Erzincan Üniversitesi
Fen Bilimleri Enstitüsü Dergisi
2018, 11(2), 277-284
ISSN: 1307-9085, e-ISSN: 2149-4584

Erzincan University
Journal of Science and Technology
2018, 11(2), 277-284
DOI: 10.18185/erzifbed.390010

Evaluation of *Neoergasilus japonicus* (Ergasilidae) Occurrence on Rudd *Scardinius erythrophthalmus* Using Fuzzy Logic Approach

Emre ÇANAYAZ[1]*, Mehmet TEKTAŞ[2], Erhan SOYLU[1]

[1]Marmara University, Vocational School of Technical Sciences, Istanbul, Turkey
[2] Bandırma Onyedi Eylül University, Labour Economics and Industrial Relations, Department of Econometrics, Balıkesir, Turkey

Geliş / Received: 04/02/2018, Kabul / Accepted: 13/07/2018

Abctract

N. japonicus is a parasitic copepod from the family Ergasilidae (Copepoda, Poecilostomatoida) and is native to eastern Asia. *N. japonicus has* spread to many countries via different reasons. The fish host of this parasite in Lake Sapanca is *S. erythrophthalmus*. This study proposes a decision-support tool that uses a fuzzy-logic model of expert knowledge to assist in multi-criteria decision-making to forecast the existence of *N. japonicus* on fish according to the fish size and temperature of water by using MATLAB programming language to help the fishery industry to detect environments suitable for procreation of the parasite. The results produced by the software were compared with data obtained by parasitological examination of rudd, *S. erythrophthalmus*, from Lake Sapanca, Turkey. A total of 122 *S. erythrophthalmus*, including 64 males and 58 females with a mean length of 24.93 ± 3.65 cm (range: 15.2–34.0 cm), were examined. The findings indicated that although there are variations between examination results and those obtained from fuzzy software, the results are consistent with one another. According to the results, 20.49% of the fish were infected according to the data obtained from the lake. The proposed FLS system predicted that 27.87% would be infected. Hence fuzzy logic based algorithm make it possible to evaluate *N. japonicus* infection.

Keywords: Fuzzy Logic, *Neoergasilus japonicus*, Parasite, *Scardinius erythrophthalmus*

Neoergasilus japonicus (Ergasilidae) Oluşumunun Rudd *Scardinius erythrophthalmus* Üzerinde Bulanık Mantık Yaklaşımının Değerlendirilmesi

Öz

N. japonicus Ergasilidae (Copepoda, Poecilostomatoida) ailesinden parazit bir kopepoddur ve doğu Asya'da yaygın bir şekilde görülmektedir. *N. japonicus* farklı nedenlerden dolayı pek çok ülkeye yayılmıştır. Bu parazitin balık konağı Sapanca Gölün'de ki kızılkanat (*S. erythrophtalmus*) balığıdır. Bu çalışma, uzman bilgisi kullanarak bulanık mantık modeli oluşturup *N. japonicus*'un konak balıkta olma ihtimalini tahmin eden çoklu kriterler kullanan bir program sunmaktadır. Bunun için MATLAB programlama dili kullanılmış, balığın total boyu ve su sıcaklığı kullanılmıştır. Amaç, balıkçılık endüstrisinde bu parazitin üreme ihtimali olan ortamların tespit edilmesine yardımcı olmaktır. Program tarafından üretilmiş sonuçlar, Sapanca Gölü'nde kızılkanat balıkları üzerinde yapılan parazitolojik incelemeler ile karşılaştırılmıştır. Boy ortalamaları 24.93 ± 3.65 cm (aralık: 15.2–34.0 cm) toplam 122 kızılkanat (64 erkek, 58 dişi) incelenmiştir. Bulanık mantık ile üretilen sonuçlar parazitoloji incelemeleri ile ufak farklar gösterse de, içlerinde tutarlı olduğu gözlenmiştir. Sonuçların ışığında gölde incelenen balıkların %20.49'üne parazit bulaşmıştır. Sistem ise, verilere göre yaptığı tahminde bunun %27.87 olacağını öngörmüştür. Dolayısı ile bulanık mantık algoritması *N. japonicus'*un algılanmasını muhtemel kılabileceğini göstermiştir.

