Neural Model for Diagnosis and Fault Detection in Modern Shrimp Ponds

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Abstract. Nowadays, the methods based on artificial neural networks (ANN) have demonstrated to be useful in the treatment of environmental problems. Water quality is an important factor in shrimp farms. This study proposes a new method for evaluating the water quality in shrimp ponds based on an ANN, this method has been developed proving the importance and potentiality of the neuronal systems in this area. ANN's are used to find a relationship among the environmental variables that affect the shrimp habitat. The results show a good response obtaining for classification of the status of the water quality; excellent, good, regular and bad. This work gives an alternative tool that is used in the treatment of the water management.

Keywords: Water quality, neural networks, aquaculture, artificial intelligence.

1 Introduction

The shrimp farming is an important activity in aquaculture field that is practiced over the world. In Mexico the total area dedicated to the shrimp farming is approximated 52,648 ha; 51,059 ha is located in the Gulf of California. The farming system most used in the Gulf of California is the semi-intensive [1]. The shrimp ponds are supervised frequently because the environment must be controlled. In the marine water exist many environmental parameters that affect the habitat, such parameters are classified in tree categories: physical, chemical and biological. A good control of the environmental variables makes a good habitat (Table 1) [2].

The water management is an important factor in farming shrimp for having a good farming period. A bad control in water quality could generate a stress, low maturing or a decreasing in the immunological system. An organism weakened has more possibilities for getting any sickness for example Yellow-Head Virus, White Spot Syndrome Virus and Taura Syndrome Virus.

This work develops a neuronal model that allows diagnosing the status of water quality and detects faults in modern shrimp ponds; also the objective of the model is obtaining a good environment that allows an optimal maturing and surviving of the organisms [3],[4].

The shrimp farms are big places, which are composed of many ponds; each one has a different habitat. The measurement made to each variable is made with manual techniques in laboratories or using sensor devices, for example pH, temperature or conductivity sensors. The needed for techniques that allow the diagnosis of the status of water quality, the analysis of the environmental variables behavior and their integration in the assessment in such process is clearly recognized. Analyzing these aspects, some alternatives have been developed in the artificial intelligence and the

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control techniques areas. Some of the methodologies are based in neuronal systems, and these systems have been proved in real environmental problems [2].

Tabla 1. Physical-chemical parameters in a shrimp pond.

High Impact	Low Impact
Temperature	Hydrogen Sulfide
Oxygen dissolved	Non Ionized Hydrogen Sulfide
Turbidity	Nitrates
Salinity	Total inorganic Nitrogen
PH	Silicate
Non ionized ammonia	Phosphorus
	Chlorophyll A
	Total suspension solids
	Potential redox
	Alkalinity
	Dioxide of Carbon
	Total Ammonia

In the habitat the environmental variables must be in a valid range of values (Table 2), if they are out of this range, could generate a negative impact into the pond. There are some variables that have a bigger impact than others, if one or some of them are out of range will destabilize the water quality generating a bad status this is represented with two states "Good" and "Regular" depending of how many variables are not controlled, in other hand, if all the variables are in range, the pond is in optimal conditions and it is known as "Excellent", and the undesired status in when one of the variables or the combination of some of them could generate an status that will be lethal for the organisms that is known as "bad". The main purpose is to use these variables with an artificial neural network (ANN) for developing a system that obtains the status of the water quality [5], [6].

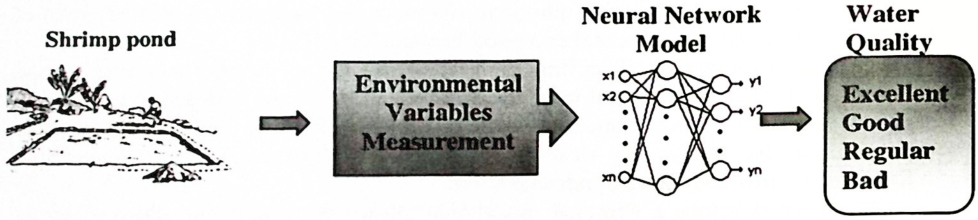

Fig. 1. The measurements of the environment will be analyzed by a model that describes the relationship among them, obtaining a status of water quality.

