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Growth and length–weight relationships of *Pseudorasbora parva* (Temminck & Schlegel, 1846) in Hirfanlı Dam Lake: Comparison with traditional and artificial neural networks approaches

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Abstract

The present study was carried out to assess the population structure and growth with length weight relations, von Bertalanffy equations and artificial neural networks (ANNs) of topmouth gudgeon fish, between May 2015 and May 2016, in the Hirfanlı Dam Lake. The age of topmouth gudgeon caught from the Hirfanlı Dam Lake ranged between I to V years. The von Bertalanffy growth function growth coefficient k was 0.5 and asymptotic length $\mathbf{L_\infty}$ was 9.13 mm fork length (FL). The weight-length relationship is given by the regression equation $W=0.01275334\times L^{3.0005}$ for all individual. Growth equations in length (mm) and weight (g g) are: $\mathbf{L_t} = 9.13\ [1–e^{–0.380\ (t + 0.5)}]$ and $W_t = 10.36\ [1–e^{–0.380\ (t + 0.5)}]^{3.0005}$ for all individual. Minimum and maximum sizes was were 2.7 and 9.2 cm FL for all individuals. Here, we examine the growth properties (length and weight) of topmouth gudgeon by modern (artificial neural networks) and traditional approaches (Length weight Relations and von Bertalanffy growth model) in the Hirfanlı Dam Lake. This study presents the first LWR, von Bertalanffy and ANNs references for this species in the Hirfanlı Dam Lake.

Keywords: Growth, Artificial neural networks, Length weight relations, Topmouth gudgeon.

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Introduction

The topmouth gudgeon, *Pseudorasbora parva* (Temminck and Schlegel, 1846), is a small cyprinid fish native in Southeast Asia (Carosi *et al*., 2016). It has been introduced to various areas in Europe and Asia (Gaviloaie and Falka, 2006) and reported by 32 countries from Central Asia to North Africa (Gozlan *et al*., 2010). *P. parva* populations transported to the new regions developed rapidly, settled down in the field and numerically became the predominant species within the fish communities they were in. Concerns about the negative ecological effects of *P. parva* on local species time has increased a lot. *P. parva* populations occurring in European fresh waters display a wide morphological variability, significantly different from one to another (Witkowski, 2006). The first record of *P.parva* in Turkey was reported by Erk'akan (1984). Populations of this fish were noted throughout the western region of Turkey only during the past 20 years. It is estimated that this invasive fish may be a threat to the endemism and biodiversity of inland water fauna, which is rapidly dispersed in Anatolia. (Ekmekçi and Kırankaya, 2006).

The topmouth gudgeon has been reported in aquatic systems in terms of distribution and biology (Rosecchi and Crivelli, 1993; Ekmekçi and Kırankaya, 2006; Britton *et al*., 2008; Yağcı *et al*., 2014), morphology and reproduction (Patimar and Baensaf, 2011; Záhorská *et al*., 2013) and growth properties (Kleanthidis and Stergiou, 2006; Britton and Davies, 2007; Záhorská *et al*., 2010; Huo *et al*., 2012; Wang *et al*., 2012; Onikura and Nakajima, 2013; Kırankaya *et al*., 2014; Aazami *et al*., 2015; Davies and Britton, 2015).

Length-weight relationship (LWR) and von Bertalanffy (VB) are important in fisheries science, notably to raise length frequency specimen to all catch, or to estimate biomass from underwater length observations (Usseglio *et al*., 2015). In recent years Artificial Neural Networks (ANNs), which are modern mathematical methods, are also used in fishing applications (Sun *et al*., 2009; Tureli Bilen *et al*., 2011; Benzer and Benzer, 2015). Numerous literature studies have been reported in the literature ANNs predict future data and their results are better than the results of modern methods (Eğrioğlu *et al*., 2008; Suryanarayana *et al*., 2008; Tureli Bilen *et al*., 2011; Benzer, 2014; Christiansen *et al*., 2014; Benzer *et al*., 2015; Al- Benzer *et al*., 2016; Benzer and Benzer 2016; Maqaleh *et al*., 2016; Ahmadi & Rodehutscord, 2017; Benzer *et al*., 2017).