Anahtar Kelimeler: Bulanık Mantık, *Neoergasilus japonicus,* Parazit, *Scardinius erythrophthhalmus*

1. Introduction

Neoergasilus japonicus (Harada, 1930) is a parasitic copepod from the family Ergasilidae (Copepoda, Poecilostomatoida) and is native to eastern Asia; it was first reported by Harada in Taiwan (1930). *N. japonicus* has spread to many countries, possibly via the aquarium trade, aquaculture, bait release, or introduction of ballast water (Hudson ve Bowen, 2002).

It has been reported in many European countries (Ponyi, 1969; Tuuha, Valtonen, ve Taskinen, 1992) as well as the United States (Hudson ve Bowen, 2002). *N. japonicus* was

*Corresponding to: emre.canayaz@marmara.edu.tr

reported in Turkey by (Soylu, 2012). The fish host of this parasite in Lake Sapanca is Scardinius erythrophthalmus (Cyprinidae). Most European rivers north of the Pyrenees and Alps, eastward to the Ural and Eya drainages, the Aral and White Sea basins, and the Black Sea basin in Europe and northern Asia Minor are natural distribution areas of *S. erythrophthalmus* (Berg, 1962). Rudd is a benthopelagic cyprinid fish with omnivorous feeding habits and a lifespan of up to 15 years.

Fuzzy Logic (FL) theory, which emerged during the twentieth century, was predicted to apply to many areas and disciplines such as economics, control systems evaluation of student performance, and many others (Allahverdi, 2009; Badwawi, Issa, Mallick, ve Abusara, 2016; Bassford ve Painter, 2016; Buemi, Giacalone, Naccari, ve Spampinato, 2016; Cordón, 2011; Fat, Mic, Kilyen, Santa, ve Letia, 2016; Gokmen et al., 2010; Katbab, 1995; Michalczuk, Ufnalski, ve Grzesiak, 2016; Setyaningrum ve Swarinata, 2014; Turksen, 1997). There are also some scientific articles about the application of fuzzy logic in the fishery industry (Boavida, Dias, Ferreira, ve Santos, 2014; Carbajal-Hernández, Sánchez-Fernández, Carrasco-Ochoa, ve Martínez-Trinidad, 2012; Cheung, Pitcher, ve Pauly, 2005; Farghally, Atia, El-madany, ve Fahmy, 2014; Hattab et al., 2013; Jarre et al., 2008; Lea et al., 1998; Margaliot, 2007; Mendel, 1995; Van Rijn, Tal, ve Schreier, 2006).

In this original research article, by using a fuzzy logic approach, we were able to model a system that predicts the existence of *N. japonicus* on S. erythrophthalmus and the results were compared with data obtained from another experiment to show that the results are compatible. FL, which is based on verbal rules, is flexible and applicable to any parasitic infections. Therefore, applying this model to other fish species will improve productivity in the fishery industry and help to deal with nonlinearities and uncertainties in the future.

2. Materials and Methods

A total of 122 rudd (S. erythrophthalmus), including 64 males and 58 females with a mean length of 24.93 ± 3.65 cm (range: 15.2–34.0 cm), were examined each month between March 2009 and February 2010. The parasitic copepod *N. japonicus* was found attached to fins of *S. erythrophthalmus* from Lake Sapanca, Turkey. As human beings, we experience the world within which we live and use our ability to reason to create order from the mass of information we receive. According to Sivanandam (Sivanandam, Sumathi, ve Deepa, 2006) there is an inherent impreciseness present in our natural language when we describe phenomena that do not have sharply defined boundaries, for example, “Emre is tall” or “Emre is young”. Concepts that we use to define the world can be called fuzzy concepts. According to Zadeh, who is the inventor of a mathematical way of representing linguistic imprecision, FL is concerned with the formal principles of approximate reasoning (L. A. Zadeh, 1965), with precise reasoning viewed as a limiting case (Lofti A. Zadeh, 1988). FL is a tool for dealing with uncertainty. Therefore, fuzzy sets are mathematical objects that model the impreciseness described above. Instead of “yes/no” or “true/false” variables, fuzzy logic uses variables like “low”, “normal”, and” high” and fuzzy sets are formed by membership functions. Therefore, fuzzy set theory provides mathematical tools for carrying out approximate reasoning processes when the available information is uncertain, incomplete, imprecise, or vague, and vagueness in modelling systems and their impacts on the system are defined in linguistic terms (Nguyen, 2002). Boundary conditions and limits of the membership function can be stated with flexible organization in fuzzy sets. The most significant difference between traditional sets and fuzzy sets is the membership function. While traditional sets can be characterized by only one membership function, fuzzy sets can be characterized by numerous membership functions. By using the concept of degrees of membership to give a mathematical definition of fuzzy sets, researchers can increase the number of circumstances encountered in human reasoning that can be subjected to scientific investigation (Nguyen, 2002). It can be said that probability deals with statistical uncertainty, whereas fuzziness has been introduced as a means of representing and manipulating non-statistical uncertainty (Bezdek, 1994). Moreover, the most significant difference between traditional sets and fuzzy sets is the membership function. While traditional sets can be characterized by only one membership function, fuzzy sets can be characterized by numerous membership functions (Şen, 2009). Therefore, one can conclude that FL is very beneficial when dealing with real-world problems, which usually involve a degree of uncertainty in the form of "vagueness" or "imprecision". Fuzzy Logic System (FLS) can be defined as nonlinear mapping of an input dataset to scalar output data. A FLS consists of four main parts: the fuzzification part, linguistic rules, the inference engine, and the defuzzification part. The general structure and components of a fuzzy system are shown in Figure 1.

