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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Growth parameters with traditional and artificial neural networks methods of big-scale sand smelt (*Atherina boyeri* Risso, 1810)

Gümüş balığının (*Atherina boyeri* Risso, 1810) geleneksel ve yapay sinir ağları yöntemleriyle büyüme parametreleri

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Abstract: In this study, the growth parameters of big-scale sand smelt (*Atherina boyeri* Risso, 1810) in İznik Lake has been determined with traditional (length weight relationships (LWRs), von Bertalanffy (VB), condition factor (CF)) and modern approaches (Artificial Neural Networks - ANNs). A total of 635 specimens (44.84% female and 55.16% male) were collected from the local fisherman during the hunting season between April 2018 to April 2019. Mean fork length (FL) (mm, min-max), mean W (g, min-max) and mean CF (value, min-max) were estimated as 67.31 mm (40.10 - 97.77 mm), 2.57g (0.53 - 7.50 g), and 0.790 (0.170-1.520) for all individuals. The length-weight relationships were determined $W=0.00001437L^{2.8602}$ for female, $W=0.00001570L^{2.8266}$ for male and $W=0.00001328L^{2.8717}$ for all individuals. The von Bertalanffy equations were determined $L_t=136.218\ [1-e^{(-0.240(t+0.51))}]$ for female, $L_t=155.042\ [1-e^{(-0.185(t+0.73))}]$ for male, and $L_t=146.916\ [1-e^{(-0.205(t+0.64))}]$ for all individuals. The values in training (MSE (Mean Squared Error) $4.52559e^{-5}$, R (correlation coefficients) $9.09347e^{-1}$), verification (MSE $4.86111e^{-5}$, R $9.00931e^{-1}$) and test data (MSE $3.391999e^{-5}$, R $9.43465e^{-1}$) were found in calculations made with ANNs. It was determined that ANNs could be an alternative for evaluating growth estimation.

Keywords: Artificial Neural Networks, big-scale sand smelt, growth parameters, length weight relationships, von Bertalanffy

Öz: Bu çalışmada İznik Gölü'nde yakalanan gümüş balığının (*Atherina boyeri* Risso, 1810) büyüme parametreleri geleneksel (boy ağırlık ilişkileri (LWR), von Bertalanffy (VB) ve kondisyon faktörü (CF)) modern yaklaşımlarla (yapay sinir ağları) incelenmiştir. Av sezonunda bölge balıkçılarından Nisan 2018-Nisan 2019 tarihleri arasında toplam 635 adet (%44,84 dişi ve %55,16 erkek) birey toplanmıştır. Tüm populasyon için ortalama çatal boy (FL) 67,31 mm (40,10 - 97,77 mm), ortalama ağırlık (W) 2,57 g (0,53 - 7,50 g ve ortalama CF 0,790 (0,170-1,520) olarak bulunmuştur. LWR dişi popülasyon için $W=0,00001437L^{2,8602}$, erkek popülasyon için $W=0,00001570L^{2,8266}$ ve tüm popülasyon için $W=0,00001328L^{2,8717}$ olarak bulunmuştur. Von Bertalanffy dişi, erkek ve tüm popülasyonda sırasıyla $L_t=136,218\ [1-e^{(-0,240(t+0,51))}]$, $L_t=155,042\ [1-e^{(-0,185(t+0,73))}]$ ve $L_t=146,916\ [1-e^{(-0,205(t+0,64))}]$ olarak tespit edilmiştir. Yapay sinir ağları (ANN) ile yapılan hesaplamalarda eğitim, doğrulama ve test verilerindeki MSE (Ortalama Kare Hata) ve R (korelasyon katsayısı) değerleri sırasıyla $4.52559e^{-5}$ $9,09347e^{-1}$, $4,86111e^{-5}$ $9,00931e^{-1}$ ve $3,391999e^{-5}$ $9,43465e^{-1}$ olarak bulunmuştur. YSA'ların büyüme tahmininin değerlendirilmesinde bir alternatif olabileceği belirlenmiştir.