ANNs generalizing, comprehending what is in a data set, classifying, and adapting to changing conditions. (Brosse *et al*., 1999). In this study, we examined the growth properties (length and weight) of topmouth gudgeon by modern (ANNs) and traditional approaches (LWR and VB growth model) in Hirfanlı Dam Lake.

Materials and methods

Study site

The study was carried out in the Hirfanlı Dam Lake (Fig. 1). Constructed in 1959, the Hirfanlı Dam Lake is on river Kızılırmak, 70 km far from the south of Kırıkkale. It is located at 856 m altitude with a capacity of 7.63 x10^9 m^3 and an area of 320 km^2. The depth, length and width of the lake are 58 m, 90 and 15 km, respectively. It is 24 km far from Ankara - Kırşehir and 30 km from Ankara - Adana (DSI, 1968).

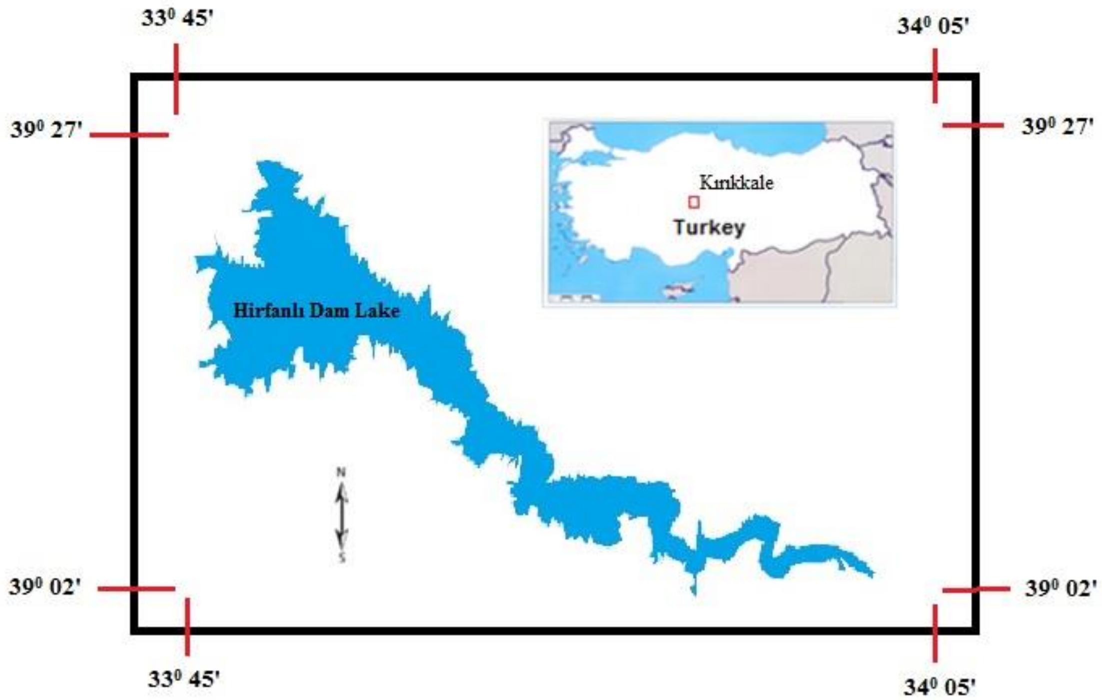

Figure 1: Hirfanlı Dam Lake.

Fish samples (*Pseudorasbora parva*, Temminck et Schlegel, 1846) were collected from the Hirfanlı Dam Lake. During the study, 356 fish specimens (139 females and 217 males) were caught in 2016. The fish samples were obtained from commercial fishing fishermen during the fishing season in the Hirfanlı Dam Lake. A 10 m long seine net, with mesh size of 10 mm, was used. Sexes were determined by dissection. Scales were made by sampling from each specimen to determine ages of fish according to Lagler (1966).

Length-weight relations

The LWR were calculated by the method, $W = aL^b$, where **W** is body weight (g), **L** the 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.

