Application of Artificial Neural Networks in Growth Models

Learning Objectives

The objectives of this chapter effects of ANNs on predicting statistical growth in fishery industry are investigated. The present study provides the first information on the population structure (age, growth and sex ratio) of the tench from Cyprinidae family (*Tinca tinca*) in Yeniçağa Lake by traditional and modern methods. Besides comparisons with conventional method are performed. Once you have mastered the materials in this chapter, you will be able to:

- Discuss the growth models with artificial neural networks for fish (*Tinca tinca* in Yeniçağa Lake).
- Understand the calculating traditional and artificial intelligence in tench.
- Identify the information data with Matlab application.
- Conversion and evaluation of tench measurements into data.
- Supporting decision makers in the fishing industry.

Chapter Outline

The aim of the fishing industry is to protect the natural habitat and fish maintenance of stocks. For this reason, all studies in fisheries must be done using new approaches on mathematical models. This design should be established in the fishing industry. A defect will occur when it is fail to meet the intended design. Hence, prediction methods play an important role to forecast the number of product fish growth. In this study, traditional approaches (Length-Weight Relationships-LWR) and Artificial Neural Networks (ANNs) approaches are examined in...
the growth models used in the fisheries industry. It is used ANNs model instead of the traditional statistical growth estimation techniques used in the fisheries industry to determine how to obtain results. The data obtained with conventional growth models are compared with the data obtained with artificial neural networks. 114 fish (*Tinca tinca*-tench) were caught in 2016 from Yeniçağa Lake (Bolu-Turkey). ANNs have been shown to be an option in assessing growth characteristics. Findings of this study are important in determining the correct estimates in fisheries management and in evaluating the growth characteristics.

**Keywords**

Artificial neural networks, tench, fisheries industry, traditional methods, modern methods, Matlab, *tinca tinca*.

1 **Introduction**

The industrialization of the world that began with the Industrial Revolution of the 18th century seems to have entered a new phase today. The industrialization process, which started with the emergence of water and steam-powered mechanical production systems, passed to the second stage by the use of electricity and mass production systems at the beginning of the 20th century. Since the 1970s, electronic and information technology, which brings production automation to a higher level, has also started to take third stage. When it came to 2011, the concept of Industry 4.0, which was first used in Germany, proclaimed the beginning of a new era all over the world. The main issues that define Industry 4.0 are the emergence of production systems based on cyber-physical systems and dynamic data processing. Industry 4.0; A very fast digital transformation is an environment in which information, communication, and internet technologies affect the production processes heavily in the world. This is the firm-level effects such as productivity, cost advantage, and profitability in production, as well as macro level effects such as growth, employment, human resources, education, investment and entrepreneurship. One of the issues that are expected to affect the concept of Industry 4.0 is the emergence of new
business models and the establishment of new initiatives. In addition to the existing forms of work, there are new applications and occupations. However, it is seen that there is not enough study in the literature. The emergence of the concept of Industry 4.0 is based on a high technology themed project conducted by the German government. The project was prepared with the computerization approach of production. Inspired by the significant transformations in the previous industrial revolutions, the project was called Industry 4.0. The concept was first used in 2011 at the Hannover Fair (Banger 2016). Industry 4.0 came to the agenda with the article titled "Industry 4.0: With the Internet of Things Going to the 4th Industrial Revolution" published in 2011 by Kagerman et al (2011). The German National Academy of Science and Engineering (Acatech) published in 2013 by the report titled "Recommendations for the Implementation of the Industry 4.0 Strategic Initiative" has gained the theoretical dimension of the subject (Acatech 2013). The use of the "Big Data", one of the main features of Industry 4.0 (ITRE 2016), in the fishing industry is exemplified. AI is the most significant tool for extracting information from data and for making decisions. At this point, in fishery industry applying modern techniques related to AI instead of conventional methods is gaining importance. Nowadays thanks to high computer technology human-beings are trying not only to resolve unsolved problems but to contribute novel approaches. From this point of view, the idea enabling intelligent machines in 1980s evolved and improved with ANNs in 1990s. In particular ANNs, a branch of AI, attracted interests of various academics and researchers. ANNs provide generalized learning based on training process (Bon and Hui 2017). Thus, ANNs has non-linear structure. Besides, ANNs outperform conventional methods in terms of performance measures and they can detect non-linear relations without any hypothesis (Türeli et al. 2011; Benzer 2015; Benzer and Benzer 2015; Benzer et al. 2015; Benzer and Benzer 2016; Benzer et al. 2016; Benzer et al. 2017; Benzer and Benzer 2017; Benzer and Benzer 2018a; Benzer and Benzer 2018b; Benzer and Benzer 2019). In the aquaculture industry, there will be no innovation without interdisciplinary work, it will not be possible to produce value-added ideas in complex socio-technical fields through various interdisciplinary collaborations and the engineers should be equipped with the skills they
have adopted modern approaches to provide interdisciplinary thinking and access to excellence. In this study, the effect of ANNs was investigated in predicting the statistical growth of fishery industry. It has also been evaluated by comparing traditional approaches with modern approaches. The present study provides the first information on the population structure (age, growth and sex ratio) of the tench from Cyprinidae family (*Tinca tinca*) in Yeniçağa Lake.