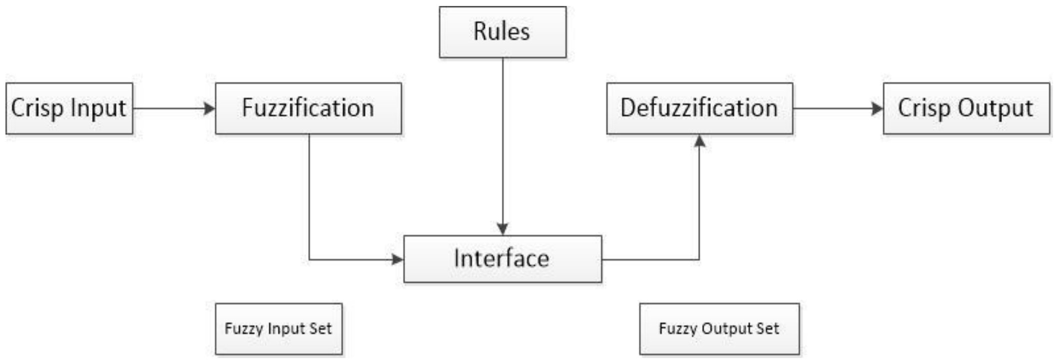

Figure 1. General structure of fuzzy logic system (Mendel, 1995).

For the proposed FLS, Mamdani type fuzzy logic sets formed by using MATLAB programming language were used. Moreover, a set was identified for each input value and membership values were assigned depending on the magnitude of the inputs. Temperature and fish size were selected as inputs due to their correlation with *N. japonicus*. Also, input values and output were shaped according to the rules defined in the fuzzy logic, and the centroid defuzzification method was used to generate a crisp output that shows the occurrence of *N. japonicus* on *S. erythrophthalmus* (Figure 2). The data on the numbers of fish and the parasite were taken from (Soylu and Soylu, 2012). We formed a mathematical model of the two inputs for estimation of the existence of *N. japonicus* using related research about *N. japonicus* and *S. erythrophthalmus* (Soylu and Soylu, 2012). These parameters can be listed as temperature and fish size (Figures 3a and 3b). Moreover, Lake Sapanca surface water temperature values between January and November are represented in Figure 4.

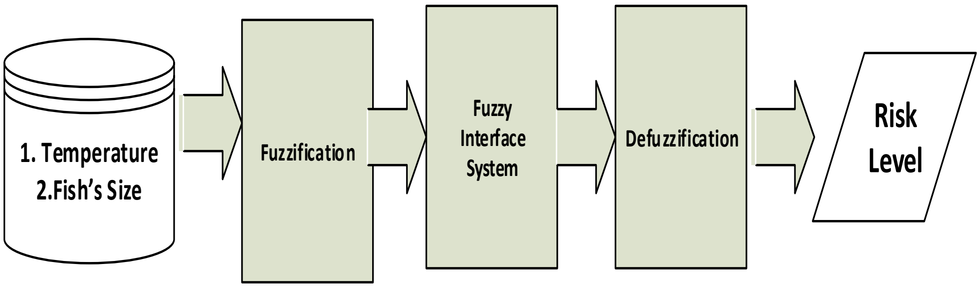

Figure 2. Structure of proposed FLS.

