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Fuzzy Inference System to Improve Catfish Care in Bioflok Pools Based on Temperature and Water Quality

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The study explores the application of the Fuzzy Inference System (FIS) to improve the maintenance of clay (Clarias gariepinus) in Biofloc ponds, focusing on critical factors such as temperature and water quality. In the context of the efficiency of the biofloc system in water quality management, the study addresses the challenges posed by dynamic environmental conditions. Through a comprehensive gap analysis, the study identifies disparities between current research and the need for a specialized approach that integrates FIS for adaptive decision-making. The urgency stems from the limited coverage of previous research in addressing temperature dynamics and water quality. This research places itself in the research landscape by supporting and refining previous findings and introducing new FIS applications. The integration of Fuzzy Logic into bio floc management decision-making is new in this study. This research, supported by the latest literature from leading journals, emphasizes the significance and originality of its approach, contributing to sustainable and adaptive aquaculture practices.
Keywords: fuzzy, biofloc, Clarias gariepinus, catfishTechnology and management of fish hatcheries

INTRODUCTION

The establishment of Pilot Minapolitan has played an important role in the development of aquaculture in Indonesia. In the framework of the rural economic development program "Aquaculture Mina", 3600 employer groups will receive more intensive training in the field of aquaculture. However, despite the growth, aquaculture faces challenges, especially in the field of fish feed supply. Feed costs for intensive fish farming can be significant and this activity is thought to have the highest feed cost component, accounting for 70% of total production costs(Suwarsito dan Mustafidah 2015). Determining the type of fish to be cultivated is one of the activities land evaluation can help farmers or fisheries operators determine the land suitability for the kind of fish to be cultivated. The process of determining the type of fish can be done by comparing the characteristics of the land to be used with the requirements for the character of the fish. Farmers should carry out the land evaluation process before the cultivation process to be compatible between the land used and the type of fish that will be cultivated on that land (Wirawan dan Azhari 2014).

Catfish is one of the ten leading agricultural commodities in Indonesia. In 2013, Indonesia dominated world catfish production with a share of 75.6% of total world catfish production. This condition makes catfish one of Indonesia's leading cultivation commodities, ranked third after gourami fish and seaweed. Apart from that, the development of catfish cultivation in Indonesia has had a higher average increase compared to the production of top superior commodities such as gourami fish and seaweed, namely 47.21%. In addition, national catfish production in 2015 experienced the highest increase compared to the top ten leading commodities, 18.88%.(Pujiharsono dan Kurnianto 2020). This fish was introduced to Indonesia from the African continent for the first time in 1984. This fish can grow four times faster in length or fallow, so it became popular in the community and was called the king catfish. Catfish have fins (Patil), which are challenging but harmless, shorter in size, and blunt with relatively long arms. Harvesting by sorting and harvesting the whole (whole) are the most commonly used processes. Harvesting by sorting, fish suitable for consumption are sorted according to the market; if they are small fish, they will be farmed. The total harvest is done by harvesting all fish of sizes that have been adapted to the method's needs by adding the fish's age. The catfish consumes a weight of 180-120 grams/head when carrying out the maintenance process for 5-6 months. Harvesting is done by placing a paragon tube on the bottom of the pond, then lowering the water in the pond so that the fish enter the paragon tube section, and then taking the fish in the tube.(Ivan Prayuda. Rakhmat Kurniawan R 2022)

Biofloc ponds are cultivation ponds. Intensive fish/pond ponds implement a probiotic system by utilizing bacterial activity to overcome water quality problems. Bacterial activity is needed to process organic waste from leftover artificial feed (pellets) and feces into a collection of microorganisms in the form of flocs so that the waste does not produce toxic gases that hurt fish metabolism but maintains good water quality and, at the same time becomes natural food for fish. (Pujiharsono dan Kurnianto 2020)

Water quality is the most important factor for farmers to get good-quality, disease-free fish on time for daily harvesting and cultivation. Unfavorable water conditions can compromise fish health, slowing fish growth and threatening catfish farmers with crop failure. Factors influencing water quality in catfish seed ponds include temperature and turbidity; therefore, water quality must be monitored daily.(Cholilulloh *et al.* 2018). The water temperature in the pool is suitable for catfish habitat and should be maintained between 20-32 degrees Celsius. If the acidity or pH is between 5.5 and 7.5, i.e. less or more than this value, the pH of the pond water is not suitable for catfish.(Maulana *et al.* 2021).

