Journal of Fisheries
Volume 7 Issue 3 Pages 719–725 December 2019
Peer Reviewed | Open Access | Online First

eISSN 2311-3111
pISSN 2311-729X

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

Manuscript history

Received 20 September 2019 | Revised 22 December 2019 | Accepted 24 December 2019 | Published online 28 December 2019

Citation

Benzer S and Benzer R (2019) Alternative growth models in fisheries: Artificial Neural Network. Journal of Fisheries 7(3): 719–725.

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 relationship between length and weight is not linear and 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 used in the same field as regression 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).

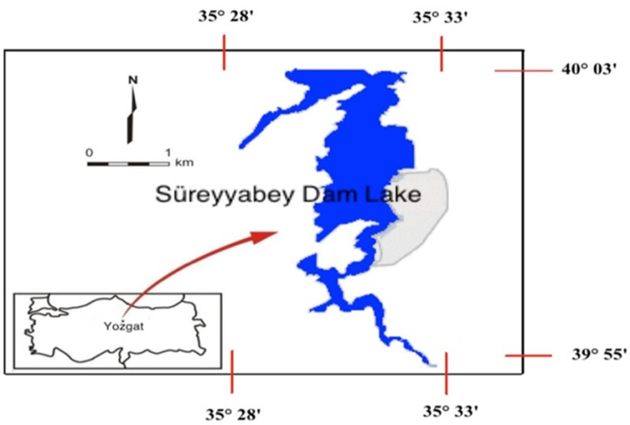

FIGURE 1 Location of Süreyyabey Dam Lake.

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).