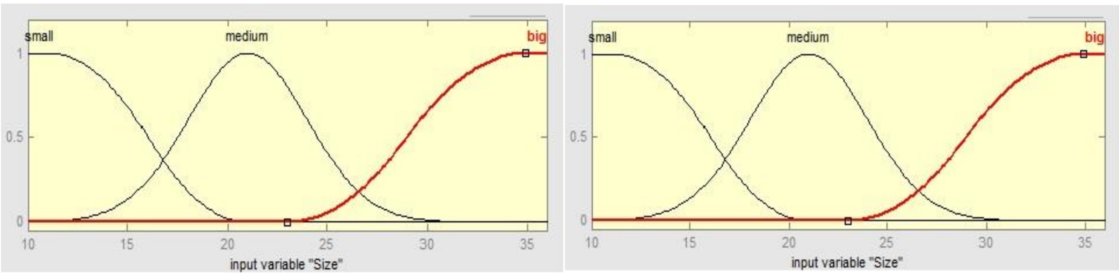

Figure 3. Mathematical input sets of temperature (a) and fish size (b) for the proposed system.

The temperature in degrees Celsius and the fish size in centimeters were used as the base parameters of the model. During the operation of the program, the user entered both into the program. There were three different conditions for each of the inputs and they were modelled as smooth curves due to their flexible structures.

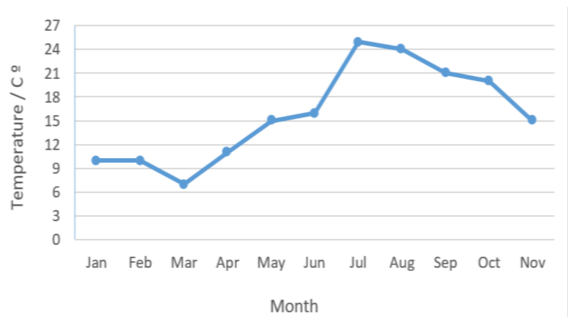

Figure 4. Surface water temperature of Lake Sapanca between January and November.

As the output, the proposed system generates a number between 0 and 100. Zero indicates that there is no *N. japonicus* parasite risk for rudd *S. erythrophthalmus* and 100 indicates that the related fish definitely have the parasite. The output of the risk levels is divided into four subgroups according to the risk classification: "low", "mid" for medium, "mid_high" for medium high and "high" (Figure 5).

As presented in Figure 1, FL systems needs to create a logical relationship between output and input. Hence, linguistic logical rules were used to perform this connection. These rules were generated with a specialist in aquatic products and aquatic parasites.

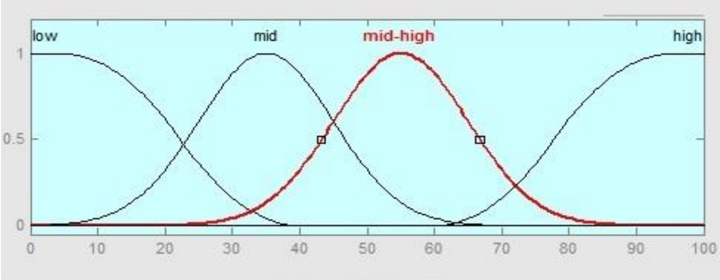

Figure 5. Output sets of the proposed system

In total, nine linguistic rules were formed according to the prior information about the parasite and related fish. For example:

"If temperature is *cold* and size is *small*, output is *low*"

"If temperature is *warm* and size is *medium*, output is *mid_high*"

As can be seen in Figure 1, the data should be fuzzified for usage of FLS, and fuzzy data should be defuzzified to generate crisp output. Therefore, for clarification of the output, the "Centroid" (Centre of Area) method was used (Figure 6).

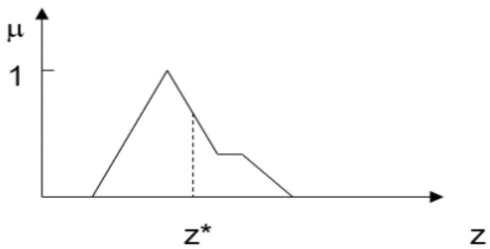

Figure 6. Centroid defuzzification method.

