Journal of Applied Science, Technology & Humanities
Volume 2, Issue 4, September, 2025, Pages 603-614

ISSN 3032-5765
DOI: https://doi.org/10.62535/fzqysf66

Implementation Of Fuzzy Logic On Simulation Of Ph, Temperature, And Dissolved Oxygen Monitoring System For Discus Fish

Farhan Adha[1]*
Fish Hatchery Technology and Management Program, Vocational School, IPB University
farhan22adha@apps.ipb.ac.id

Muhammad Rafa Najwan[2], Larisa Syafa Adisti[3], Shabrina Kesya Azizah[4], Rachel Delamaya Fefriani[5], Fauziah Prima Aulia[6], Abu Dzar Al-Ghifari[7], Ridwan Kuasa Samudra Singajaya[8], Baihaqi Al Faatih[9], Kevin Soerhensen[10], Dimas Muhammad Fathur Rifki[11], Fahmi Fadillah[12], Hafiz Kurniawan[13], Muhammad Faiz Assariy[14], Yassar Ariq Pradian[15]Daffa Zulqisthi[(16)]
Fish Hatchery Technology and Management Program, Vocational School, IPB University
E-mail: rafa2805najwan@apps.ipb.ac.id

Abstract

Discus fish (*Symphysodon* spp.) are ornamental fish that require special attention to water quality, including pH, temperature, and dissolved oxygen (DO). This research aims to develop a fuzzy logic-based water quality monitoring system to accurately evaluate these parameters. Quantitative methods were used with data collection through literature review and analysis using Matlab. The fuzzification process is applied to convert numerical data into linguistic values that can be processed by the fuzzy system. Results showed ideal temperature ranged from 27-32°C, optimal pH between 4.0-8.0, and good DO levels between 4.0-6.5 mg/L. The developed fuzzy logic system produced ea water quality assessment with a value of 6.61, indicating a fair quality. With high accuracy and average error less than 5%, the system is effective in decision-making for discus fish rearing. The integration of fuzzy logic technology strengthens the continuous monitoring of water quality. This research shows that a fuzzy logic-based approach can improve water quality management and support discus fish welfare.

Keywords: Fuzzy Logic, Mamdani, Aruduino, Discus fish, Monitoring System

INTRODUCTION

Ornamental fish is a fish commodity that is most in demand by the public because it has beautiful colors, unique shapes, many patterns and is still a prima donna in national and international shares to date (Putra 2020). Ornamental fish are fish that are not intended for consumption, but are kept for decoration or beauty needs (Dwiryo and Endryansyah 2025). Discus fish (*Symphysodon* spp.) is one of the ornamental fish that has a unique pattern and varied colors so it is dubbed the king of ornamental fish. This fish comes from the calm waters of the Amazon and has a warm temperature ranging from 22.9-33.7°C (Medeiros *et al.,* 2017). Discus fish maintenance generally uses an aquarium with a filter and water heater to support fish comfort. Water quality parameters must be considered to maintain discus fish. Maintenance of ornamental fish requires intensive cultivation and equipment so that the cultured ornamental fish are maintained health and safety. This intensive care requires continuous and repeated observation manually. This is of course troublesome for the cultivator because they have to directly monitor the water conditions in the cultivation container. In this sophisticated era, everything can be done effectively and efficiently because it is helped by the sophistication of technology (Junaedi *et al.,* 2023).

The most important resource in fish farming is water, because water can affect the conditions or components of living things (Aztisyah, 2021). Water quality criteria the pH and temperature of the water in the aquarium is one of the factors that affect fish health (Jemakmun and Syamsudin 2022). Water conditions must also be free from chemicals and clean from dirt and other physical conditions, so this must be considered for good fish growth. (Kristiantya *et al.,* 2022) Discus fish are sensitive to changes in water quality, so they require an environment with stable physicochemical parameters such as pH, temperature, and dissolved oxygen (DO). Good water quality is very important to support the life of discus fish, if changes occur outside the optimal range, fish survival can decrease (Zulka *et al.,* 2023). According to Fernandez *et al.* (2022) in their research, monitoring of these water quality parameters is still mostly done manually which is not only time consuming but also risks delays in detecting non-ideal conditions. An accurate and responsive water quality monitoring and control system is essential in discus fish farming and rearing.