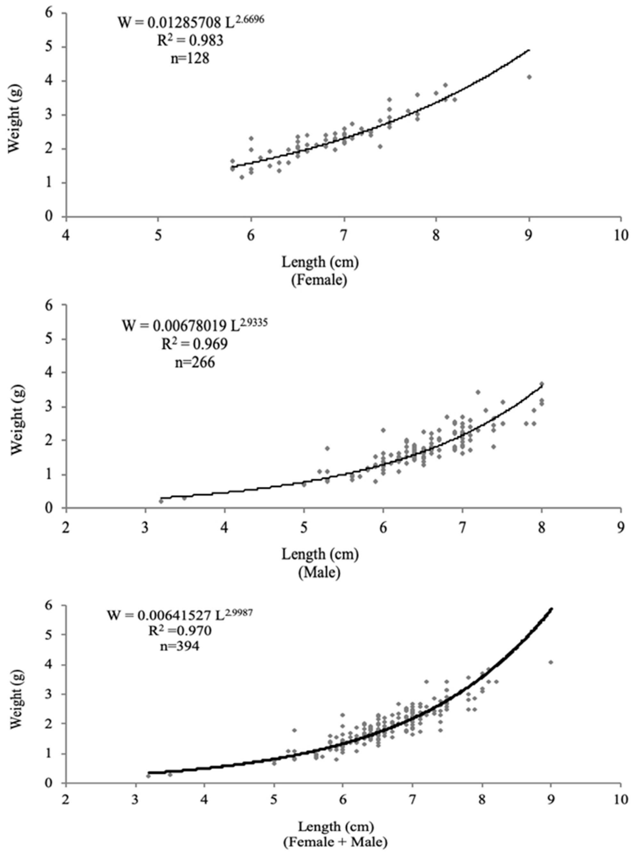

FIGURE 2 Length-weight relationships of *Atherina boyeri.*

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

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

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

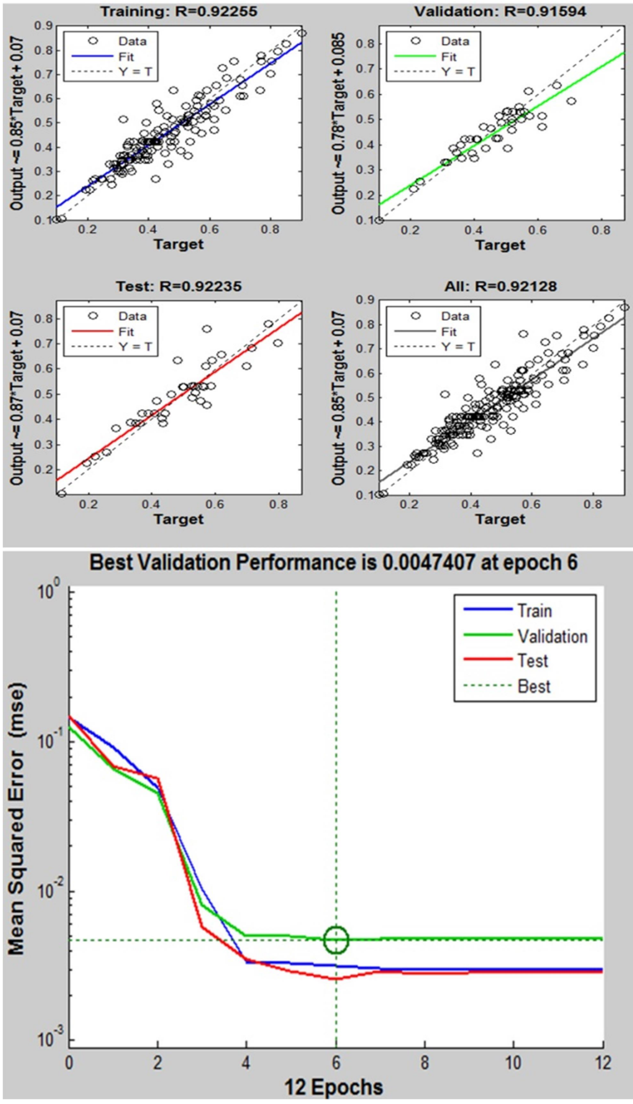

FIGURE 3 Relationships and performances of Artificial Neural Networks (ANNs).

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

ACKNOWLEDGEMENTS

This study was presented at the International Symposium on Limnology and Freshwater Fisheries in 2017 (LIMNO-FISH 2017, İsparta, Turkey).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Andreu-Soler A, Oliva-Paterna FJ, Fernández-Delgado C and Torralva M (2003) Age and growth of the sand smelt, *Atherina boyeri* Risso, 1810, in the Mar Menor coastal lagoon (SE Iberian Peninsula). Journal of Applied Ichthyology 19: 202–208.

Apaydın Yağcı M, Alp A, Yağcı A, Cesur M and Bilgin F (2015) Growth and reproduction of sand smelt *Atherina boyeri* Risso, 1810 in Lake Eğirdir, Isparta, Turkey. Indian Journal of Fisheries Sciences 6(1): 1–5.

Bagenal TB and Tesch FW (1978) Age and growth. pp. 101–136. In: Bagenal T (Ed) Methods for assessment of fish production in fresh waters. IBP Handbook No. 3. Blackwell Scientific Publications, Oxford.

Bartulović V, Glamuzina B, Conides A, Gavrilovic A and Dulcic J (2006) Maturation, reproduction and recruitment of the sand smelt, *Atherina boyeri* Risso, 1810 (Pisces: Atherinidae) in the estuary of Mala Neretva River (southeastern Adriatic, Croatia). Acta Adriatica 47: 5–11.

Benzer R (2015) Population dynamics forecasting using Artifıcial Neural Networks. Fresenius Environmental Bulletin 24(2): 460–466.

Benzer S (2016) Growth characteristics of *Atherina boyeri* Risso 1880 in Mogan Lake. International Conference on Biological Sciences, Konya Turkey. 21–23 October 2016.

Benzer S (2018) First record of the sand smelt *Atherina boyeri* Risso 1810 in the Süreyyabey Dam Lake Yeşilırmak Basin Turkey. Annals of Biological Sciences 6(2): 14–18.

Benzer S and Benzer R (2016) Evaluation of growth in pike (*Esox lucius* L., 1758) using traditional methods and artificial neural networks. Applied Ecology and Environmental Research 14(2): 543–554.

Benzer S and Benzer R (2017) Comparative growth models of big-scale sand smelt (*Atherina boyeri* Risso, 1810) sampled from Hirfanlı Dam Lake, Kırsehir, Ankara, Turkey. Computational Ecology and Software 7(2): 82–90.

Benzer S and Benzer R (2019) Growth and length–weight relationships of *Pseudorasbora parva* (Temminck & Schlegel, 1846) in Hirfanlı Dam Lake: comparison with traditional and artificial neural networks approaches. Iranian Journal of Fisheries Sciences. DOI: 10.22092/ijfs.2018.119889.

Benzer S, Benzer R and Gül A (2016) Developments in science and engineering. St. Kliment Ohridskı University Presssofia, Chapter 5: Artificial Neural Networks Application for biological systems: the case study of *Pseudorasbora parva*. ISBN 978-954-07-4137-6.

Benzer S, Benzer R and Günal AÇ (2017) Artificial Neural Networks approach in morphometric analysis of crayfish (*Astacus leptodactylus*) in Hirfanlı Dam Lake. Biologia 72(5): 527–535.

Benzer S, Karasu Benli Ç and Benzer R (2015) The comparison of growth with length-weight relation and artificial neural networks of crayfish, *Astacus leptodactylus*, in Mogan Lake. Journal of Black Sea/Mediterranean Environment 21(2): 208–223.