It is needed to indicate that water quality (WQ) in seawater is a function of the environmental variables; the next equation describes the relationship:

$$\text{Water Quality} = f\,(\text{Temp, DO, Salt, Turb, NIA, PH}, \ldots) \tag{1}$$

Where Temp is temperature, DO is dissolved oxygen, Salt is salinity, Turb is turbidity and NIA is non ionized ammonia [7]. There are also some relationships between variables, for example the equation that represent the changes with pH in the Gulf of California (Hernandez and Zirino, 2003), is a function of total CO_2 (*Ct*), total alkalinity (*At*) and pressure (*P*):

$$\partial pH = \left(\frac{\partial pH}{\partial Ct}\right)\partial Ct + \left(\frac{\partial pH}{\partial At}\right)\partial At + \left(\frac{\partial pH}{\partial P}\right)\partial P \qquad (2)$$

The environmental variables have relationships among them and trying to represent them is very complex to establish as the equation 2, however this complexity can be expressed with an ANN. The ANN is a powerful and efficient tool for recognizing and classifying patterns, that is why the ANN is used on intelligent systems. The ANN's are used in non-lineal mathematical relationships that are so hard to describe. In this study a neuronal system has been used for establish this relationship among them for evaluating the status of water quality.

Table 2 Ranges of environmental variables.

Environmental variables	Ranges of values
Temperature (°C)	23° – 30°
Salinity (mg/l)	15 – 25
pH (mg/l)	7.6 – 8.6
Dissolved oxygen (mg/l)	6 – 10

2 Materials and Methods

2.1 Study area and water quality data

The measurements of the environmental variables were made in ponds located in Bahía de Kino in the Gulf of California, near from Sonora Estate, the water resources were obtained from seawater (Fig. 1). A total of 3000 measurements were made in a period of shrimp farm. The variables measured were pH, temperature, salinity, dissolved oxygen.

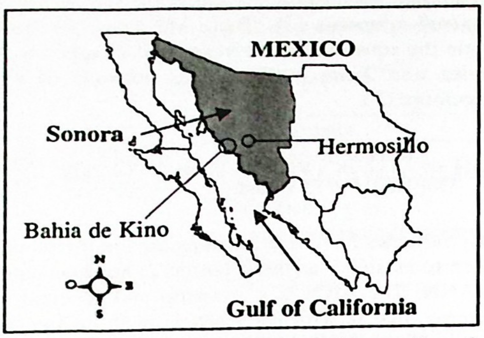

Fig. 2 Map of Sonora, Mexico indicating the two regions with sampling of shrimp farms (Bahia de kino and Hermosillo).

2.2 Artificial Neural Networks

The artificial neural networks were applied in this study for providing a non lineal relationship among the environmental variables (Input set) and the status classification for the water quality (Desire output). The environmental variables present no lineal relationships that are very hard to establish with a mathematical expression, in order to describe it, the ANN is a good technique to represent the behavior among them [8].

An ANN is constructed of singles processing elements called nodes o neurons, which are connected with some parameters called weights. The neurons are accommodated in a layer structure. The first layer is known as the input, and it is where the information of all environmental variables is introduced, the final layer is known as the output layer, this layer is where the neurons process all the data extracted giving a desired response. The layers used between the input and the output layer are denominated hidden layers (figure 4), and there is not a limit about how many hidden layers an ANN could contain [9], 10[].

Each neuron has a function, which is determined by the inputs that receives to other neurons (figure 3).

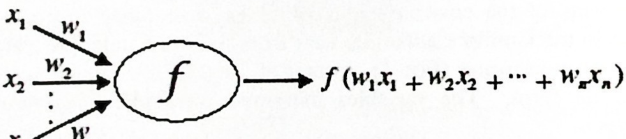

Fig.3 Representation of a neuron.

The behavior of a node can be expressed by the next equation:

$$s_i = \sum_{j=1}^{n} y_i w_{ij} + b_i \qquad (1)$$

Where w_{ij} are the weights that interconnect the different neurons j of the previous layer with the actual neuron i, b_i is the bias of the neuron, y_i is the output of the neuron in the last layer and S_i is the new output. The result will be processed by a new function that is called the transfer function; the most common are the next:

$$y_j = \frac{1}{1+e^{-S_i}} \qquad \text{Exponencial} \quad (2)$$

$$y_j = \tanh(s) \qquad \text{Tangencial} \quad (3)$$

$$y_j = \begin{cases} 1 & y_j > 1 \\ y_j & -1 < y_j < -1 \\ -1 & y_j < -1 \end{cases} \qquad \text{Lineal} \quad (4)$$

The learning method (memorizing) of an ANN's is made using a data set extracted by a database. The data set contains the input values (patterns) and the output values (desired response). The ANN is able to establish a relationship between the input and the output values [6].