Von Bertalanffy equations

Growth was estimated using the VB growth curve model ($L_t = L_\infty(1 - e^{-k(t-t0)})$) and weight where $\mathbf{L_t}$ = the fork length (cm) at age t, $\mathbf{L_\infty}$ = the asymptotic length (theoretical maximum length), **k** = the Brody growth coefficient (proportional to rate at which $\mathbf{L_\infty}$ is reached), **t** =the age (years), $\mathbf{t_0}$ = the age at zero length, $\mathbf{W_t}$ is the weight of the fish in g at age **t,** $\mathbf{W_\infty}$ is the asymptotic weight of (theoretical maximum weight) the fish in gram (g) and **b** is the constant in the LWR (Sparre and Venema, 1992). The VB growth parameters were estimated for both sexes determined.

Artificial neural networks

ANNs is a potential computational tool that can be used to estimate seperation performance. It has been successfully used in many problem-solving areas like engineering, accounting, medicine, biology and fisheries. This computer model is considered as a system to receive inputs, to modify weights, and train the network before a desired response is produced at the output (Hopgood, 2000; Faris *et al*., 2014). ANNs can be used to estimate the behavior of a system with known parameters and to optimize a system (Sinha *et al*., 2013; Samli *et al*., 2014). Growth partameters were estimated using the artificial neuron model ($y(k) = F(\sum_{i=0}^{m} w_i(k).x_i(k))$) where $w_i(k)$= weight value in discrete time k where i goes from 0 to m, $x_i(k)$= input value in discrete time k where i goes from 0 to m, F = a transferfunction, $y_i(k)$ = output value in discrete time k (Krenker *et al*., 2011). To solve problems in this study, the supervised learning method trained with the network structure (Back-propagation Networks) was applied.

Identification models and statistics

Neural Network Toolbox of Matlab was applied for the ANNs computations. MATLAB (matrix laboratory) is a multiparadigm numerical computing environment and fourth-generation programming language. Data were categorized as three parts: training, validation and test sets. The Matlab functions were applied for "training", "testing", and "validation" and the results of these are respectively 70 %, 15 % and %15.

In this study, the sum of squared error and mean absolute percentage error (MAPE are used as the two performance criteria by Matlab where Y_i is the actual observation value, e_i is the difference between the actual vale and prediction value, and n is the number of total observations. Variables are reported as Mean ± S_x. Means were compared using the t-test (Hald, 1952; Panofsky and Brier 1968). Statistical analyses were performed using SPSS softwares (ver 21).

Results

There were about 39.04 % females, 60.96 % males, and discrepancies among age groups were not significant (p>0.05) in the Hirfanlı Dam Lake. The age group caught from Hirfanlı Dam Lake ranged between I to V. Most of the samples studied in the present study belonged to II and III year age group in the Hirfanlı Dam Lake. The fork length of individuals which were caught (FL) were between 2.7 and 9.2 cm and their weights (W) were ranged between 0.366 and 8.307 g in the Hirfanlı Dam Lake. In all groups, the differences between the gender were insignificant (p>0.05).

The length and weight of an individual were known and they were calculated with the logarithmic using the regression coefficient ($W=a\ L^b$). The LWR curve is shown in Fig. 2 for female and male. Growth equations of the length of an individual at any age were calculated with the VB growth equation using age-length relationship growth data according to sex and the length.