## 2 Methodology

### 2.1 Study area

The Lake Yeniçağâ is located in in west Black Sea region of Turkey (40° 46' 45" N, 32° 01’ 33" E), within the borders of the city Bolu and in the north of the town Yeniçağâ (Fig. 1). Lake Yeniçağâ is a shallow eutrophic freshwater lake with maximum depth of 5.2 m (Saygı and Demirkalp 2004), 989 m above sea level, and covers surface area of about 260 ha (Kılıç and Becer 2013).

![Fig. 1. The study area (Yeniçağâ Lake).](image-url)
2.2 Data collection

This study was carried out on 114 (54 females and 60 males) caught by using a gill nets (18 mm–55 mm mesh sizes) in Yeniçağa Lake in 2016. The fish samples taken from fishermen during the hunting season were transported to the laboratory to record the fork length (L) to the nearest 0.1 cm and body weight (W) to the nearest 0.1 g. The gender of the fish was determined from the gonads. Scales were sampled from each specimen for age determination according to Lagler (1966).

2.3 Length–weight relationship (LWR) equation

LWR equation is a traditional method used for the determination of the growth features of populations. From the collected samples; sex and length composition, the average length and weight weight, and the length–weight relationship for each sex and combined sexes were identified. The relationship between length (L) and body weight (W) for nearly all species of fish can normally be represented by the "length-weight relationship" following equation:

\[ W = aL^b \]  

Equation 1

Where W is the body weight of fish (in g), L is the length (in cm) and 'a' and 'b' are constants. The parameter 'b' (also known as the allometry coefficient) has an important biological meaning, indicating the rate of weight gain relative to growth in length or the rate at which weight increases for a given increase in length. If b is equal to 3, isometric pattern of growth takes places, if b is not equal to 3, then allometric pattern of growth takes places, it may be positive if it is greater than 3 or negative otherwise (Ricker 1973). The a and b constants could be estimated from linear functions. However, many functional relationships observed in fishery biology such as length-weight relationship are not linear. Fortunately, such curvilinear functions can often be transformed into linear functions by taking the logarithm or the natural logarithms of both sides.
\[ \ln W = \ln a + b \ln L \] 

Equation 2

\[ \log W = \log a + b \log L \] 

Equation 3

This equation is equivalent the regression equation:

\[ y = a + b \cdot x \] 

Equation 4

This mean that; \( y \) is equivalent to \( \ln W \), \( a \) which represents the \( y \)-intercept (the point where the line crosses the \( y \) axis) of the regression line is equivalent to \( \ln a \), \( b \) is the slope of the line, and \( x \) is equivalent to \( \ln L \).

### 2.4 Artificial Neural Networks (ANNs)

ANNs are computational systems that simulate biological neural networks and can be defined as a specific type of parallel processing system based on distributional or connectionist methods (Andrews et al. 1995; Hopgood 2000).

Artificial Neural Networks (ANNs) are used in three basics methods:

- As biological nervous system models and intelligence.
- As real time adaptive signal processing controllers implemented in hardware for applications such as robots.
- As methods of data analytic.

In several years of artificial neural models (ANNs) network has developed to predict. There are three featured steps in developing an ANNs based solution:

- Scaling or data transformation.
- Definition of Network architecture as in Fig. 2, when the number of hidden layers, the number of nodes in each layer and connectivity between the nodes and set, learning algorithm construction in order to train the network.
Artificial Neural Networks model diagram.
That contain of an input layer, a series of hidden layer, an output layer and connections between them. Nodes in the input layer represent possible influential factors that affect the network output and have no computational activities, while the layer of output contains one or more nodes that produce the output of network. Hidden layer may consist a large number of hidden processing nodes. A feed-forward back-propagation network propagates the information from the input layer to the output layers, compares the network output with known target, and propagates the error term from the layer of output back to the layer of input, by using a learning mechanism to adjust the biases and weights. ANNs are simulations of biological nervous systems using mathematical models. They are networks with simple processor units, interconnections, adaptive weights and scalar measurement functions (e.g., summation and activation functions) (Rumelhart et al. 1986). ANNs mathematical expression is seen in Fig. 3. Y is the neuron's output, x is the vector of inputs, and w is the vector of synaptic weights.