Anahtar kelimeler: Yapay sinir ağları, gümüş balığı, büyüme parametreleri, boy ağırlık ilişkileri, von Bertalanffy

INTRODUCTION

The distribution area of *Atherina boyeri* includes the Mediterranean, Black Sea, the Atlantic and Marmara Sea from south of Spain to Morocco and Madeira (Leonardos and Sinis, 2000; Leonardos 2001). The species have been reported exotic from Türkiye inland waters from İznik Lake (Çetinkaya et al., 2011), İznik Lake (Özeren, 2004), Sapanca Lake (Geldiay and Balık, 1996), İznik Lake (Gaygusuz, 2006), İznik Lake (Özeren, 2009), Mogan Lake (Benzer, 2016), Hirfanlı Dam Lake (Gençoğlu and Ekmekçi, 2016), Hirfanlı Dam Lake (Benzer and Benzer, 2017) and Yamula Dam Lake (Benzer, 2020). The *Atherina boyeri* is considered to be an invasive exotic fish species in Turkish inland waters (Küçük et al., 2017).

Length-weight relationship (LWR) is significant in fish biology (Sayfullin and Shakirova, 2014). LWR parameters (*a* and *b* value) allow us to estimate the weight of the fish from the length, calculate the condition index, and compare the morphology and life processes of populations in different habitats (Petrakis and Stergiou, 1995).

Artificial Neural Networks (ANNs) are computer systems developed to derive new information through learning, which is one of the features of the human brain. ANNs is a mathematical modeling of the learning process inspired by the human brain (Bon and Hui, 2017). Since ANNs have a nonlinear structure, they perform better than traditional methods in terms of performance criteria. They can detect nonlinear relationships without any hypothesis (Hyun et al., 2005; Türeli Bilen et al.; 2011; Benzer and Benzer, 2016; Benzer and Benzer, 2017; Özcan and Serdar, 2018; Özcan and Serdar, 2019; Özcan, 2019; Benzer, 2020; Benzer and Benzer, 2020a; Benzer and Benzer, 2020b).

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In this article, besides the traditional approaches, it is aimed to determine the ecology, age and growth patterns of atherinid species with modern approaches. These features aim to make a useful contribution to the definition of Atherinides as well as the commonly used traditional taxonomy.

MATERIALS AND METHODS

İznik Lake, which is the largest lake in the Marmara Region and the fifth largest in Türkiye, has an area of 313 km^2. Located in the southeast of the Marmara Region, within the borders of Bursa province, between 40°23'-40°30' north latitudes and 29°20'- 29°42' east longitudes, Lake İznik is a tectonic freshwater lake (Nümann, 1958; Figure 1).

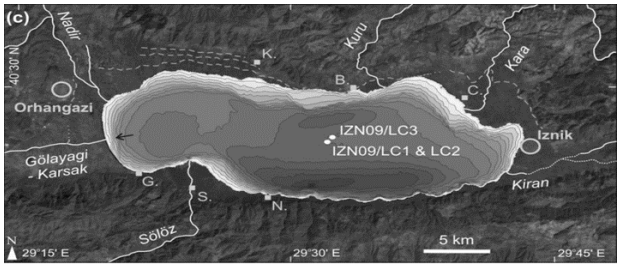

Figure 1. İznik Lake, Bursa, Türkiye

Fish samples (635 individuals) were obtained from fishermen during the hunting season, so ethical approval was not required. The specimens were fixed within 4% formaldehyde solution in polyethylene jars and transferred to the Laboratory. Samples were weighed with a digital scale of ± 0.1 g accuracy and lengths measured with an electronic caliper with an interval of 0.01 mm. Sexes were determined by examination of the gonads macroscopically., Age determination was performed from scales (Lagler, 1966) which taken from the section between dorsal fin and lateral line of each fish, and examined with a binocular microscope and a projection device for all *Atherina boyeri* individuals.

The general regression equation: $W = a \times L^b$ was used to calculate the length-weight relationship, where W weight (g) of fish, L length (mm) of fish, a and b are the parameters of the equation (Bagenal and Tesch, 1978).