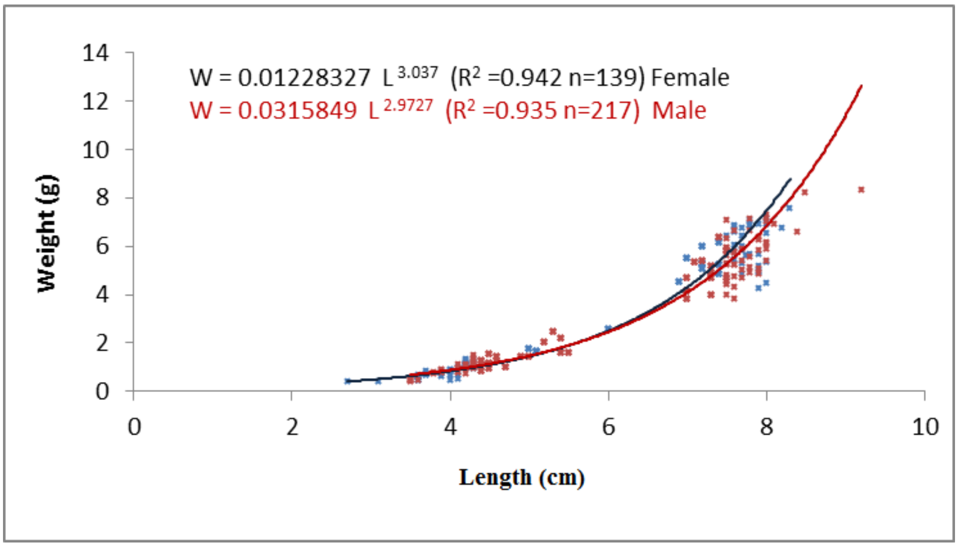

Figure 2: Length–weight relationships in female and male.

A multilayer feed-forward neural network was used for ANNs. A schematic representation of a typical ANNs is shown in Fig. 3. Fig. 4 illustrate graphical presentation by ANNs data.

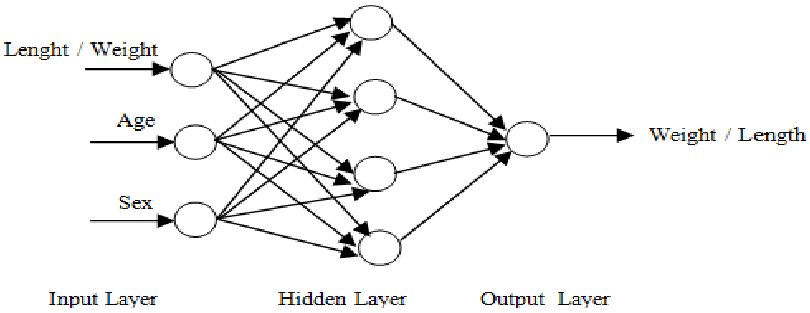

Figure 3: An ANNs schema.

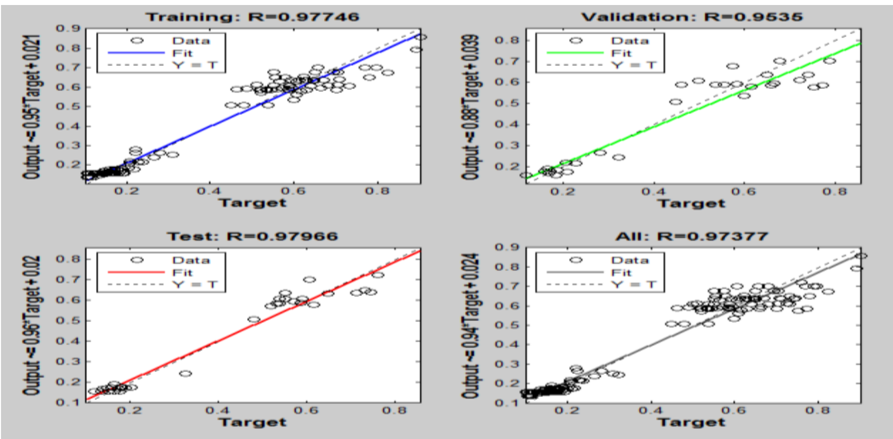

Figure 4: Relationship for ANNs.

The values came from actual, ANNs, LWR and VB data are shown in Table 1. The actual data, which is collected from the Hirfanlı Dam Lake, were shown according to the ages of group with average length and weight. The calculated data obtained from the ANNs, LWR and VB equations were presented according to the ages of group with length and weight. Table 1 were prepared in order to compare data of the fish in the Hirfanlı Dam Lake with tradional methods (LWR and VB) and modern method (ANNs).

Table 1: Actual data, ANNs, von Bertalanffy and length-weight relation with MAPE results.