Boudinar AS, Chaoui L and Kara MH (2016) Age, growth and reproduction of the sand smelt *Atherina boyeri* Risso, 1810 in Mellah Lagoon (Eastern Algeria). Journal of Applied Ichthyology 32(2): 302–309.

Çetinkaya S, Uysal R, Yegen V, Cesur M and Bostan H (2011) The growth characteristics of sand smelt (*Atherina boyeri*, Risso 1810) in Lake İznik (Türkiye), Turkish Journal of Fisheries and Aquatic Sciences 11: 641–648.

Çevik C, Gündoğdu S and Ergüden SA (2018) New record of the big-scale sand smelt *Atherina boyeri* Risso, 1810 (Atherinidae) in the Seyhan Dam Reservoir (Seyhan River Basin, Turkey). Natural and Engineering Sciences 3(2): 133–140.

Christiansen F, Bertulli CG, Rasmussen MH and Lusseau D (2015) Estimating cumulative exposure of wildlife to non-lethal disturbance using spatially explicit capture–recapture models. The Journal of Wildlife Management 79(2): 311–324.

Congiu L, Rossi R and Colombo G (2002) Population analysis of the sand smelt *Atherina boyeri* (Teleostei Atherinidae), from Italian coastal lagoons by random amplified polymorphic DNA. Marine Ecology Progress Series 229: 279–289.

DSI (2019) Report Dame. The General Directorate of State Hydraulic Works. www.dsi.gov.tr

Fausett L (1994) Fundamentals of neural networks. Prentice Hall, New York.

Freyhof J and Kottelat M (2008) *Barbus pergamonensis*. In: IUCN Red List of Threatened Species. Version 2014.2. Gland, Switzerland: IUCN.

Gaygusuz Ö (2006) İznik Gölünde yaşayan Gümüş balığı (*Atherina boyeri* Risso, 1810) 'nın üreme ve büyüme biyolojisi. MSc Thesis, İstanbul: İstanbul University. Science Institute. 45 pp (in Turkish).

Gençoğlu L and Ekmekçi FG (2016) Growth and reproduction of a marine fish, *Atherina boyeri* Risso 1810, in a freshwater ecosystem. Turkish Journal of Zoology 40: 534–542.

Gençoğlu L and Ekmekçi FG (2016) Growth and reproduction of a marine fish, *Atherina boyeri* Risso 1810, in a freshwater ecosystem. Turkish Journal of Zoology 40: 534–542.

Huang GB, Zhu QY and Siew CK (2016) Extreme learning machine: theory and applications. Neurocomputing 70(1): 489–501.

İlhan A and İlhan D (2018) Marmara Gölü (Manisa) ve Homa Lagünü (İzmir) 'nden Yakalanan Gümüş Balığı (*Atherina* *boyeri* Risso, 1810)'nın Boy-Ağırlık İlişkisi ve Kondisyonu, Karadeniz Fen Bilimleri Dergisi 8(1): 25–34 (in Turkish).

İlhan A and Sarı HM (2015) Length-weight relationships of fish species in Marmara Lake, West Anatolia, Turkey. Croatian Journal of Fisheries 73(1): 30–32.

Kırankaya SG, Ekmekçi FG, Yalçın-Özdilek S, Yoğurtçuoğlu B and Gençoğlu L (2014) Condition, length–weight and length–length relationships for five species from Hirfanlı resevoir Turkey. Journal of Fisheries Sciences 8: 208–213.

Krenker A, BešTer J and Kos A (2011) Introduction to the Artificial Neural Networks. In: Suzuki K (Ed) Artificial Neural Networks - methodological advances and biomedical applications. InTech Open. DOI: 10.5772/644.

Küçük F, Güçlü SS, Gülle I, Güçlü Z, Çiçek NL and Diken G (2012) Reproductive features of big scale sandsmelt, *Atherina boyeri* (Risso, 1810), an exotic fish in Lake Egirdir (Isparta-Turkey). Turkish Journal of Fisheries and Aquatic Sciences 12: 729–733.

Küçük F, Gülle İ and Güçlü SS (2006) Effect on fishery and lake ecosystem of non-native sand smelt (*Atherina boyeri* Risso, 1810) in Eğirdir Lake, I. Ulusal Balıklandırma ve Rezervuar Yönetimi Sempozyumu, 7–9 (in Turkish).

Le Cren ED (1951) The Length-weight relationship and seasonal cycle in gonadal weight and condition of perch (*Perca fluviatilis*). Journal of Animal Ecology 20: 201–219.

Leonardos I and Sinis A (2000) Age, growth and mortality of *Atherina boyeri* Risso, 1810 (Pisces: Atherinidae) in the Mesolongi and Elotikon lagoons (W. Greece). Fisheries Research 45: 81–91.