Growth was calculated using the von Bertalanffy Equations (VB) growth equation (Sparre and Venema, 1992) and growth performance index (φ') (Munro and Pauly, 1983).

$$L_t = L_\infty\left[1 - e^{-K(t-t_0)}\right]$$

$$\varphi' = Log\ K + 2.Log\ L_\infty$$

L_t is the FL (cm) at age t; L_∞ is asymptotic theoretical maximum fork length, K is the Brody growth coefficient, t is the age, t_0 is the age at zero length and same parameters are available for W.

One-sample t test was used in the analysis of the data revealing whether there is a difference between our φ' value and φ' of the studies in the literature. SPSS 23 program was used in the analysis of the data. Confidence interval was 95% (significance level 0.05 p<0.05).

The Condition Factor (CF) was calculated for all individual fish for *A. boyeri,* by using the conventional formula described by (Worthington and Ricardo, 1936):

$$CF = \mathrm{W}\ \frac{100}{L^3}$$

where CF is the condition factor, W (g) is the weight and L_∞ (cm) is the length.

Each neuron in the hidden or output layer combines and modifies the entries in the previous layer, creating a total connection. The neuron output (y_j) is calculated by equation (Hekayati and Rahimpour, 2017).

$$y_j = f\left(\sum_{i=1}^{M} w_{ij}x_{ij} + b_{ij}\right)$$

The equation y_j gives w_{jj} x_{jj} weight evaluations and bias relation value in the j^{th} neuron and b_j. In the calculation of ANNs, error functions used in both training and test data were calculated with the Mean Squared Error (MSE) (Masoud, 2014).

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)$$

Metrics are used to monitor and measure the performance of a model (during training and testing). The mean absolute percentage error (MAPE) is error measure, low result is measure that show high performance that is inversely proportional to performance (Wang and Xu, 2004). Performance metric is a part of ANNs which can be mathematically written as follows:

$$MAPE = \frac{100}{n}\sum_{j}^{n}\frac{|e_j|}{|A_j|}$$

Linear activation function and Levenberg-Marquardt backpropagation algorithm (*trainlm*) are used in the configuration of ANNs. The learning rate is 0.01, the number of iterations is 1000, 15% of the data is used as verification data, 15% is used as test data, and 70% is used as training data. The transfer function mainly uses a sigmoid or a logistic function, which gives values in the range of (0,1).

RESULTS

The sex of the species was 44.84 % females and 55.16 % males (sex ratio 1:1.23). The age of *A. boyeri* caught from İznik Lake ranged between I to IV years and among the different age groups, II and III year classes were dominant in the population. The sample size of the 1, 2, 3 and 4 age groups (female + male) was determined as 3 + 3, 143 + 281, 82 + 80, 30 + 13, respectively. Mean fork length (FL) (mm, min-max), mean W (g, min-max) and mean CF (value, min-max) were founded 67.31 (40.10- 97.77), 2.57 (0.53 - 7.50), and 0.790 (0.170-1.520) for all individuals.

Length-weight relationships were calculated using the data of all fish samples (Table 1). The *b* value for females was higher than for male's individual. The relationship between the age and length is given in Figure 2 as a von Bertalanffy growth.

Table 1. LWRs growth equations and parameters of *A. boyeri* population in İznik Lake

Sex (Individual number)	LWRs growth equations	R^2	L_∞	t_o	K	φ'
Female (258)	W=0.00001437 $L^{2.8602}$	0.947	136.258	-0.51	0.240	3.74
Male (377)	W=0.00001570 $L^{2.8266}$	0.942	155.042	-0.73	0.185	3.73
Female + Male (635)	W=0.00001328 $L^{2.8717}$	0.941	146.919	-0.64	0.205	3.82

R^2: correlation coefficients, L_∞: asymptotic theoretical maximum fork length, t_o: age at zero length, K: Brody growth coefficient, φ':growth performance index