Cultivating freshwater fish, especially catfish, is one of the businesses that is most popular with many people. Cultivating catfish requires very simple supervision and maintenance because cultivating catfish requires a pond with good water quality. The suitability of the water quality in the pond that does not meet standards will endanger the catfish's health, and their growth will be hampered. The water quality in the biofloc media must be by the fish's needs. Water quality that needs to be maintained in cultivation includes a temperature of 25-32℃, pH 6.5-8.5, and dissolved oxygen (DO)> 3mg/l. Several studies of catfish ponds only use monitoring. However, from this research, there was a problem: changing the water manually by removing a few percent of the water first and then replacing it with better quality water from a reservoir or a well. To keep the water quality stable and in good condition, a control system is needed that drains and adds water to the catfish pond. Based on the results of interviews with students of the Technology and management of fish hatcheries study program, Faculty of Vocational School, IPB University it is known that the water quality factor is very influential on the success of production from catfish cultivation. Basically, the Control System is a system that regulates one or more variable recommendations, which are placed within a specified range of values. In this research, the control system is used as a pump controller. Apart from that, system monitoring is defined as activities that include action on information regarding a process that is being implemented. In this article, we examine the creation of a water quality control system in the form of controlling acidity, pH, and water temperature in catfish cultivation with control from a control system that regulates variable quantities.

METHODS

This research was conducted in the Technology and Management of Fish Hatcheries study program at the Faculty of Vocational School, IPB University. The method used is fuzzy Mamdani. Data was collected by direct observations and interviews at the cultivation pond owned by the program. The variables used in this research were water quality (pH), temperature, and treatment.

A. Fuzzy Logic

Fuzzy logic is an improvement on Boolean logic. It introduces the concept of partial truth, which states that classical logic can be expressed in binary terms (0 or 1, black or white, yes or no) with a degree of truth (Aini Samosir *et al.* 2020).

B. Fuzzification

Fuzzification is a form of fuzzy input that has been changed from entering values with definite truth (Crisp Input).

C. Inference

Inference is reasoning using fuzzy input and fuzzy rules that have been created. The following is the inference process using the Tsukamoto method:

a. Calculate the α-predicate value for each rule (α1, α2, α3,......, αn) with the MIN implication function.

$$\alpha\text{-predicate}_n=\min[\mu A(x);\mu B(y)]$$

b. Calculate the inference results explicitly (crips) for each rule (z1, z2, z3,....., zn) from each known α-predicate value

D. Defuzzification

Defuzzification is a crisp value according to the membership function determined by changing the fuzzy output value. $Z = \frac{\int_a^b f_{(x)} X dx}{\int_a^b f_{(x)} dx} = \frac{\sum Moment}{\sum Area}$

Data collection techniques

Data collection techniques used during the implementation of fieldwork practices and the production of tools according to the needs of partners include several approaches, including

1. Problem Identification

   This position focuses on the problems encountered, such as the difficulties in decision-making when applying a large number of assessment criteria and the most efficient and effective use of time to obtain and produce appropriate new assessment reports with responsibility for each standard.

2. Literature Study

   Authors' data are collected using books, journals, papers, books, and scientific resources, including visiting relevant online research and understanding sites, texts, or documents related to the author's research and reading on the subject around

3. Data Collection

   Direct field surveys and interviews with students of the Technology and Management of Fish Hatcheries study program, Faculty of Vocational School, IPB University on criteria for quality catfish production

RESULTS AND DISCUSSION

1. Fuzzy Calibration Methodology:

The fuzzy calibration process in the temperature and water quality context involves defining appropriate linguistic variables and membership functions. The fuzzy inference system must understand the relationship between input temperature and water quality and the output of catfish care decisions. This methodology includes variable selection, fuzzy rule formulation, and the Mamdani inference mechanism to obtain accurate results appropriate to the biofloc pond's conditions.

As we conclude the interview, it is important to consider the input and output variables. The defining set for these variables is.

Table 1. Input Variable Water Quality

Water Quality(pH)	**State**
[4 5 6]	Low
[6.5 7.5 7.9]	Good
[8 9 10]	High

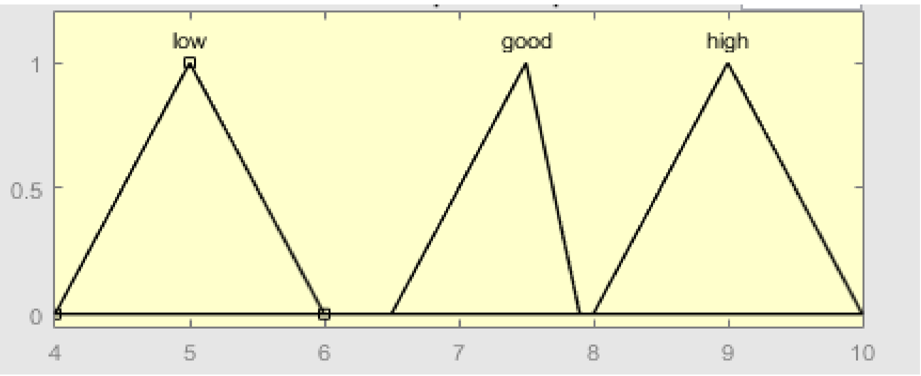

Figure 1. Member set of Water Quality(pH)