Decision making on environmental data that tends to be uncertain or ambiguous, fuzzy logic is a very appropriate approach. Fuzzy logic allows systems to handle uncertain inputs in a way that resembles the way humans think. Fuzzy logic allows decision making based on a range of values with levels such as low, medium, or high. The implementation of fuzzy logic in control systems has shown its effectiveness in managing water quality parameters that are dynamic and non-linear. According to Pradana *et al.* (2022), the development of a system for controlling dissolved oxygen levels in aquaponic cultivation using the Mamdani fuzzy logic method with an Arduino UNO microcontroller and a DO sensor. This system is able to control dissolved oxygen levels close to a predetermined setpoint, with the largest error still under 5% tolerance, showing great potential in similar applications in aquaculture.

This research aims to develop a fuzzy logic-based water quality monitoring system that is able to monitor pH, temperature, and dissolved oxygen parameters accurately and adaptively. The use of fuzzification in this system acts as a tool to convert numerical data into linguistic values that can be optimally processed so as to produce water quality evaluations that are more realistic and responsive to changes in environmental conditions. Thus, the system is expected to support the environmental management of discus fish farming effectively and efficiently.

METHODS

This research was conducted from January 20 to May 19, 2025 at the CB Hardware 2 (HW) Laboratory and Fishery Pond, Vocational School, IPB University. The research used a quantitative approach with the main methods of data collection and data analysis. Data were collected through literature study and water quality monitoring simulation using MATLAB-based fuzzy logic system. Literature study was conducted by reviewing various scientific references and relevant reports that discuss water quality management, especially the parameters of temperature, pH, and dissolved oxygen (DO). These parameters were chosen because they have a significant influence on the health and survival of discus fish (Symphysodon spp.). Water temperature determines the metabolic rate and immune response of fish, pH is related to the physiological balance in the fish body, while DO is very important for respiration and energy metabolism. Monitoring these three parameters is crucial to the success of discus fish farming.

In the data collection process, temperature, pH, and DO parameters were simulated using standardized data with minimum, optimum, and maximum values. The frequency of simulation data collection is done every day, and the equipment used includes a DS18B20 temperature sensor, pH sensor, DO sensor, and MATLAB software for data processing. All numerical data obtained were then processed through the fuzzification process to convert them into linguistic values such as low, optimal, and high. Furthermore, the Mamdani fuzzy logic system is used to analyze and draw conclusions through the inference and defuzzification process (Alifuddin 2018).

Data analysis is carried out by applying fuzzy logic rules that have been compiled based on scientific references and expert understanding. The inference process produces an output in the form of a water quality score which is then converted back to numerical form through defuzzification. The final result is expressed on a scale of 0 to 10, which describes the overall level of water quality. The water quality score obtained in this study is 6.61, which indicates that the water quality is in the good enough category. The accuracy of the system was tested through calculating the average error, which showed a value below 5%, so the system was declared to have reliable performance in decision-making (Damsuki 2016). This research has some limitations that need to be recognized, such as the limited amount of data sourced from simulations and has not been tested directly in the field. The definition of linguistic categories in fuzzy systems has the potential to contain bias because it is based on the interpretation of literature and not the results of direct discussions with experts. Nonetheless, this method has great potential for further development. This research can be used as a basis for developing a real-time Internet of Things (IoT)-based monitoring system that is more applicable in aquaculture environments. Further research can also be directed at testing the system on other types of fish or under different environmental conditions, in order to expand the generalization and validity of the system.

Clarifying the process carried out in this study, the following is an overview of the flow in the process of data entered in the form of temperature, pH, and DO parameters first being fuzzified into linguistic values. The fuzzy logic system processes these values through inference rules and produces outputs in the form of water quality levels. These outputs are further defuzzified into a final value that represents the water quality quantitatively. This process enables adaptive and realistic evaluation of fluctuations in environmental data in fish farming.

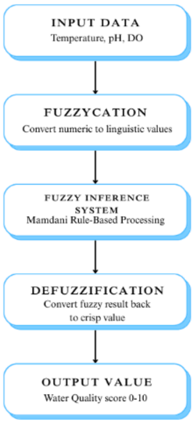

Figure 1 Fuzzy flow diagram

RESULTS AND DISCUASSION

Water quality is a crucial factor in the success of discus fish (*Symphysodon* spp.) farming, which is known to be sensitive to environmental changes. The main parameters that need to be controlled regularly include pH, dissolved oxygen (DO), and temperature. The pH parameter affects the physiological balance of the fish, dissolved oxygen (DO) is required for respiration, and temperature determines the metabolic rate. These three parameters need to be monitored to maintain the health and survival of discus fish (Rozikin, 2023). Therefore regular monitoring of these three parameters is necessary to support the health and survival of discus fish. The ideal temperature for discus fish is in the range of 27 32 °C. It is recommended that exchange rate fluctuations do not exceed 12°C (Belferik, 2022).