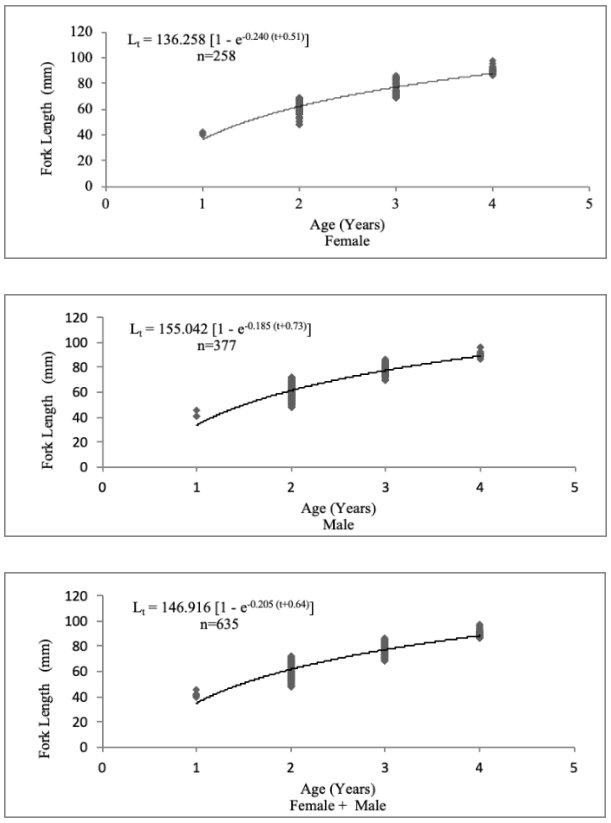

Figure 2. von Bertalanffy growth equations of *A. boyeri* in İznik Lake

The values in training (MSE (Mean Squared Error) 4.52559e^{-5}, R (correlation coefficients) 9.09347e^{1}), verification (MSE 4.86111e^{-5}, R 9.00931e^{-1}) and test data (MSE 3.391999e^{-5}, R 9.43465e^{-1}) were found in calculations made with ANNs. It is seen that it was gathered around the normalization line when the distribution of the data was examined (Figure 3).

After determining that the data distribution is appropriate, ANNs model to be used with coding written with MATLAB application was established (Figure 4). It is used as age, sex and fork length as input data; weight data is also used as output data. The hidden layer was set up as 10. ANNs result relationships can be seen in Figure 5. The mean FL and W values for 1, 2, 3 and 4 years and the mean values obtained from the ANN model, LWR and VB equations are presented in Table 2.

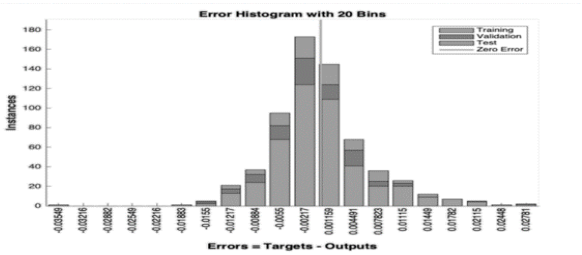

Figure 3. Distribution of data from İznik Lake

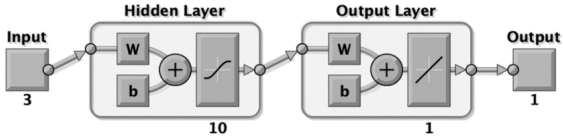

Figure 4. Artificial Neural Networks Model

Table 2. İznik Lake data and calculated values for ANNs, LWR and VB (Mean Fork Length (FL): mm; Mean Weight (*W*): g)

Age	İznik	ANNs	MAPE	LWR	MAPE	VB	MAPE
	FL W	FL W	FL W	FL W	FL W	FL W	FL W
1	41.950 0.669	42.120 0.671	0.405 0.299	43.395 0.607	3.445 9.267	40.947 0.512	2.390 23.467
2	61.652 1.896	61.820 1.905	0.273 0.475	62.370 1.883	1.165 0.685	61.403 1.530	0.403 19.303
3	76.981 3.628	77.130 3.733	0.194 2.894	78.184 3.872	1.562 6.725	77.253 2.958	0.353 18.467
4	90.241 5.537	90.310 5.486	0.077 0.921	90.585 5.477	0.381 1.083	90.165 4.612	0.084 16.705

FL: Fork length, W: Weight

DISCUSSION

Çetinkaya et al. (2011) (2.5:1), Özeren (2009) (1.7:1) and Gençoğlu and Ekmekçi (2016) (1.14:1) reported higher ratios than female male sex ratio of *A. boyeri* in İznik Lake (1:1.46). Although the gender ratio in most species is close to 1, it can vary from species to species, differ from one population to another, and may vary from year to year in the same population (Clarke, 1983).