This method is not only the most prevalent but also the easiest defuzzification method for FL systems. In this method, the program finds the point where a vertical line would slice the aggregate set into two equal masses. Mathematically, this center of gravity can be expressed as in Equation 1 (Eq.1).

$$Z^* = \frac{\int \mu(z) \times z \times dz}{\int \mu(z) \times dz} \qquad (1)$$

3. Results

The system was tested on 122 *S. erythrophthalmus* samples collected from Sapanca Lake for the presence of *N. japonicus*. *N. japonicus* was found in 25 of the 122 *S. erythrophthalmus* specimens. Therefore, according to the samples collected from the lake, 20.49% of the total samples were infected by *N. japonicus*, while the FLS system determined that 27.86% of the fishes could be infected due to the parameters mentioned in the method section. A surface diagram of the proposed FLS and general rule viewer of the MATLAB® Fuzzy Logic Toolbox are presented in Figures 7 and 8, respectively.

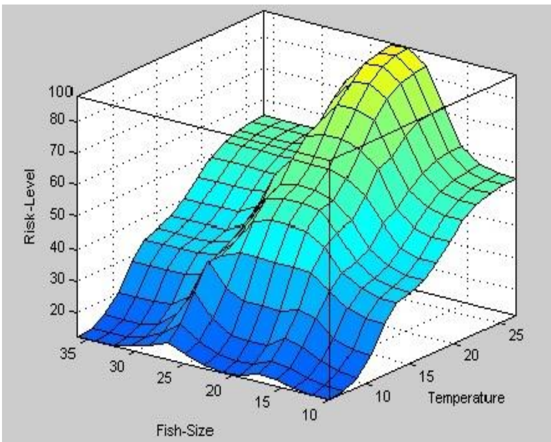

Figure 7. Surface diagram of proposed FLS.

All of the information about the fish size and the lake temperature was fuzzified and defuzzified according to the principles described in the method section.

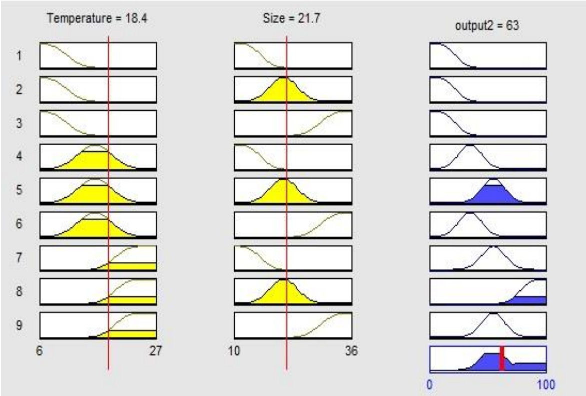

Figure 8. General rule viewer of proposed FLS.

Figure 9 presents two parameters: the number of infected fish from Lake Sapanca according to the data collected by (Soylu and Soylu, 2012) and the number of fish classified as being at high risk of infection according to the output of the system. Furthermore, Table 2 reports the *N. japonicus* infection parameters of the rudd.

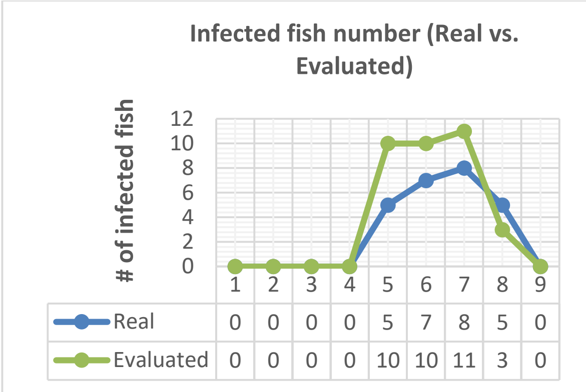

Figure 9. Number of infected fish: real versus simulation results.

Table 1. *N. japonicus* infection parameters of *S. erythrophthalmus* and infection parameters predicted by FLS for Lake Sapanca.