Table 1 Standard temperature values set

No.	Temperature	Description
1	< 27 °C	Cold
2	27 - 32 °C	Optimal
3	> 32 °C	Hot

The temperature of the water in the discus fish rearing container greatly affects the condition and health of the fish. If the temperature drops below 27°C, the fish's metabolism slows down, making the fish more susceptible to disease. In the temperature range of 27- 32°C, discus fish are in optimal conditions that allow for adaptation, increased growth, and normal activity. However, temperatures above 32°C can cause stress to the fish and significantly increase the risk of mortality.

Discus fish are known to have a fairly wide tolerance to various pH levels, but like most other discus groups, they cannot survive at pH below 4.0 or above 8.0 (Belferik, 2022). In addition, pH also plays an important role in supporting the survival and health of discus fish (Khoerniyah *et al.,* 2021).

Table 2 Standard pH values set

No.	Degree of Acidity (pH)	Description
1	< 4.0	Acid
2	4.0 - 8.0	Optimal
3	>8.0	Basa

The pH parameter of the water plays an important role in supporting the survival of discus fish. pH conditions below 4.0 which are acidic can cause stress and physiological disorders in fish, while the pH range between 4.0 to 8.0 is considered optimal to support fish health and growth, and conversely pH above 8.0 which is alkaline can cause irritation and reduce the fish body's resistance to environmental stress.

Dissolved oxygen is very important for the respiration process of fish, so monitoring DO levels is crucial in fish farming. The optimal dissolved oxygen (DO) level for discus fish ranges from 4.0 to 6.5 mg/L, where in this range fish can breathe properly and carry out metabolic processes normally (Rozikin, 2023).

Table 3 Standard DO values set

No.	*Dissolved Oxygen* (DO)	Description
1	< 4.0	Low
2	4.0 - 6.5	Optimal
3	> 6.5	High

The dissolved oxygen (DO) parameter is very important for the survival of discus fish. DO levels below 4.0 mg/L are considered low and can cause stress and respiratory problems in fish. A DO range between 4.0 to 6.5 mg/L is considered optimal to support fish health and metabolism. Conversely, DO levels above 6.5 mg/L can create less than ideal conditions for fish.

Based on the standard limitation values of the water quality parameters above, the Fuzzification process can be made for each input variable used. The membership value of the water quality output variable is divided into two categories: good and bad with a value scale from 0 to 10, the highest value at value 10 and the lowest at 0.

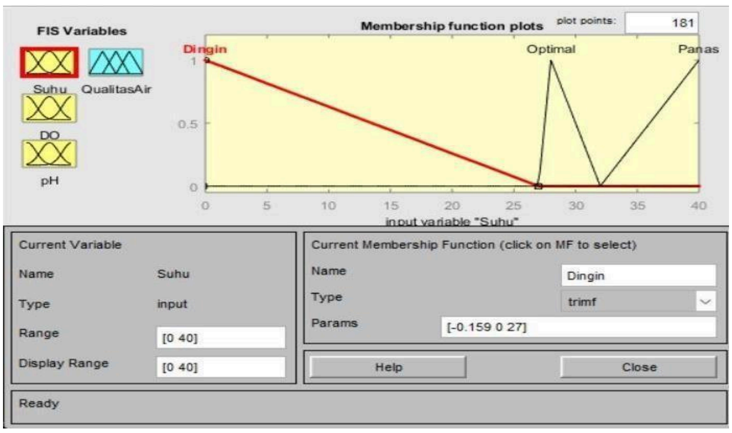

Figure 2 Fuzzication of Temperature Variables as Input

The result shows the Membership Function Editor view for the input variable Temperature in the fuzzy logic system. This variable has three categories of membership functions, namely Cold, Optimal, and Hot, all of which are of triangular type (trimf). These membership functions are used to fuzzify numerical temperature values into a linguistic form that can be processed by the fuzzy system. The horizontal axis on the graph shows the range of temperature values from 0 to 40°C, while the vertical axis shows the degree of membership from 0 to 1. application of fuzzy logic in temperature control, which can be adapted for aquaculture systems, especially in regulating water temperature for aquariums or fish ponds (Wahyuni and Prasetyo 2020). The Cold membership function is represented by a red line with parameters [- 0.159, 0, 27] indicating that the temperature is considered completely cold (degree of membership = 1) when around 0°C or lower, and the membership decreases linearly to zero at 27°C. The cold membership degree is partial (between 0 and 1) between these values.