The slope (*b*) values of the LWR in all gender is found as a 2.8717. Bigger *b* values for *A. boyeri* were reported by Bartulovic et al. (2006), Pombo et al. (2005), Gaygusuz (2006), Özeren (2009), Patimar et al. (2009), Çetinkaya et al. (2011), Lorenzoni et al. (2015), Gençoğlu and Ekmekçi (2016), Boudinar et al. (2016), İlhan and İlhan (2018), but it differed

from those found by Benzer (2016, 2020), Benzer and Benzer (2017, 2019) (Table 3). The fact that the b value of the individual in our study was b<3 is considered to be a factor, either that the large samples are elongated by changing their body shape or that the small individual are well fed (Kuriakose, 2017).

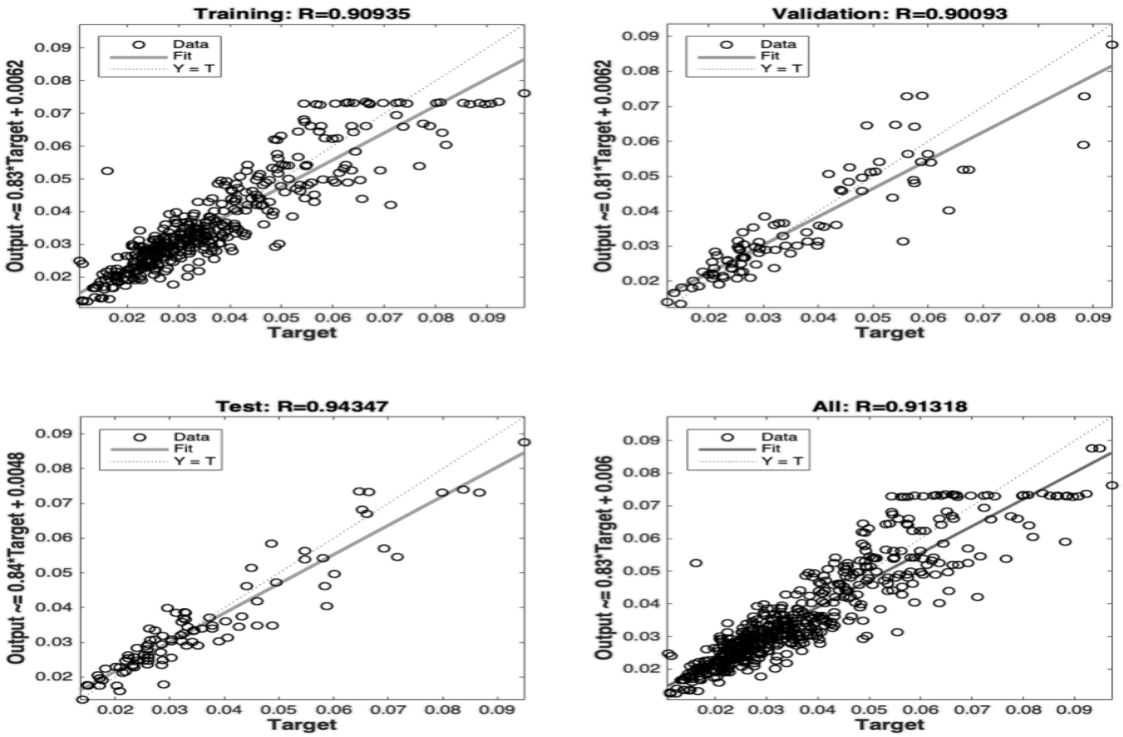

Figure 5. Regression curves by Artificial Neural Networks of *A. boyeri* in Iznik Lake

In all L_∞ value in the von Bertalanffy equations examined, L_∞ value of Pombo et al. (2005), Bartulovic et al. (2006), Gaygusuz (2006), Özeren (2009), Lorenzoni et al. (2015), Boudinar et al. (2016) were smaller İznik Lake. Patimar et al. (2009) and Çetinkaya et al. (2011) reported higher L_∞ value than İznik Lake (Table 4). Although the (L_∞) values obtained are similar to other studies, the difference in the studies can be explained by changes in environmental conditions and temperature. For example, L_∞ will increase when the temperature decreases (Kyritsi and Kokkinakis, 2020).