Months	**EFN**	**IFN**	**P (%)**	**Fifn**	**fP (%)**
March	12	0	0	0	0
April	14	0	0	0	0
May	16	0	0	0	0
June	16	0	0	0	0
July	20	5	25	10	50
August	13	7	53.84	10	76.92
September	13	8	61.53	11	84.61
October	13	5	38.46	3	23.07
November	5	0	0	0	0

EFN: Number of fish examined, **IFN:** Number of infected fish, **P:** Prevalence (%), **fIFN**: Number of infected fish according to the FLS output, **fP**: Prevalence according to the FLS output (%)

4. Discussion

The proposed FLS system was designed to calculate the risk of infection of *S. erythrophthalmus* by *N. japonicus*. Although different applications of FL to aquaculture can be found in the literature, to the best of our knowledge, our study is the only one to carry out infection risk prediction for *N. japonicus*. To test the FLS's performance, real data obtained from the rudd population in Lake Sapanca were used and compared with predictions generated by FLS.

According to the results, 20.49% of the fish were infected according to the data obtained from the lake. The proposed FLS system predicted that 27.86% would be infected in relation to inputs according to fish size and water temperature. Although the percentages are not the same, with respect to general risk analyses of infection by *N. japonicus*, the results are consistent with the natural contagion risk for rudd. One of the reasons for the difference in results was that not all of the fish in the high-risk group caught from the lake were infected. Besides that, the most important reason for the difference is the low number of fish examined. It is expected that increasing the sample number would give more consistent results in the comparison with the FLS's performance. According to the data collected from Lake Sapanca, there was an increment in parasite number in summer due to the temperature of the lake. As can be seen in Figure 9 and Table 2, this was compatible with the temperature trend. There was a huge rise in numbers of infected rudd, especially in July and August, when the *N. japonicus* infection risk increased. This consistent trend can be seen in Table 2, too. Some of the prevalence results are higher than they should be due to the small number of rudd samples. The prevalence may also show variation in other lakes. Our future studies will investigate the extent to which different parasites and infection parameters affect other fish species with increased sample. Moreover, different kinds of soft computing methods like artificial neural networks, genetic algorithm, will be combined with fuzzy logic algorithms to form hybrid systems to increase performance of the proposed system for other infectious parasite detection in fish species.

5. References

Allahverdi, N. 2009. Some applications of fuzzy logic in medical area. Paper presented at the Application of Information and Communication Technologies, AICT 2009. International Conference on.

Badwawi, R.A., Issa, W., Mallick, T., Abusara, M. 2016. DC microgrid power coordination based on fuzzy logic control. Paper presented at the 2016 18th European Conference on Power Electronics and Applications (EPE'16 ECCE Europe).

Bassford, M., Painter, B. 2016. Intelligent Bio-Environments: Exploring Fuzzy Logic Approaches to the Honeybee Crisis. Paper presented at the 2016 12th International Conference on Intelligent Environments (IE).

Berg, L.S. 1962. Freshwater fishes of the U.S.S.R. and adjacent countries. Jerusalem: Israel Program for Scientific Translations.

Bezdek, J.C. 1994. Fuzziness vs. probability. IEEE Transactions on Fuzzy Systems, 2, 1-3.

Boavida, I., Dias, V., Ferreira, M.T., Santos, J.M. 2014. Univariate functions versus fuzzy logic: Implications for fish habitat modeling. Ecological Engineering, 71, 533-538.

Buemi, A., Giacalone, D., Naccari, F., Spampinato, G. 2016. Efficient fire detection using fuzzy logic. Paper presented at the 2016 IEEE 6th International Conference on Consumer Electronics-Berlin (ICCE-Berlin).

Carbajal-Hernández, J.J., Sánchez-Fernández, L.P., Carrasco-Ochoa, J.A., Martínez-Trinidad, J.F. 2012. Immediate water quality assessment in shrimp culture using fuzzy inference systems. Expert Systems with Applications, 39(12), 10571-10582.

Cheung, W.W.L., Pitcher, T.J., Pauly, D. 2005. A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing. Biological Conservation, 124(1), 97-111.

Cordón, O. 2011. A historical review of evolutionary learning methods for Mamdani-type fuzzy rule-based systems: Designing interpretable genetic fuzzy systems. International Journal of Approximate Reasoning, 52(6), 894-913.

Farghally, H.M., Atia, D.M., El-madany, H. T., Fahmy, F.H. 2014. Fuzzy Logic Controller based on geothermal recirculating aquaculture system. The Egyptian Journal of Aquatic Research, 40(2), 103-109.

Fat, R., Mic, L., Kilyen, A.O., Santa, M.M., Letia, T.S. 2016. Model and method for the stock market forecast. Paper presented at the 2016 IEEE International Conference on Automation, Quality and Testing, Robotics (AQTR).