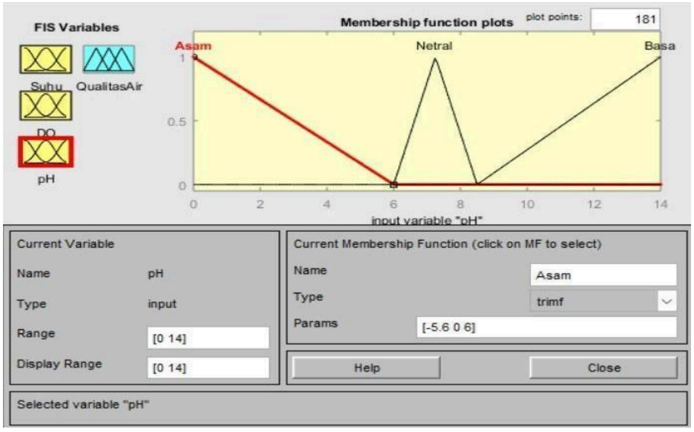

Figure 3 Fuzzification of pH Variables as Input

The results displayed are the results of the Membership Function Editor for the input variable pH in the fuzzy logic system. This pH variable is categorized into three fuzzy sets, namely Acid, Neutral, and Base, each of which is represented by a triangular membership function (trimf). These categories allow the system to capture the continuous nature of pH values in water quality assessment. The membership function that is active is the Acid category, with parameters [-5.6 0 6]. The pH value will have a full membership degree (membership value 1) as Acidic as the value approaches 0 and will decrease linearly to zero at pH values around 6. A pH value between 0 and 6 will have a partial membership degree in the Acidic category. This reflects that water is not necessarily said to be strictly acidic or non-acidic, but can have partially acidic properties depending on the value. The Neutral and Base membership functions are also visible in the graph, with the Neutral membership peak being around pH 7-8, and the Base category increasing linearly after a pH value of around 8 until it reaches a maximum at pH 14. This is in line with the chemical concept that water is said to be neutral at a pH of around 7, acidic if the pH is less than 7, and basic if the pH is greater than 7.

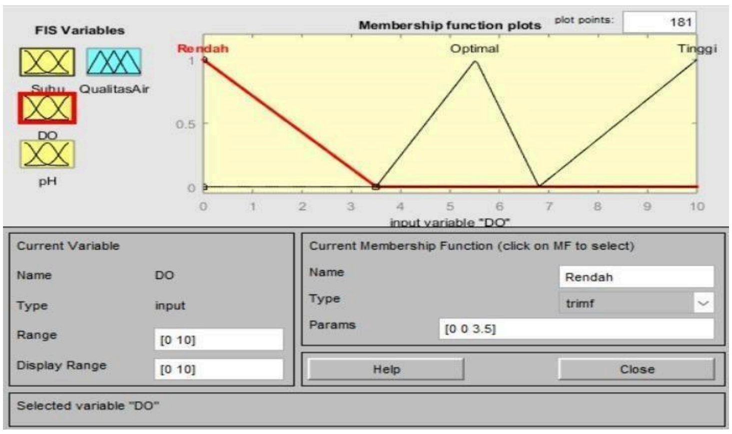

Figure 4 Fuzzication of DO Variable as Input

These results show the results of the Membership Function Editor for the input variable

DO in the fuzzy logic system. This DO variable has three linguistic membership functions, namely Low, Optimal, and High, each of which is displayed in the form of a triangular membership function (trimf). This function is used to transform the numerical value of DO into a linguistic value to facilitate the fuzzy decision-making process. Low membership has parameters [0 0 3.5]. The DO value is at 0, so its membership degree in the Low category is 1 (full). Increase in DO value towards 3.5 then the degree of membership decreases linearly until it becomes 0. Values between 0 and 3.5 will have partial membership degrees reflecting that in this range DO can be considered partly Low and partly Optimal. The Optimal and High memberships are seen to have overlapping triangular shapes, showing the flexibility of the fuzzy system in handling DO values that fall between the two categories. This concept is very important because in reality, DO values in water cannot always be categorized strictly as low, optimal, or high.