Fig. 2. Artificial Neural Networks model diagram.
Biological and Mathematical explanation for ANNs design.

In case of biological neuron information comes into the neuron via dendrite, soma processes the information and passes it on via axon. In case of artificial neuron the information comes into the body of an artificial neuron via inputs that are weighted (each input can be individually multiplied with a weight). The body of an artificial neuron then sums the weighted inputs, bias and “processes” the sum with a transfer function. At the end an artificial neuron passes the processed information via output(s). Benefit of artificial neuron model (Krenker et al. 2011) simplicity can be seen in its mathematical description below:

\[ y(k) = F \left( \sum_{i=0}^{m} w_i(k) \cdot x_i(k) \right) \]

\text{Equation 5}

Where:
- \( w_i(k) \) is weight value in discrete time \( k \) where \( i \) goes from 0 to \( m \),
- \( x_i(k) \) is input value in discrete time \( k \) where \( i \) goes from 0 to \( m \),
- \( F \) is a transfer function,
- \( y_i(k) \) is output value in discrete time \( k \).

As seen from a model of an artificial neuron and its equation (5) the major unknown variable of our model is its transfer function. Transfer function defines the properties of artificial neuron and can be any mathematical function.
2.5 Normalization

The supervised learning method trained with the network structure (Back-propagation Networks) will be used to solve problems in this study. The transfer function (6), (VN is normalized data, VN is data to be normalized, Vmin is the minimum value of the data, Vmax is the maximum value of the data) mostly used a sigmoid or a logistic function, gives values in the range of [0,1] and can be described as (normalization):

\[ V_N = 0.8 \times \left( \frac{V_R - V_{\text{min}}}{V_{\text{max}} - V_{\text{min}}} \right) + 0.1 \quad \text{Equation 6} \]

2.6 Estimation Accuracy Validation

For this research, the Mean Absolute Percentage Error (MAPE) is used for estimation accuracy. MAPE is defined as:

\[ \text{MAPE} = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{|\text{Estimated}_i - \text{Actual}_i|}{\text{Actual}_i} \right) \quad \text{Equation 7} \]

Comparisons can be made with more than one method by MAPE, because it is easy to interpret with its relative measurements. The smaller the values of MAPE, the closer are the forecasted values to the actual values.

\[ \text{MAPE} = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{c_i}{Y_i} \right| \times 100 \quad \text{Equation 8} \]

MAPE is the preferred error measure of the software measurement (MATLAB) researches.
2.7 Statistics

The MAPE benchmark refers to forecast errors as a percentage, and can therefore negate the disadvantages that may arise when correlating models developed for examines with different values. These features of MAPE are considered to be superior to those of other evaluation statistics. The MAPE results were assessed according to literature (0%–10%: Very Good, 10%–20%: Good, 20%–50%: Acceptable, 50%–100%: Wrong and Faulty) (Witt and Witt 1992; Lewis 1982). The coefficient correlation ($R^2$) calculated by the LWR regression model was 0.971. When the coefficient correlation ($R^2$) was evaluated in both ANNs and LWR model, the results of ANNs were better, although they did not seem close to each other. It is evaluated that comparing the MAPE values together with $R^2$ values can give a healthy result (Gentry et al. 1995).

2.8 Data Editing for MATLAB

Neural Network Toolbox of MATLAB was used for the ANNs calculations. This study was performed on 114 *Tinca tinca* (54 females and 60 males) taken from fishermen during hunting season caught in Yeniçağa Lake. The data were divided into three equal parts: training, validation and test sets. The Matlab functions were used for “training”, “testing”, and “validation”. They were used randomly; 70% in training, 15% in testing, and 15% in the validation of the fish.

3 Literature Review

3.1 *Tinca tinca*

In Turkey, Cyprinidae are the richest and the most important family of fish, and its members are distributed world-wide. These family members are distributed widely in fresh water sources (Geldiay and Balık 1996). Tench, *Tinca tinca* (L.), is widely distributed in Europe and Asia,
and has been introduced into the America, South Africa and Austria (Rosa 1958).