Age	Gender	ACTUAL DATA		ANNs		MAPE (%)		Length Weight Relations		MAPE (%)		Von Bertalanfy		MAPE (%)	
		Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight
1	Female	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Male	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	All	3.974	0.854	3.951	0.899	0.561	5.250	4.060	0.801	2.156	6.194	3.967	0.850	0.186	0.515
2	Female	5.300	1.900	5.307	1.882	0.128	0.926	5.256	1.948	0.826	2.553	5.743	2.499	2.457	31.498
	Male	4.838	1.446	4.827	1.430	0.225	1.098	4.829	1.427	0.178	1.307	5.612	2.430	2.466	68.036
	All	4.930	1.537	4.903	1.439	0.539	6.346	4.936	1.530	0.152	0.456	5.599	2.389	2.384	55.510
3	Female	7.213	5.312	7.206	5.283	0.087	0.558	7.374	4.968	2.232	6.485	6.884	4.303	4.552	19.007
	Male	7.218	4.935	7.177	4.935	0.574	0.013	7.343	4.689	1.735	4.981	6.715	4.162	6.968	15.645
	All	7.216	5.094	7.188	5.072	0.381	0.430	7.367	4.797	2.021	5.827	6.715	4.122	6.936	19.067
4	Female	7.666	6.060	7.628	5.994	0.492	1.079	7.700	5.978	0.446	1.345	7.615	5.825	0.655	3.878
	Male	7.588	5.293	7.572	5.324	0.199	0.580	7.519	5.438	0.908	2.749	7.486	5.766	1.340	8.944
	All	7.614	5.548	7.589	5.438	0.315	1.998	7.575	5.635	0.512	1.554	7.479	5.694	1.771	2.626
5	Female	7.967	6.025	7.980	5.367	0.173	10.921	7.685	6.720	3.533	11.548	8.084	6.967	1.472	15.646
	Male	8.088	6.414	7.999	6.523	1.099	1.694	8.021	6.576	0.835	2.524	8.024	7.101	0.794	10.713
	All	8.031	6.232	7.978	5.911	0.665	5.138	7.873	6.614	1.966	6.140	8.001	6.972	0.381	11.876

Discussion

Topmouth gudgeon which is a small species of fish attains maximum lengths between 60 and 120 mm TL (but typically up to 50 mm), maturing usually in the first year of life (Gozlan *et al*., 2010). It was found 3.52 - 25.49 g for weight and 6.1 and 11.1 cm for length in the Egirdir Lake (Yağcı *et al*., 2014). The SL of all the topmouth gudgeon population changed from 9.26 to 81.89 mm in the Lake Lichenskie (Záhorská *et al*., 2013). The fork length of individuals which were caught were between 15 and 104 mm and their weights were ranged between 0.20 and 10.40 g for the Ciemięga River (Rechulicz, 2011). The fork length of individuals which were caught were between 18.02 and 96.24 mm in the Hirfanlı Resevoir (Kırankaya *et al*., 2014). Females fork length 2.1 - 59.8 mm, males 1.9 - 89.2 mm; females weight 28.7 - 73.1 g, males weight 30.2 – 89.2 g at the Gelingüllü Dam Lake (Yalçın Özdilek *et al*., 2013).

The slope (b) values of the LWR is a 2.9727 for males and 3.037 for females in the Hirfanlı Dam Lake. While Wang *et al*.

(2012) found b values as a 3.120 for the Yangtze River, Huo *et al.* (2012) found b values as a 3.02 for the Tarım River. It was calculated as b=2.93, b=2.73 for females and males individual respectively (Patimar and Baensaf, 2011) for Wetland of Alma-Gol. The b value determined at the Hirfanlı Dam Lake is similar to the results of some studies (Patimar and Baensaf, 2011; Aazami *et al*., 2015; Radkhah and Eagderi, 2015) (Table 2).

Table 2: LWR (a and b), growth (L_∞, K, t_0) parameters in literature.