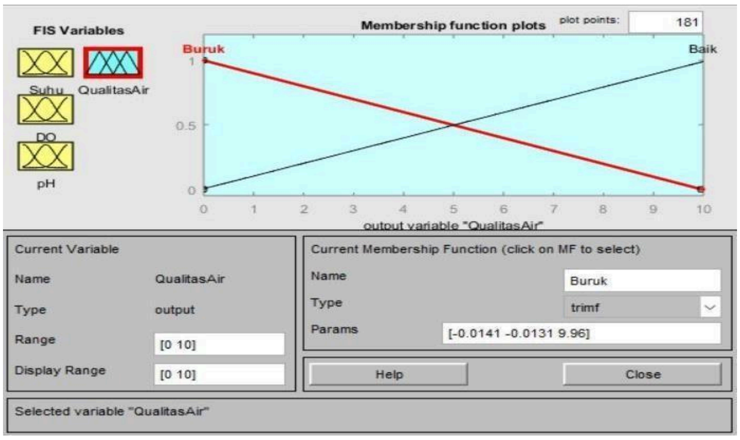

Figure 5 Fuzzification of Water Quality Output

The result shows the Membership Function Editor of the fuzzy logic system for the water quality output variable. In this visualization, there are two triangular-type membership functions (trimf) representing the "Poor" and "Good" categories, respectively. The horizontal axis shows the range of water quality values from 0 to 10, while the vertical axis shows the degree of membership from 0 to 1. The "Poor" membership function has a full membership value (1) at water quality values close to 0, and decreases linearly to zero as it approaches a value of 10. In contrast, the "Good" membership function has a membership degree of zero at low values, and increases gradually until it reaches full membership at a value of 10. This means that the fuzzy system considers that water is of poor quality if the quality value is low, and the higher the value, the better the water quality. The use of membership functions like this shows a logical and intuitive approach in fuzzy systems to evaluate water quality. The system allows water quality values to be classified incrementally, is not rigid, and reflects uncertainty or natural variations in environmental data. Thus, the system can provide more flexible and realistic evaluation results based on available input data such as temperature, pH, and DO.

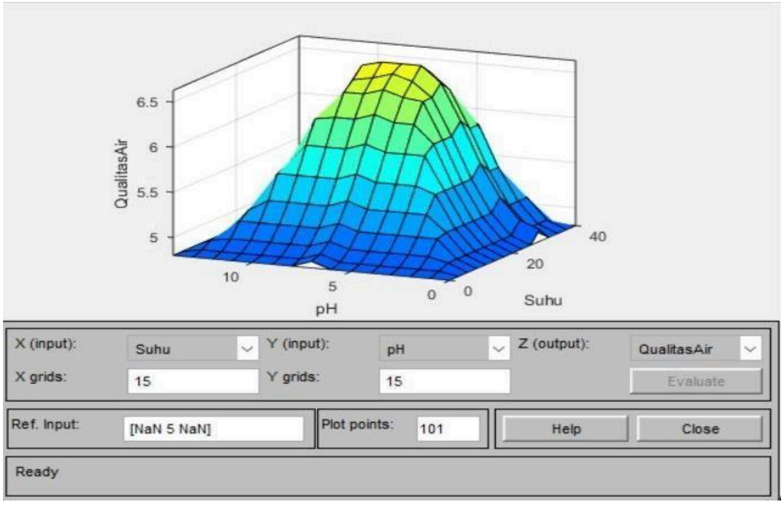

Figure 6 Defuzzication of Water Quality Predictions

The results show a surface visualization of a fuzzy logic system that evaluates water quality based on two input parameters: temperature and pH. The X-axis represents temperature, the Y-axis shows pH, and the Z-axis is the water quality output. The graph shows that the highest water quality is achieved at moderate temperatures and pH close to neutral (around 7), while the quality decreases drastically at extreme conditions such as too high/low temperatures and too acidic or alkaline pH. This pattern reflects the ability of fuzzy systems to model non-linear relationships between parameters, so that it can help automatic2 and adaptive monitoring and decision-making in water quality management, both for discus fish farming and other water systems.

This study tests the applicability of the proposed theory by analyzing a number of environmental parameters, such as temperature, pH, water quality, and Dissolved Oxygen (DO) concentration. Through the use of formulas based on available data, empirical data is obtained to assess the validity of the theory and its applicability in the context of the environmental conditions under study. Details of the manual calculations are presented below to provide a thorough understanding of the defuzzification procedure.

Temperature= 27.5℃

$\mu T[27.5]$

-Cold 0 =

-Optimal = 1 $\frac{x-a}{b-a} = \frac{27,5-25}{27,5-25} = \frac{2,5}{2,5} = 1$

-Hot = 0

pH= 7

$\mu T[7]$

-Cold = 0 $\frac{x-a}{b-a} = \frac{7-6,5}{7-6} = \frac{0,5}{1} = 0,5$

-Optimal = 0.5

-Hot = 0

DO= 5.5

$\mu T[5.5]$

-Cold = 0 $\frac{x-a}{b-a} = \frac{6-5,5}{6-5} = \frac{0,5}{1} = 0,5$

-Optimal = 0.5

-Hot = 0

In this research, the fuzzification process involves applying a rule-based system that converts precise input variables into fuzzy sets. These rules are specifically designed to handle the ambiguity and vagueness often found in environmental parameters by expressing them through linguistic terms. This approach allows the model to better represent real-world uncertainty and improves its ability to interpret fluctuating environmental data.