In all growth performance index examined, φ' value of Pombo et al. (2005), Lorenzoni et al. (2015), Gençoğlu and Ekmekçi (2016), Bartulovic et al. (2006), Boudinar et al. (2016), were smaller İznik Lake. Gaygusuz (2006), Özeren (2009), Patimar et al. (2009) and Çetinkaya et al. (2011) reported higher φ' value than İznik Lake (Table 4). The φ' value determined in this study was tested with the phi-prime index values in all studies and was found to represent the value in the 95% confidence interval (3.1526 -3.9703).

Although there was no enough study about condition factor value of *A.boyeri* in the literature; Çetinkaya et al. (2011) (0.780 for male and 0.822 for female) and Benzer and Benzer (2020c) reported similar condition value (0.804 for all gender) with *A. boyeri* in İznik Lake (0.790 for all gender).

The results obtained with ANNs gave better MAPE results compared to LWR and VB results (Table 2). The MAPE value of the model considered in the estimate should be less than 20%. The performance that gives the smallest value is determined as the highest model (Gilliland, 2010). According to these results, ANNs method has been found to give better predictive results in all cases. The obtained results are examined, it is determined that the best results are given by ANNs, VB and LWR respectively.

A.boyeri is generally distributed among the stagnant water systems of the Mediterranean coast, the Black Sea, the Azov Sea and the Caspian Sea (Kottelat and Freyhof, 2007). Although their natural distribution areas are marine and transition water systems, they have entered freshwater resources and are described as alien species in these habitats. It is an economically important species due to the export of *A.boyeri* in Türkiye. *A.boyeri* is an invasive species. It is important for economic, and their proliferation increases rapidly. *A.boyeri* needs to be followed in many ecosystems for all the reasons.

For years, many scientists have studied the superiority of artificial intelligence (AI) in solving regression problems over conventional classification and statistical models.Benzer and Benzer, (2016) studied the performance of an artificial neural network model, as one of the benchmark modeling techniques in Machine Learning studies, and a statistical linear regression model in fish growth in Mogan Lake. Elsewhere, Benzer et al. (2022) classified the fish age by taking into account the biological characteristics of the fish.

Table 3. Comparison of *A. boyeri* length-weight parameters in different locations

Study Area	*n*	*a*	*b*	R^2	GT	Reference
Ria de Aveiro	2503	3.3×10^{-3}	3.35	-	A+	Pombo et al. (2005)
Mala Neratva River	1200	3.4×10^{-3}	3.24	-	A+	Bartulavic et al. (2006)
İznik Lake	1136	$3.2 \times 10^{-3*}$	3.336	0.991	A+	Gaygusuz (2006)
İznik Lake	922	$4.0 \times 10^{-3*}$	3.20	0.978	A+	Özeren (2009)
Gomishan Wetland	2256	$5.3 \times 10^{-3*}$ $5.0 \times 10^{-3*}$	3.06^{m} 3.0630^{f}	-	A+	Patimar et al. (2009)
İznik Lake	237	8.0×10^{-3} 7.45×10^{-3}	2.98^{m} 3.05^{f}	0.993 0.996	A− A+	Çetinkaya et al. (2011)
Trasimeno Lake	3998	-2.326 -2.366	3.139^{m} 3.168^{f}	0.956 0.968	A+ A+	Lorenzoni et al. (2015)
Hirfanlı Dam Lake	674	$3 \times 10^{-6*}$	3.16	-	A+	Gençoğlu and Ekmekçi (2016)
Mellah Lagoon	1402	4.6×10^{-3}	3.179	0.944	A+	Boudinar et al. (2016)
Mogan Lake	488	$1.374 \times 10^{-3*}$	2.81	0.964	A−	Benzer (2016)
Hirfanlı Dam Lake	1449	$1.3 \times 10^{-2*}$ $1.7 \times 10^{-2*}$ $1.39 \times 10^{-2*}$	2.77^{m} 2.62^{f} 2.74	0.971 0.977 0.973	A− A− A−	Benzer and Benzer (2017)
Marmara Lake	185	5.9×10^{-4}	3.118	0.920	A+	İlhan and İlhan (2018)
Süreyyabey Dam Lake	394	1.2×10^{-3} 6.7×10^{-3} 6.4×10^{-3}	2.67^{m} 2.95^{f} 3.00	0.983 0.969 0.970	A− A− I	Benzer and Benzer (2019)
Yamula Dam Lake	594 516	9.7×10^{-3} 10.7×10^{-2}	2.8690 2.8169	0.950 0.934	A− A−	Benzer (2020)
İznik Lake	635	$1.570 \times 10^{-5*}$ $1.437 \times 10^{-5*}$ $1.328 \times 10^{-5*}$	2.8266^{m} 2.8602^{f} 2.8717	0.942 0.947 0.941	A− A− A−	This Study

