. The dam provides irrigation services to 66.165 ha areas and generates 51 GWh of energy annually (DSI 2019).

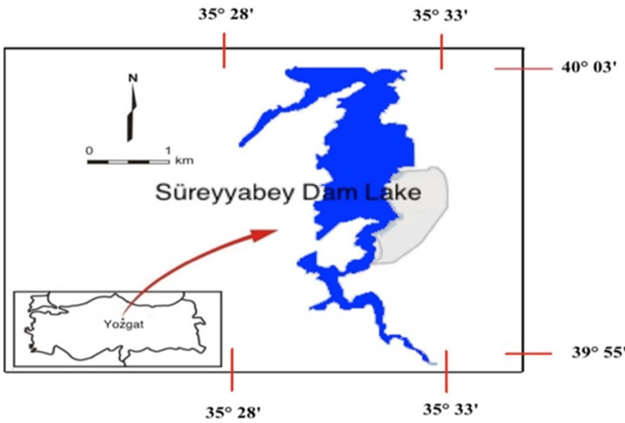

FIGURE 1 Location of Süreyyabey Dam Lake.

2.2 Data collection

A total of 394 specimens including 32.49% (*n* = 128) female and 67.51% (*n* = 266) male were studied. Specimens were collected from Süreyyabey Dam Lake during the fishing season between May 2015 and May 2016 with the help of local fishermen. The lengths (total, fork and standard) and weights of the specimens were measured and recorded following Bagenal and Tesch (1978).

2.3 Mathematical models

2.3.1 Length-weight relation equation

The length–weight formulas (Le Cren 1951) were used for the calculation of the growth features of populations relationships.

$W = aL^b$

where *W* = weight of fish (g); *L* = observed total length (mm); a = regression intercept; *b* = regression slope.

The logarithmic transformation of the formula above is Log W = log *a* + *b* log *L*

2.3.2 Artificial neural networks (ANNs)

ANNs, inspired by biological neural networks and revealed some performance characteristics similar to biological neural networks is an information processing system (Fausett 1994; Ramos-Nino *et al.* 1997; Sivanondom *et al.* 2006). ANNs that simulate the way the human brain works simply can learn from data, generalise, work with an unlimited number of variables and so on has many important features (Huang *et al.* 2016). The smallest unit underlying the operation of ANNs is called artificial nerve cell or process element. The simplest artificial nerve cell consists of five main components: inputs, weights, splicing function, activation function and outputs. The artificial neural networks calculations (Krenker *et al.* 2011) were used in this study.

$$\sum_{i=1}^{p} W_i x_i + b$$

$$y = f(n) = f(\sum_{i=1}^{p} W_i x_i + b)$$

where x_i = inputs; *f(n)*= activation function; y_i = output value. In order to solve the developed ANNs problem, back propagation networks were used as a trained supervised learning method. The data used in ANNs were subjected to normalization process for range of [0, 1].

$$V_N = 0.8\,x\left(\frac{V_R - V_{min}}{V_{max} - V_{min}}\right) + 0.1$$

where V_N = normalized data; V_{min} = minimum data; V_{max} = maximum data. The data were divided into three equal parts: training, validation and test sets. The ANNs calculations in MATLAB, the data of fish are divided into three parts as training, validation and test sets as 70%, 15% and 15% respectively.

2.4 Statistical tests

The statistical analyses were performed using SPSS software whereas the ANNs model was studied by the use of Matlab Release 2015a program. Mean Absolute Percentage Error (MAPE) were used as the two performance criteria.

$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{e_i}{Y_i} \right| * 100$$

Where, Y_{io} = actual observation value; Y_{ip} = prediction value; e_i = difference between the actual value and prediction value; n = the number of total observations.

3 | RESULTS AND DISCUSSION

The total length and weight (min - max) of the total specimen (n = 394) were 32 – 90 mm and 0.225 – 4.062 g respectively. LWR models were found for females, males and all individuals. The LWRs were W = 0.01285708 $L^{2.67}$ (R^2 = 0.983) for females, W = 0.00678019 $L^{2.95}$ (R^2 = 0.969) for males and W = 0.00641527 $L^{2.87}$ (R^2 = 0.970) for all (pooled) individuals (Table 1 and Figure 2).