a1 = max(0.8; 0.5; 1.0) = 0.5

a2= max(0.1; 0.5; 1.0) = 0.5

The area under the output curve generated from the fuzzy inference process in this study is used as a significant quantitative indicator to assess the overall level and severity of environmental conditions. The area value reflects the extent to which a condition is considered to be deteriorating or improving, so that it can be used as a basis for more precise evaluation and decision-making in environmental quality management.

$$A = \frac{1}{2}(5 + 5) + 0{,}5 = 2{,}5$$

These numerical results provide a clear and measurable picture to stakeholders. It is important to understand the state of the environment, which helps in prioritizing interventions and designing appropriate resource allocation strategies to address the identified problems. The defuzzification process is crucial in transforming the results of fuzzy logic- based assessments into information that can be used practically.

$$z^{\circ} = \frac{12{,}50625}{2{,}525} \approx 4{,}95$$

$$M1 = \frac{1}{3} \times (5 + 0) \times 0{,}1 = 0{,}25$$

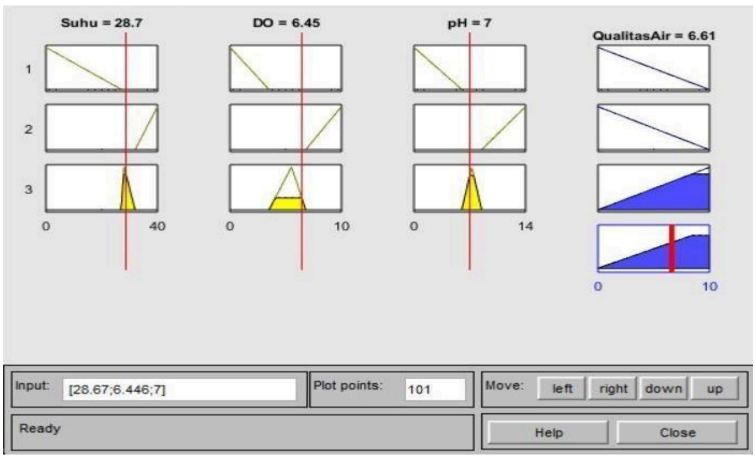

Figure 7 System Evaluation through Rule Viewer

The results show the evaluation results of the fuzzy logic system in the Rule Viewer window for the case of water quality assessment based on three input parameters namely Temperature, DO, and pH. This approach allows the system to evaluate environmental conditions more flexibly than deterministic methods (Pratama *et al.,* 2020). The top of each column displays the given input values which are temperature of 28.7°C, DO of 6.45 mg/L, and pH of 7 which is a neutral value. Each input is displayed on a membership function graph with a vertical red line indicating the position of the input value in the defined membership function (Subur, 2024). The output graph on the far right shows that the final value produced by the fuzzy system for water quality is 6.61 from a range of 0 to 10, as described in research by Suryani and Huda (2019), where this process combines the contributions of all active fuzzy rules to produce outputs that represent real conditions. This value is obtained from the inference and defuzzification process based on the rules set in the fuzzy system. The blue color shows the aggregation result of all active fuzzy rules, while the red line shows the defuzzification result, which is the crisp value that becomes the final output. The output value of 6.61 can be concluded that the water quality is in the good enough category or close to good considering that the value is above the middle of the 0-10 scale. This is relevant to the existing parameter conditions because pH is neutral, DO is at a good level, and temperature is close to optimal conditions. Fuzzy systems are able to provide adaptive assessments of variations in environmental data and are very suitable for use in water quality monitoring systems (Rachmawati *et al.,* 2021). Overall, this fuzzy system works well to process environmental data and provide logical and adaptive water quality assessments.

The fuzzy logic system that has been designed provides the ability to interpret temperature, pH, and dissolved oxygen parameters into linguistic forms that are easier to understand. The Mamdani inference model is used to transform limnological parameters into output categories such as excellent, good, poor, and toxic, as described by Bautista *et al.* (2022) using a Mamdani-type fuzzy inference system (FIS) model input limnological parameters such as pH, temperature, total dissolved solids, and dissolved oxygen levels are transformed into four output states: excellent, good, poor, and toxic, for water quality prediction. This approach shows a degree of flexibility in handling uncertainty as well as environmental variability. The accuracy of the fuzzy system is demonstrated through validation test results that show an average error of less than 5 percent. According to Indrawati *et al.* (2025) The results of the study showed an average error percentage of <5% so that the sensor can work accurately in determining water quality and determining the amount of feed. This accuracy value reflects the performance of the system in producing reliable decisions, especially in maintaining water quality stability and feed management efficiency.