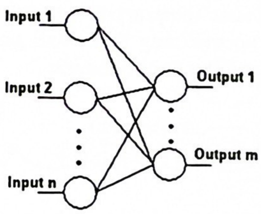

Fig. 4. ANN architecture.

The feature of the ANN's makes them an attractive case of study for resolving complex problems in engineering.

3. Results

Low concentrations of dissolved oxygen and high variations were observed in the most quantity of measurements made in the shrimp ponds. The conditions of the pond depend of the variations of the environmental variables for example the temperature and dissolved oxygen. The analysis made by the ANN showed that in the mayor part of the measurements the status of the water quality was a risk condition, the dissolved oxygen was one of the main factor of this result, due in the measurements obtained the values were lower than 4 mg/l, the high salinity concentrations was a second factor.

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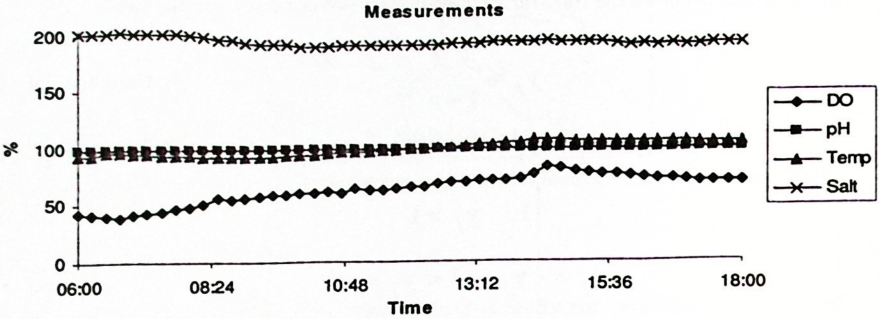

Fig. 2 Measurements obtained in a farming day.

3.1 Pre-processing

Some preprocessing steps make more efficient the RNA [3]. All the environmental variables were preprocessed before training the ANN, normalizing the data set in a range of [0, 1] is important because there are some variables that have big values and another that have low values, normalizing them will generate that all variables have the same range, to do this we used the next equation:

$$\text{var} = \frac{x - \min(x)}{\max(x) - \min(x)} \tag{5}$$

Where X is the environmental variable and var is the normalized variable.

3.2 Patterns

When the shrimp farming is in process the weather is always in change and the environmental variables could disestablish the habitat [7], [8], [9], this problem is generated by the combinations of the bad controlled variables, such problems could be classified as follows:

1. Excellent: all the environmental variables are controlled.
2. Good: One variable is out of range; however it not represents any problem.

3. Regular: some variables are out of range and the combination of them could disestablish the habitat.
4. Bad: One or some variables are in range that could generate several or lethal problems in the habitat.

The Table shows the range of the controlled environmental variables. The combinations of the values of the environmental variables create patterns that define de status of the water quality. A complete data set that contains all the possibilities is huge, this problem was resolved creating an artificial dataset which cover different cases, and this set was composed of 7000 patterns.

The nature of this parameter and their relationship with the water quality make them an excellent set for their processing with an ANN.

3.3 ANN Model

The ANN developed in this work is backpropagation 4 – 10 – 10 – 10 – 4 layered network; the input layer receives all the data set information (Environmental variables values). The output layer gives the final status of the water quality (excellent, good, regular, bad). The three hidden layers is constructed by 10 neurons each one and its functions is to do a processing between the input layer with the output layer. The topology was determined by proving different kinds of ANN's, this topology was the best in time processing and response. We found that there were not significant differences with a bigger numbers of neurons in the hidden layer, and a lower number of neurons the ANN's had not a good response [10],[11],[12]. The activation functions used were exponential; using about 400 iterations for the training, the mse obtained was of $1x10^{-3}$.