*Tinca tinca*, is a fish with an economic importance which shows a large distribution in inland waters of Turkey. They are highly resistance against external influences and diseases in spite of their body covered with thin scales and a mucus layer (Geldiay and Balık 1996). Due to they contact the mud of lake bottom continuously, they have an important role in the determination of mineralization (Demirsoy 1998). They also prevent the transition of inorganic nutrient salts, nitrogen and phosphorus accumulated in sediment to the water in eutrophic lakes because they feed on aquatic plants (Nikolsky 1963). Some of the researches related to Tinca tinca in Turkey and in the world are as follows: The growth properties of tench (*Tinca tinca* L., 1758) was investigated in Kesikköprü Dam Lake (Altındağ et al. 1998), Vegoritis Lake (Sinis et al. 1999), Lake Dgal Wielki (Pimpica and Pinos 1999), Bayındır Dam Lake (Altındağ et al. 2002), Çivril Lake (Balık et al. 2004), Beyşehir Lake (Balık et al. 2009), Hirfanlı Dam Lake (Benzer et al. 2009), two gravel pit lakes (Wright and Giles 1991), Seyhan Dam Lake (İngüden Alagöz and Göksu 2010), Kapulukaya Dam Lake (Benzer et al. 2010), Çamkörü Pond (İnnal 2010) and Trasimeno Lake (Pompei et al. 2012).

### 3.2 LENGTH–WEIGHT RELATIONSHIPS (LWR)

Length-weight relationships (LWR) is a widely used method, namely, in fish biology, ecology and fisheries studies. It is widely used in the determination of fishery measurement when sampling large species, mostly because of the difficulty and time required to record weight in the field (Andrade and Campos 2002). LWR for fish are predicted using the average length and weight (Mendes et al. 2004; Tosunoğlu et al. 2007). The LWR describes the correlation mathematically between the length and weight of the fish as well as the estimated values (Beyer 1991) of its length and weight. LWR are beneficial for the conversion of length equations to weight for use in stock calculation models (Lindqvist and Lathi 1983; Deval et al. 2007) and in predicting stock biomass with narrow sample (Verdiell-Cubedo et al. 2006). These re-
results also let scientists make identifications on morphological properties among species or among populations of the same species from various habitats (Moutopoulos and Stergiou 2002; Etchison et al. 2012). Critically, LWR were used to inform on the condition of freshwater samples and to evaluate whether somatic growth was isometric or allometric (Ricker 1973). The prediction of the relationship parameters between a and b can explain the connection regarding ecological events and life history. Environmental causes may affect crayfish growth by feeding and food resources. Length-weight values may probably demonstrate the differences in growth that may be correlated with environmental stress across the species (Westman and Savolainen 2002; Olsson 2008). The most frequently researched dimensions for crustaceans are carapace length, body length, total length, body width, and wet weight (Primavera et al. 1998). Differences in length between individual body parts are used to demonstrate the morphological changes between the male and female fish species (Lindqvist and Lahti 1983). These differences are also utilized in determining fish populations, its relative growth, comparing the populations of the same species, the morphology of fish species and the systematic assignment of fish (Lindqvist and Lahti 1983; Skurdal and Qvenild 1986; Gillet and Laurent 1995). The dimensions may be favorable to be able to convert into the desired length values when only one of the other length measurements is known and the LWR may be used to predict length from weight (Tosunoğlu et al. 2007).

### 3.3 ARTIFICIAL NEURAL NETWORKS (ANNs)

ANNs has been used in biology and in different disciplines of fisheries rather than in sciences (Tureli Bilen et al. 2011). Exercises of ANNs has included forecast the fish species distributions (Maravelias et al. 2003), fish predicting in a river (Mastrorillo et al. 1997), predicting macro invertebrate diversities (Park et al. 2003), population of aquatic insects (Obach et al. 2001), modeling freshwater fish (Joy and Death 2004), fish population modeling (Benzer 2015; Benzer and Benzer 2015; Benzer et al. 2015; Benzer and Benzer 2016; Benzer et al. 2016; Benzer et al. 2017; Benzer and Benzer 2017; Benzer and Benzer 2018a; Benzer...
and Benzer 2018b; Benzer and Benzer 2019). There are many publications on management information systems approaches in fisheries, biology and similar research areas (Fish et al. 1995; Lek and Guégan 1999; Olden and Jackson 2001; Teles et al. 2006; Goethals et al. 2007; Cabreira et al. 2009; Sholahuddin et al. 2015; Rocha et al. 2017; Ouali et al. 2017). Compared to traditional methods, ANNs has supported better conclusions in the evaluation of future data (Suryanarayana et al. 2008; Tureli Bilen et al. 2011). For limited values, the normality and their independence from the predicted values, ANNs is asserted to be an excellent model which gives excellent predictions. ANNs is also recorded to have accomplishment compared to linear regressions (Sun et al. 2009). Besides, ANNs is more favorable for its speed and flexibility (Brosse et al. 2009).