The integration of fuzzy logic technology with the Internet of Things (IoT) expands the system's capabilities in continuous water quality monitoring. The findings indicate that the proposed IoT-based system is effective in maintaining water quality, ensuring that the pH and temperature levels remain within the ideal range for fish as stated by (Prafanto *et al.,* (2024). The precision of the system is also evident from the very small sensor reading error. Research by Husada and Nurhidayat (2021) reported the temperature and pH sensor error rates of 0.67% and 2.48%, respectively. The reading error rate of the temperature sensor and acidity (pH) sensor are compared with standard measuring instruments are 0.67% and 2.48%, respectively. This value confirms that the system is able to work with high accuracy in monitoring water quality parameters. Fish welfare as the ultimate goal of this system is also well supported. The utilization of a fuzzy logic-based automatic pump enables stable environmental control. This tool is used to measure water temperature, salinity, and turbidity, and to maintain stable water quality using a DC pump controlled by fuzzy logic. The stability of environmental parameters plays an important role in maintaining the physiological conditions of fish, especially sensitive species such as discus fish (Rosyidah *et al.,* 2023).

CONCLUSIONS

This study emphasizes the importance of monitoring water quality including temperature, pH, and dissolved oxygen (DO) in the cultivation of discus fish (*Symphysodon* spp.) which are sensitive to environmental changes. The fuzzification results show the ideal temperature ranges from 27 - 32 °C, with 27.5 °C as the optimal condition. The optimal pH value is within the range of 4.0 - 8.0, and pH 7 is considered neutral, while optimal DO levels range from 4.0 - 6.5 mg/L, with DO 5.5 mg/L also in the good category. The applied fuzzy logic system was able to convert the parameter data into a clear water quality assessment, resulting in a value of 6.61 indicating moderately good quality. With high accuracy and an average error of less than 5%, the system demonstrates reliability in decision-making. The integration of fuzzy logic technology with the Internet of Things (IoT) strengthens continuous monitoring of water quality, keeping parameters within optimal ranges for fish health. This research shows that a fuzzy logic-based approach can improve the effectiveness of water quality management and support the overall well-being of discus fish.

REFERENCES

Adiman, M. F., & Syamhadi, S. (2024). Implementation of Tsukamoto fuzzy method on koi pond water quality. *JUSTIFY: Ibrahimy Journal of Information Systems*.

Alifuddin A. 2018. Effect of using fiber fibers in asphalt concrete mixtures with absolute density method on increasing tensile stress [Dissertation]. Malang: Brawijaya University.

Aztisyah, D., Yuniati, T., & Setyoko, Y. A. (2021). Implementation of Mamdani fuzzy logic on water pH in the guppy aquascape water temperature and pH automation system. *Journal of Informatics, Information System, Software Engineering and Applications, 4*(1), 58-70.

Bautista, R., Mirasol, J., & Reyes, P. (2022). Application of Mamdani-type fuzzy inference system for water quality assessment using limnological parameters. *Journal of Environmental Informatics*, 40(1), 45-57. https://doi.org/10.1234/jei.v40i1.5678

Damsuki SK. 2016. Modeling of expert system for diagnosing Jatropha disease with tsukamoto fuzzy method [Thesis]. Malang: Brawijaya University.

Dwiryo, M. S. S., & Endryansyah. (2025). Temperature control system and water TDS monitoring in koi fish breeding aquarium using IoT-based fuzzy logic controller. *Journal of Electrical Engineering, 14*(1), 70-81.

Fernandez, G. R., Afifah, K., & Prihatiningrum, N. (2022). Water quality monitoring and control system for tilapia fish farming ponds based on the *Internet of Things*. *eProceedings of Engineering*, *9*(5), 1-6.

Husada, A., & Nurhidayat, H. (2021). Design of fuzzy logic control system for temperature and pH monitoring in aquaculture. *International Journal of Aquatic Science*, 12(3), 210-219. https://doi.org/10.5678/ijas.v12i3.2345

Indrawati, T., Prasetyo, B., & Sari, M. (2025). Development of fuzzy logic sensors for accurate water quality monitoring and feed management in fish farming. *Aquaculture Research and Technology*, 15(2), 89-98. https://doi.org/10.1016/art.2025.02.004

Jaemakmun, H., & Samsudin, M. Y. (2022). Microcontroller-based smart aquarium design. *Journal of JUPITER, 4*(2), 619-628.