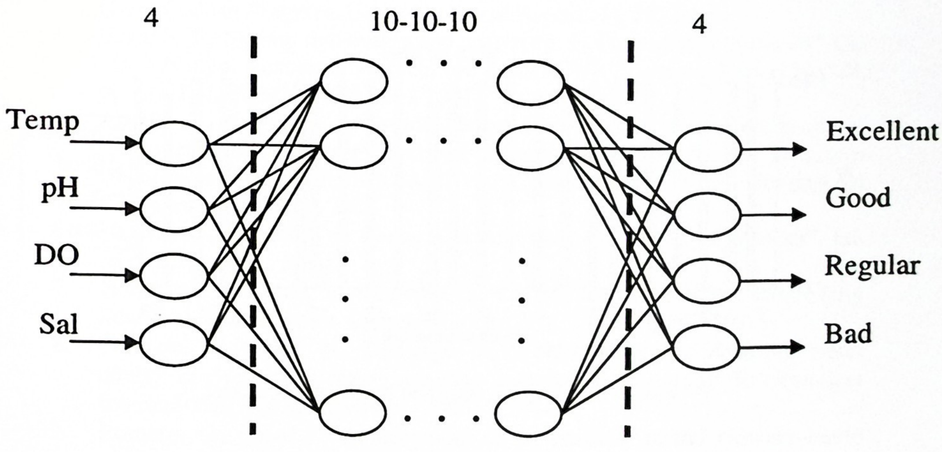

Fig. 4. Topology of the ANN. The 4 input layer is receives the environmental variables values, the four output layer is the response of the water quality in the shrimp habitat.

3.4 Water Quality Index

The measurement was tested with the neural network model; the results showed good performance of the ANN, obtaining a water quality status, however for practical reasons the output of the neurons was transformed for obtaining a index of water quality WQI, this process was done using a fuzzy logic system. The WQI is obtained in a range of [0,1], when the WQI is 0 means a bad water quality, in other hand if the WQI is 1, means a excellent water quality, and the values between 0 to 1 represents the good and regular status [8].

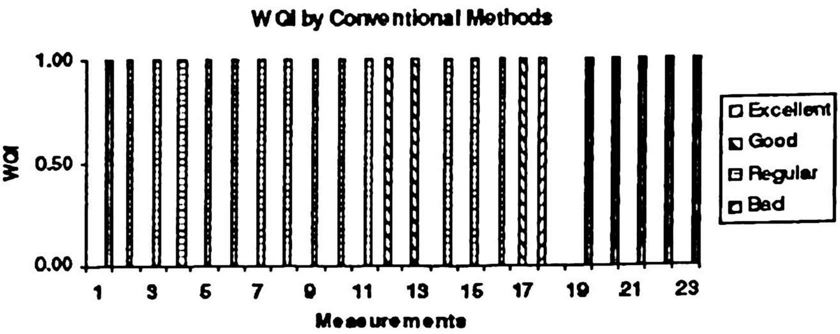

Fig. 3 The WQI is obtained by conventional methods.

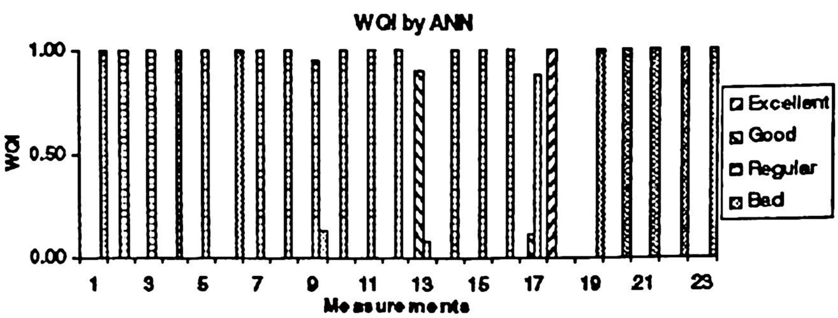

Fig. 4 The WQI is obtained by the ANN model.

4 Discussion

In this work, we present a neural model that gives a diagnosis for fault detection in management of water in shrimp; a mathematical equation that describes the behavior of the environmental variables in water management is very complex to develop. A research of the shrimp habitat was made for obtaining the environmental variables that have the highest impact in the WQI.

An ANN can model non linear systems in aquaculture systems; the topology of the network depends of how complex is the environment system. There are some questions about the regression methodologies because their purpose is to find the parameters that define the best linear approximation to the input and the output.

According with the results, the ANN gives a good diagnosis of the water management. We can conclude that the model proposed is an excellent tool for the diagnosis and detection of faults in modern shrimp ponds. The main advantage of our model over other evaluating methods is: speed on the assessment of water quality and its portability to another aquaculture system.

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