Study Area	Length Range	a	b	L_∞	k	t_0	Ref.
Iran	4.15-6.87	0.0172	2.848	-	-	-	Esmaeili & Ebrahimi (2006)
Lake Doirani, Lake Mikri Prespa and Lake Volvi	5.4-8.3	0.0472	2.117	-	-	-	Bobori *et al.* (2010)
Tajan River	4.6-7.5	0.0091	3.1				Aazami *et al*. (2015)
Sur Pond	18.16-67.57	-	-	49.82[a] 59.35[b]	0.212[a] 0.210[b]	-1.646[a] -1.071[b]	Zahorska *et al*. (2010)
Wetland of Alma-Gol	-	0.014[a] 0.010[b]	2.73[a] 2.93[b]	-	-	-	Patimar and Baensaf (2012)
Ushize River	-	-	-	49.71	0.97	-0.60	Onikura and Nakajima (2013)
Sirwan River	3.0-7.2	0.004	3.37	-	-	-	Hasankhani *et al*. (2014)
Hirfanlı Dam Lake	18.02-96.24	-2.2432	3.3237	-	-	-	Kırankaya *et al*. (2014)
Tajan River	4.6-7.5	0.0091	3.1	-	-	-	Aazami *et al.* (2015)
Zarrineh River	3.1-7.5	0.0097	3.15	-	-	-	Radkhah and Eagderi, (2015)
Tiber River Basin	-	0.021	2.673	-	-	-	Carosi *et al*. (2016)
Mogan Lake	4.2 - 9.2	0.00001264[a] 0.0000202[b]	2.9409[a] 2.8395[b]	10.764[a] 10.064[b]	0.316[a] 0.375[b]	-0.74[a] -0.57[b]	Benzer *et al*. (2016)
Hirfanlı Dam Lake	2.7-9.2	0.0315[a] 0.0122[b]	2.9727[a] 3.037[b]	9.27[a] 8.82[b]	0.380[a] 0.359[b]	-0.50[a] -0.59[b]	This study

[a] male, [b] female

The **b** value is frequently 3.0 and usually between 2.5 and 3.5. Owing the approximately cubic relationships between fish length and weight, changes in weight are relatively more than changes in length as the fish growth. The **b** values are specific and change with sex, age, seasons, physiological conditions, growth increment and nutritional status of fish (Ricker, 1973; Bagenal and Tesch, 1978).

Differences of the length and weight in the fish growth can be clarified as a reaction (Nikolsky, 1963). The VB growthequations were: $L_t = 8.82\,[1 - e^{-0.445\,(t+0.32)}]$ for females, $L_t = 9.27\,[1 - e^{-0.359\,(t+0.59)}]$ for males and $L_t = 9.13\,[1 - e^{-0.380(t+0.50)}]$ for all individual for the Hirfanlı Dam Lake (Table 2). The VB growth equations parameters of *P. parva* which are located in various locations are given in Table 2.

The estimated growth parameters are model dependent; as a result, model choice uncertainty may be quite high in certain data sets. Disregarding this uncertainty may cause consequential overestimation of the precision and estimation of the confidence intervals of the parameters below the nominal level. This uncertainty has serious implications, e.g., when comparing the growth parameters of different fish populations. The set of candidate models should involve at least the VB model, one or more sigmoid growth curves, and one or more non-asymptotic models (Katsanevakis and Maravelias, 2008). An older population that is not caught is used in the VB model. The VB model gives better results with advancing age (Narinc *et al*., 2010).

ANNs performance criteria (MAPE, SSE and r^2 - Coefficient correlation) has been found to give better results (Table 3). The MAPE criterion refers to prediction errors as a percentage. MAPE values obtained from the model less than 10% are classified as "high accuracy" and stated as appropriate estimators (Lewis, 1982; Witt and Witt, 1992). As seen in Table 3, ANNs gives better results than LWR and VB. In the literatures, it is stated that ANNs MAPE values are lower than traditional methods (Tureli *et al*., 2011; Benzer *et al*., 2015; Benzer and Benzer, 2016; Benzer *et al*., 2016; Benzer and Benzer, 2017).

Table 3: Performans results with LWR, VB and ANNs.

	SSE		MAPE (%)		r^2
	Length	**Weight**	**Length**	**Weight**	**(Coefficient correlation)**
LWR	876.376	1758.621	1.361	4.034	0.937
VB	-	-	2.332	17.919	-
ANNs	270.380	471.189	0.492	3.832	0.974

VB value is not calculated for comparison (SSE and r^2). VB is only available for all ages.

Growth properties of top mouth gudgeon in the Hirfanlı Dam Lake have been revealed by LWR, VB and ANNS. Using ANNs as an estimation tool in the study found that it gave very good results. Therefore, ANNs were considered to be an option in the evaluation of growth properties. The potential use of accurate forecasts in decision making and fisheries management are supported directly by the findings of the present study.

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