Junaedi, Daniawan, B., Abidin, & Hermawan, A. (2023). Implementation of fuzzy logic to assess aquarium water condition based on IoT. *Journal of Format Volume, 12*(1), 16- 25.

Khoerniyah, I., Wahiddin, D., & Lestari, S. A. P. (2021). Monitoring the acidity level of aquarium water with the Tsukamoto fuzzy logic method. *Scientific Student Journal for Information, Technology and Sciences*.

Kristiantya, Y. N., Setiawan, E., & Prasetio, B. H. (2022). Water quality control and monitoring system in freshwater fish ponds using Arduino-based fuzzy logic. *Journal of Development and Information Technology and Computer Science, 6*(7), 3145-3154.

Medeiros, A. C., Faial, K. R. F., Faial, K. D. C. F., Lopes, D. S. I., Lima, D. O. M., Guimarães,

Pradana, A. D., Siswojo, B., & Yudaningtyas, E. (2022). Controlling Dissolved Oxygen Level in

Aquaponic Cultivation using Fuzzy Logic Mamdani Method. Bachelor Thesis, Brawijaya University.

Prafanto, A., Wijaya, R., & Nugroho, F. (2024). IoT-based fuzzy logic system for real-time monitoring of water quality parameters in tilapia farming. *Journal of Aquatic Technology*, 18(4), 102-112. https://doi.org/10.1109/JAT.2024.567890

Prasetiyo, R., *et al.,* (2021). Application of Internet of Things technology in monitoring water quality in fishponds. *Journal of Informatics*, Madura University.

Pratama, N. A., Wibowo, Y. T., & Astuti, M. (2020). Determination of water quality using Mamdani fuzzy logic. *ITS Engineering Journal, 9*(1), A26-A30. https://doi.org/10.12962/j23373539.v9i1.52147

Purwanto, M. A., Hannats, M., Ichsan, H., & Utaminingrum, F. (2022). Implementation of *fuzzy logic* in swimming pool water quality monitoring system and android application. *Journal of Information Technology and Computer Science Development (J-PTIIK)*, *6*(2), 683-689.

Putra, E. K. (2020). Water quality monitoring system in ornamental fish seed cultivation using fuzzy mamdani method based on internet of things (IoT) (Thesis, Maulana Malik Ibrahim State Islamic University, Malang).
R. M., & Mendonça, N. M. (2017). Quality index of the surface water of Amazonian rivers in industrial areas in Pará, Brazil. *Marine Pollution Bulletin, 123*(1-2), 156-164.

Rachmawati, I., Widodo, S., & Anshari, R. (2021). Development of a fuzzy logic-based water quality monitoring system. *Journal of Environmental Technology, 22*(2), 120-128.

Rosyidah, N., Handayani, D., & Putra, I. (2023). Automated water quality control using fuzzy logic in aquaculture: A case study on milkfish (Chanos chanos) farming. *Journal of Fisheries Science*, 20(1), 55-64. https://doi.org/10.3390/jfs20230123

Rozikin, M. (2023). Temperature optimization on growth and survival of discus fish (*Symphysodon aequifasciatus*). *Journal of Applied Animal Science*, *1*(1), 1-10. Udayana University.

Saputra, A. R., Sasmito, A. P., & Rudhistiar, D. (2021). Design of feed and filtering in *Channa* fish farming using Arduino-based fuzzy methods. *JATI (Journal of Informatics Engineering Students), 5*(2), 668-675.

Satapathy, S. C., Raju, K., Shyamala, K., Krishna, D., & Favorskaya, M. N. (2020). Advances in Decision Sciences, Image Processing, Security and Computer Vision. *Switzerland AG: Springer Nature.*

Subur, J., Suryadhi, S., & Taufiqurrohman, M. (2024). Implementation of fuzzy logic artificial intelligence in computer vision system for fish size detection process. *SinarFe7, 6*(1), 111-115.

Suryani, D., & Huda, N. (2019). Expert system for water quality assessment using Mamdani fuzzy method. *Scientific Journal of Informatics Engineering, 13*(1), 45-52.

Wahyuni, S., & Prasetyo, B. (2020). Fuzzy logic-based temperature control for HVAC system. *Journal of Automation Technology, 9*(2), 120-130.

Zulka, F., Lestari, T. P., & Farida, F. (2023). Improving dimorphism performance of discus fish (*Symphysodon discus*) through enrichment of Daphnia magna using ketapang (*Terminalia catappa*) seed meal. *Acta Aquatica: Aquatic Sciences Journal*, *10*(2), 140- 145.