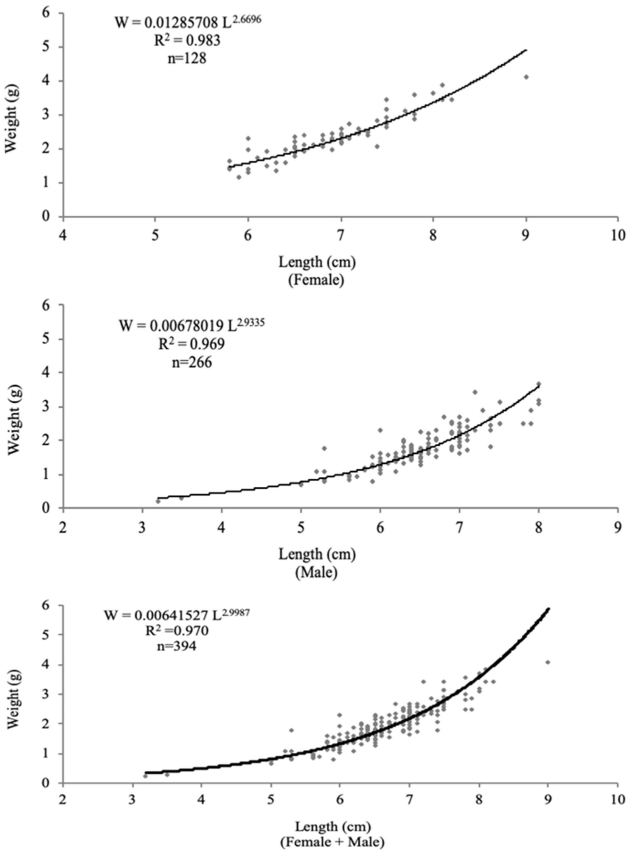

FIGURE 2 Length-weight relationships of *Atherina boyeri.*

TABLE 1 Length-weight relationships (LWRs) of *Atherina boyeri* in Süreyyabey Dam Lake.

Groups	LWRs	R^2
Total length		
Female	W = 0.01285708 × $L^{2.67}$	0.983
	Log W = –1.8909 + 2.6696 Log L	
Male	W = 0.00678019 × $L^{2.95}$	0.969
	Log W = –2.1688 + 2.9535 Log L	
Pooled	W = 0.00641527 × $L^{3.00}$	0.970
	Log W = –2.1928 + 2.9987 Log L	
Fork length		
Female	W = 0.01359338 × $L^{2.74}$	0.982
	Log W = –1.8667 + 2.7353 Log L	
Male	W = 0.0111345 × $L^{2.81}$	0.970
	Log W = –1.9533 + 2.8099 Log L	
Pooled	W = 0.01026462 × $L^{2.87}$	0.971
	Log W = –1.9887 + 2.8659 Log L	
Standard length		
Female	W = 0.01605976 × $L^{2.76}$	0.983
	Log W = –1.7943 + 2.7554 Log L	
Male	W = 0.01622219 × $L^{2.72}$	0.973
	Log W = –1.7899 + 2.7163 Log L	
Pooled	W = 0.01467295 × $L^{2.79}$	0.973
	Log W = –1.8335 + 2.7857 Log L	

Among the studied individuals, 372 were used in the learning process and 122 were used in the test and verification process of ANNs. Prediction performances of ANNs trained and tested with length and weight variables of big-scale sand smelt are shown in Figure 3.

The results obtained by ANNs and LWR equation were compared by considering MAPE results. It was seen that ANNs give better results than LWR (Table 2 and Figure 2). Therefore ANNs can be an alternative method in the evaluation of growth estimation of fishes.

Table 2 Results with LWR and ANNs

Sex	Raw data		ANNs		MAPE (%)		LWRs		MAPE (%)	
	L	W	L	W	L	W	L	W	L	W
F	6.498	2.335	6.537	2.319	0.595	0.669	6.563	2.272	0.988	2.655
M	5.929	1.742	5.906	1.760	0.381	1.000	6.039	1.654	1.855	5.035
All	6.113	1.935	6.103	1.933	0.182	0.034	6.222	1.840	1.763	4.885