Gokmen, G., Akinci, T.Ç., Tektaş, M., Onat, N., Kocyigit, G., Tektaş, N. 2010. Evaluation of student performance in laboratory applications using fuzzy logic. Procedia-Social and Behavioral Sciences, 2(2), 902-909.

Hattab, T., Ben Rais Lasram, F., Albouy, C., Sammari, C., Romdhane, M.S., Cury, P., et al. 2013. The Use of a Predictive Habitat Model and a Fuzzy Logic Approach for Marine Management and Planning. PLoS ONE, 8(10), 76430.

Hudson, P.L., Bowen, C.A. 2002. First Record of *Neoergasilus japonicus* (Poecilostomatoida: Ergasilidae), A Parasitic Copepod New To The Laurentian Great Lakes. Journal of Parasitology, 88(4), 657-663.

Jarre, A., Paterson, B., Moloney, C.L., Miller, D.C.M., Field J.G., Starfield, A.M. 2008. Knowledge-based systems as decision support tools in an ecosystem approach to fisheries: Comparing a fuzzy-logic and a rule-based approach. Progress in Oceanography, 79(2–4), 390-400.

Katbab, A. 1995. Fuzzy logic and controller design-a review. Paper presented at the Southeastcon '95. Visualize the Future., Proceedings., IEEE.

Lea, R., Dohmann, E., Prebilsky, W., Lee, P., Turk, P., Hao, Y. 1998. A fuzzy logic application to aquaculture environment control. Paper presented at the Fuzzy Information Processing Society - NAFIPS, 1998 Conference of the North American.

Margaliot, M. 2007. Mathematical Modeling of Natural Phenomena: A Fuzzy Logic Approach. In P. P. Wang, D. Ruan & E. E. Kerre (Eds.), Fuzzy Logic: A Spectrum of Theoretical & Practical Issues (113-134). Berlin, Heidelberg: Springer Berlin Heidelberg.

Mendel, J.M. 1995. Fuzzy logic systems for engineering: a tutorial. Proceedings of the IEEE, 83(3), 345-377.

Michalczuk, M., Ufnalski, B., Grzesiak, L. M. 2016. Particle swarm optimization of the fuzzy logic controller for a hybrid energy storage system in an electric car. Paper presented at the 2016 18th European Conference on Power Electronics and Applications (EPE'16 ECCE Europe).

Nguyen, H.T. 2002. A First Course in Fuzzy and Neural Control: CRC Press, Inc.

Ponyi, J., Molnar, K. 1969. Studies on the parasite fauna of fish in Hungary V. Parasitic copepods. Parasitologia Hungarica 2, 137-148.

Şen, C.G. 2009. An Integrateg Approach to Determination and Evaluation of Production Planning Performance Criteria. Journal of Engineering and Natural Sciences, 27, 4-5.

Setyaningrum, A.H., Swarinata, P.M. 2014. Weather prediction application based on ANFIS (Adaptive neural fuzzy inference system) method in West Jakarta region. Paper presented at the Cyber and IT Service Management (CITSM), International Conference on.

Sivanandam, S.N., Sumathi, S., Deepa, S.N. 2006. Introduction to Fuzzy Logic using MATLAB: Springer-Verlag New York, Inc.

Soylu, E., Soylu, M.P. 2012. First record of the non-indigenous parasitic copepod *Neoergasilus japonicus* (Harada, 1930) in Turkey. Turkish Journal of Zoology, 36(5), 662-667.

Turksen, I.B. 1997. Fuzzy logic: review of recent concerns. Paper presented at the Systems, Man, and Cybernetics, 1997. Computational Cybernetics and Simulation., IEEE International Conference on.

Tuuha, H., Valtonen, E.T., Taskinen, J. 1992. Ergasilid copepods as parasites of perch *Perca fluviatilis* and roach *Rutilus rutilus* in central Finland: seasonality, maturity and environmental influence. Journal of Zoology, 228(3), 405-422.

Van Rijn, J., Tal, Y., Schreier, H.J. 2006. Denitrification in recirculating systems: theory and applications. Aquacultural engineering, 34(3), 364-376.

Zadeh, L.A. 1965. Fuzzy sets. Information and Control, 8(3), 338-353.

Zadeh, L.A. 1988. Fuzzy Logic. Computer, 21(4), 83-93.