Lorenzoni M, Giannetto D, Carosi A, Dolciami R, Ghetti L and Pompei L (2015) Age, growth and body condition of big-scale sand smelt *Atherina boyeri* Risso, 1810 inhabiting a freshwater environment: Lake Trasimeno (Italy). Knowledge and Management of Aquatic Ecosystems 416: 9–15.

Özcan Eİ and Serdar O (2018) Artificial Neural Networks as new alternative method to estimating some population parameters of Tigris loach (*Oxynoemacheilus tigris* (Heckel, 1843)) in the Karasu River, Turkey. Fresenius Environmental Bulletin 27(12B): 9840–9850.

Özeren SC (2009) Age, growth and reproductive biology of the sand smelt *Atherina boyeri*, Risso 1810 (Pisces: Atherinidae) in Lake İznik, Turkey. Journal of Fisheries International 4: 34–39.

Pallaoro A, Franicevic M and Matic S (2002) Age, growth and mortality of big scale sandsmelt, *Atherina* (*Hepsetia*) *boyeri* Risso, 1810 in the Pantana Lagoon, Croatia. Periodicum Biologorum 104(2): 175–183.

Patimar R, Yousefi M and Hosieni SM (2009) Age, growth and reproduction of the sandsmelt *Atherina boyeri* Risso, 1810 in the Gomishan Wetland, South-east Caspian Sea. Estuarine, Coastal and Shelf Science 81(4): 457–462.

Pombo L, Elliott M and Rebelo JE (2005) Ecology, age and growth of *Atherina boyeri* and *Atherina presbyter* in the Ria de Aveiro, Portugal. Cybium 29: 47–55.

Ramos-Nino ME, Ramirez-Rodriguez CA, Clifford MN and Adams MR (1997) A comparison of quantitative structure-activity relationships for the effect of benzoic and cinnamic acids on Listeria monocytogenes using multiple linear regression, artificial neural network and fuzzy systems. Journal of Applied Microbiology 82: 168–176.

Rumelhart DE, Hinton GE and Williams RJ (1986) Parallel distributed processing: explorations in the microstructure of cognition. MIT Press Cambridge, MA.

Saç G, Aydoğan K, Özuluğ O and Özuluğ M (2016) Resettlement of *Atherina boyeri* Risso, 1810 in Büyükçekmece Reservoir (İstanbul, Turkey). FishTaxa 1(1): 27–28.

Sezen B (2005) Research on biological characteristics of sand smelt (*Atherina boyeri* Risso, 1810) population in Homa Lagoon (Izmir). MSc thesis. Ege University, İzmir.

Sivanondom SN, Sumathi S and Deapa SN (2006) Introduction to neural networks using Matlab 6.0, Tat McGraw-Hill Publishing Company Limited, New Delhi.

Suryanarayana I, Braibanti A, Rao RS, Ramam VA, Sudarsan D and Rao GN (2008) Neural networks in fisheries research. Fisheries Research 92: 115–139.

Tarkan AS, Copp GH, Top N, Özdemir N, Önsoy B, Bilge G, Filiz H, Yapıcı S, Ekmekçi G, Kırankaya Ş, Emiroğlu Ö, Gaygusuz Ö, Gürsoy Gaygusuz Ç, Oymak A, Özcan G and Saç G (2012) Are introduced gibel carp *Carassius gibelio* in Turkey more invasive in artificial than in natural waters? Fisheries Management and Ecology 19: 178–187.

Tarkan S, Bilge G, Sezen B, Tarkan A, Gaygusuz O, Gürsoy C, Filiz H and Acıpınar H (2007) Variations in growth and life history traits of sand smelt, *Atherina boyeri*, populations from different water bodies of Turkey: influence of environmental factors. Commission Internationale Pour L'exploration Scientifique De La Mer Mediterranee 38: 611.

Taskavak E, Gurkan S and Bayhan B (2012) Biometric properties of the sandsmelt *Atherina boyeri* Risso, 1810 from the Izmir Bay (Aegean Sea). Journal of FisheriesScience.com 6(1): 18–25.

Türeli Bilen C, Kokcu P and Ibrikci T (2011) Application of Artificial Neural Networks (ANNs) for weight predictions of blue crabs (*Callinectes sapidus* Rathbun, 1896) using predictor variables. Mediterranean Marine Science 12(2): 439–446.

Ünlü E, Gaygusuz Ö, Çiçek T, Bilici S and Coad BW (2017) New record and range extension of the big-scale sand smelt *Atherina boyeri* Risso, 1810 (Atherinidae) in the Devegecidi Dam Lake, Tigris River Basin, Turkey. Journal of Applied Ichthyology 33(1): 63–68.

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