L, length; W, weight, MAPE: Mean Absolute Percentage Error; F, female; M, male

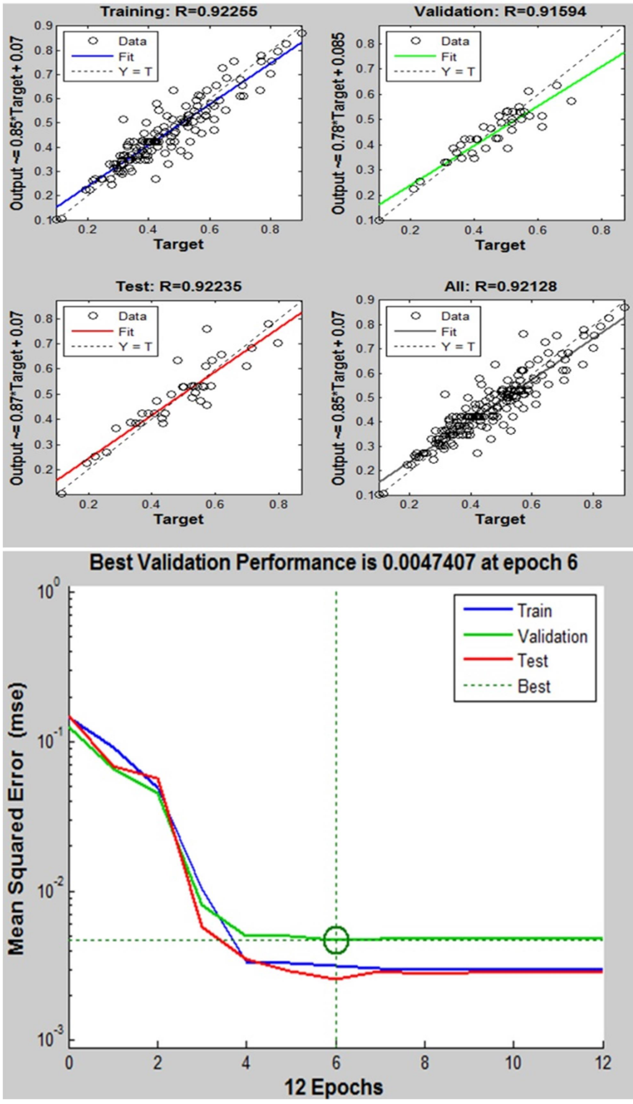

FIGURE 3 Relationships and performances of Artificial Neural Networks (ANNs).

As seen in Table 2, ANNs gives better results with lower MAPE values than LWRs. It is reported that ANNs MAPE ratios are low in comparison to traditional methods (Türeli Bilen *et al.* 2011; Benzer 2015; Benzer *et al.* 2015, 2016, 2017; Benzer and Benzer 2016, 2017, 2019; Özcan and Serdar 2018). There have been various studies on LWR parameters of *A. boyeri* from other study locations (Table 3). The slope (*b*) value for *A. boyeri* found in this study is similar to others (e.g. Sezen 2005; Patimar *et al.* 2009; Çetinkaya *et al.* 2011) (Table 3).

4 | CONCLUSIONS

Consequently, LWRs have been used frequently to estimate weight and length. The results of the study were examined by adding the ANNs approach to the traditional estimation method (*i.e.* LWR). This research also provides growth information by LWRs and ANNs approaches that would be useful for sustainable management of fisheries in Süreyyabey Dam Lake. Finally, it is recommended that the big-scale sand smelt population should be carefully monitored in the future to ensure sustainable economic yield employing non-conventional mathematical approaches (e.g. ANNs, fuzzy logic, box–jenkins method etc.) in study area and other inland waters.

TABLE 3 Length-weight relationships (LWRs) parameters of *Atherina boyeri* reported in different studies from Turkey.

Study sites	LWR values			Reference
	N	*a*	*b*	
Mala Neretva River	1200	3.4×10^{-3}	3.24	Bartulavic *et al.* (2006)
Ria de Aveiro	2503	3.3×10^{-3}	3.35	Pombo *et al.* (2005)
Homa Lagoon	1640	5.2×10^{-3}	3.08	Sezen (2005)
Eğirdir Lake	1481	6.6×10^{-3}	2.96	Küçük *et al.* (2006)
İznik Lake	1136	3.2×10^{-3}	3.336	Gaygusuz (2006)
İznik Lake	922	4.0×10^{-3}	3.20	Özeren (2009)
Gomishan Wetland	2256	5.3×10^{-3} 5.0×10^{-3}	3.06[a] 3.0630[b]	Patimar *et al.* (2009)
İznik Lake	237	8.0×10^{-3} 7.45×10^{-3}	2.98[a] 3.05[b]	Çetinkaya *et al.* (2011)
Marmara Lake	101	8.4×10^{-3}	2.908	İlhan and Sarı (2015)
Eğirdir Lake	1681	5.9×10^{-3}	3.20	Apaydın Yağcı *et al.* (2015)
Trasimeno Lake	3998	−2.326 −2.366	3.139[a] 3.168[b]	Lorenzoni *et al.* (2015)
Hirfanlı Dam Lake	674	3×10^{-6}	3.16	Gençoğlu and Ekmekçi (2016)
Mellah Lagoon	1402	4.6×10^{-3}	3.179	Boudinar *et al.* (2016)
Mogan Lake	488	1.37×10^{-3}	2.81	Benzer (2016)
Hirfanlı Dam Lake	1449	1.3×10^{-2} 1.7×10^{-2} 1.39×10^{-2}	2.77[a] 2.62[b] 2.74	Benzer and Benzer (2017)
Marmara Lake	185	5.9×10^{-4}	3.118	İlhan and İlhan (2018)
Süreyyabey Dam Lake	394	1.2×10^{-3} 6.7×10^{-3} 6.4×10^{-3}	2.67[a] 2.95[b] 3.00	This study

[a], male; [b], female; N, number; a, regression intercept; b, regression slope

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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CONTRIBUTION OF THE AUTHORS
SB & RB data collection, data analysis and visualisation and manuscript preparation

S Benzer https://orcid.org/0000-0002-8548-8994
R Benzer https://orcid.org/0000-0002-5339-0554