4 Results and Discussion

The data used in LWR and ANNs were about 47.37 % females and 52.63 % males (sex ratio 1:1.11). Average total length and weight values were calculated as 16.50 cm and 123.15 g. A total of 114 individuals, total size distribution was 11.5 – 24.0 cm and weight distribution ranged from 30.0 to 350.0 g. The distribution curve graph was plotted for all length and weight values using MATLAB application (Fig. 4).

Fig. 4. Total length and weight distribution of fish data.
For all individuals; $W = a L^b$ is calculated as exponential regression equation and the graph of equation is shown in Fig. 5.

Fig. 5. Length and weight relationship for all individuals (LWR).

When the fish data is examined, there is a strong positive correlation between the weight data with input data and length data with output data. It was evaluated that the problem can be solved by linear regression because the data are linearly related. MATLAB application was written with the coding of the shapes and ANNs parameters were calculated one by one. The ANNs distribution curve is shown in Fig. 6.
Fig. 6. ANNs regression graph.

The coding written in MATLAB, the mean absolute error and the root mean square error are calculated from the error functions used in both training and test data. In training data, MAE 0.6809, RMSE 0.8338; in the test data, MAE 0.6605, RMSE 0.7754 was found. The coding written in MATLAB, the Tinca tinca (tench) fish data obtained from Yeniçağa Lake and the estimation data obtained with ANN are shown in Fig. 7.
Fig. 7. Fish (Tinca tinca) in Yeniçağa Lake and predict data.

It is observed that the model has a positive result in solving the problem related to many variables which have no linear relationship between them (Türeli Bilen et al. 2011; Benzer 2015; Benzer and Benzer 2015; Benzer et al. 2015; Benzer and Benzer 2016; Benzer et al. 2016; Benzer et al. 2017; Benzer and Benzer 2017; Benzer and Benzer 2018a; Benzer and Benzer 2018b; Benzer and Benzer 2019). Traditional statistical methods can be analyzed according to past demand conditions, factors affecting demand, economic indicator relationships and demand estimation is performed. Past events are analyzed by statistical methods and projections are made about the future. Some of the most commonly used statistical methods are the following: Regression method, Correlation coefficient method, Curve fitting method, Time series analysis method, Moving averages method (Tekin 2008). The traditional methods used in the fishing industry are the regression model and the Von bertalanffy method. The data in the weight-to-weight relationship show normal distribution. In the regression analysis of normal distribution data it is stated that there is a linear relation-
ship between dependent and independent variables (Sarı 2016; Bahçecitapar and Aktaş 2017). This is an important mistake that affects the accuracy of estimation. It is observed that it has better results due to the lack of this error factor (Türeli Bilen et al. 2011; Benzer and Benzer 2015; Benzer et al. 2015; Benzer and Benzer 2016; Benzer et al. 2016; Benzer et al. 2017; Benzer and Benzer 2017; Benzer and Benzer 2018a; Benzer and Benzer 2018b; Benzer and Benzer 2019). It was listed Box-Jenkins methods (AR-MA Model, ARIMA Model, Simulation Model), fuzzy logic and artificial neural networks as modern estimation methods. Some properties of artificial neural networks, although they depend on the nature of the problem and the neural network model used, give better results than traditional information processing methods. Today, enterprises use the artificial neural network method in prediction studies that are vital in almost all decision making processes. In this study, it has been shown that the model of length weight estimation developed with ANNs can also be used in the fishing industry. In future studies, estimations can be proposed by using ANNs models with different architecture. Time series and fuzzy logic approaches can be used as an alternative to ANNs.

5 References


References


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6 Key Terms

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7 Questions for Further Study

Describe the principal steps in the planning phase. What are the major deliverables?

Compare modern methodologies and traditional methodologies.

What does normalization mean in artificial neural networks?

How do error comparisons be made in artificial neural networks?

8 Exercises

In the fisheries industry, you can use the traditional methods for the samples taken from ecosystems. Find the growth models and draw growth curve. What do you say?

In the fisheries industry, you can use the modern methods (artificial neural networks) for the samples taken from ecosystems. Find the growth models and draw growth curve. What do you say?

Compare the traditional methods and modern methods (artificial neural networks).

According to the error rates, which method gave better results. What do you say about ecosystem?

Artificial neural networks can be used in other areas of the industry. Discuss.

9 Further Reading