n:number. *a*: regression intercept, *b*: regression slope, R^2:coefficient of determination, SE_b:standard error of b, GT:shape of growth; I:Isometric, A:Allometric, m male, f female, * mm

Table 4. Comparison of *A. boyeri* growth parameters in different locations

	n	t_m	L_∞	*K*	t_0	φ'	Reference
Ria de Aveiro	2503	3	11.6	0.099	-3.797	2.59	Pombo et al. (2005)
Mala Neratva River	1200	-	13.503	-	-	-	Bartulavic et al. (2006)
İznik Lake	1136	4	128.83*	0.305	-0.089	3.93	Gaygusuz (2006)
İznik Lake	922	4	141.11*	0.270	-0.490	3.98	Özeren (2009)
Gomishan Wetland	2256	4	155.17* 162.77*	0.280 0.270	-0.738 -0.727	4.21 4.26	Patimar et al. (2009)
İznik Lake	237	4	15.6	0.238	-0.199	4.06	Çetinkaya et al. (2011)
Trasimeno Lake	3998	4	10.031	0.180	-0.443	1.65	Lorenzoni et al. (2015)
Hirfanlı Dam Lake	674	4	151.02^{m*} 156.78^{f*}	0.148 0.197	-0.148 -0.197	3.52 3.88	Gençoğlu and Ekmekçi (2016)
Mellah Lagoon	1402	3	9.49^{m} 11.67^{f}	0.316 0.179	-0.928 -1.514	3.35 3.14	Boudinar et al. (2016)
İznik Lake	635	4	136.258^{f*} 155.042^{m*} 146.919*	0.510 0.730 0.640	-0.240 -0.185 -0.205	3.74 3.73 3.82	This Study

n:number. t_m: maximum age of the sample, L_∞: asymptotic theoretical maximum fork length, *K*:brody growth coefficient, t_0: age at zero length, φ': growth performance index, m male, f female, * mm.

Using artificial intelligence studies for long-term population monitoring with fewer samples in a certain ecosystem is considered advantageous for ecosystem protection and rapid calculation. It will be useful to evaluate it together with traditional methods.

CONCLUSION

As a result, it was found that the use of ANNs as a prediction tool provides high performance in *A.boyeri* individuals in Iznik Lake. The distribution areas of these invasive species should be determined to prevent irreparable losses in fish biological diversity in the world. Necessary studies should be carried out to determine the invasive fish action plans on native fish species in habitats such as fisheries, disease, hybridization, food, and habitat competition. It is found that the population of *A.boyeri* reflects the expected and previously observed features of the species in natural waters, but it is necessary to activate the national law of fishing,

exploiting and protecting aquatic resources to continuation the fish populations in the freshwater as an economic resource.

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AUTHORSHIP CONTRIBUTIONS

All authors contributed equally to the idea, data collections, design and writing of the manuscript.

CONFLICTS OF INTEREST

The author declares that there is no conflict of interest on this manuscript.

ETHICS APPROVAL

No specific ethical approval was necessary for this study.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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