From the each state and the design graph, the water quality member set follows

$$F(x,a,b,c)\{Low(x)\{x<4 \quad ;0\ 4 \le x \le 5 \quad ; \frac{x-4}{5-4}\ 5 \le x \le 6 \quad ; \frac{6-x}{6-5}\ x > 6 \quad ;0\ \ Good(x)\{x\ < 6.5\ ;0\ 6.5 \le x \le 7.5 \quad ; \frac{x-6.5}{7.5-6.5}\ 7.5 \le x \le 7.9 \quad ; \frac{7.9-x}{7.9-7.5}\ x > 7.9\ \ ;0\ \ High(x)\{x<8 \quad ;0\ 8 \le x \le 9 \quad ; \frac{x-8}{9-8}\ 9 \le x \le 10 \quad ; \frac{10-x}{10-9}\ x > 10 \quad ;0$$

The measured water quality (pH) values are 6.6 from the interview, which is included in the good parameters and the defining membership degree are,

$$\mu_{x\_good}[6{,}6] = \frac{6{,}6-6{,}5}{7{,}5-6{,}5} = \frac{0{,}1}{1} = 0{,}1$$

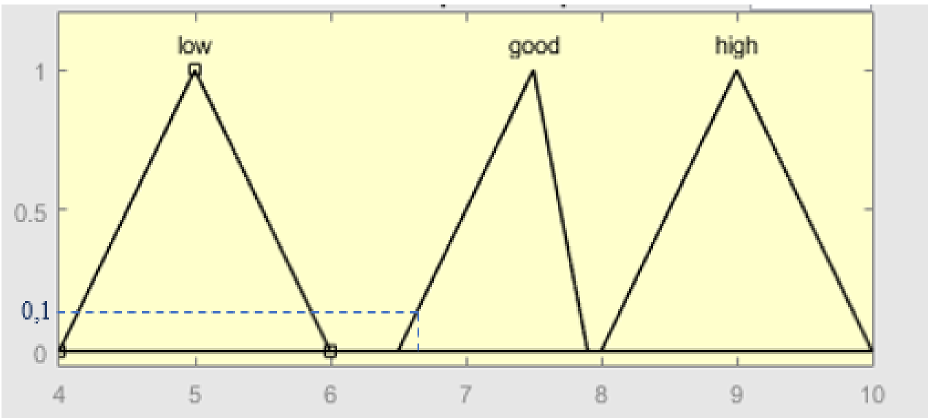

Figure 2. Membership degree of 6.6 pH value

For the second input variable, temperature will have set as

Table 2. Input variable Temperature

Temperature (℃)	**State**
[25 26 27]	Cold
[28 29 30]	Normal
[31 32 33]	Warm

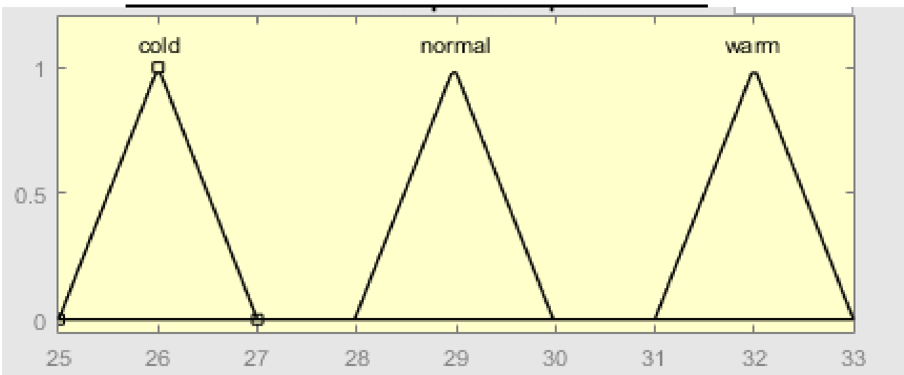

Figure 3 Member set of Temperature

$$F(x,a,b,c)\{Cold(x)\{x < 25 \quad ;0 \; 25 \le x \le 26 \quad ; \frac{x-25}{26-25} \; 26 \le x$$
$$\le 27 \quad ; \frac{27-x}{27-26} \; x > 27 \quad ;0 \;\; Normal(x)\{x \; < 28 \,; 0 \; 28 \le x$$
$$\le 29 \quad ; \frac{x-28}{29-28} \; 29 \le x \le 30 \quad ; \frac{30-x}{30-29} \; x > 30 \; ;0 \;\; Warm(x)\{x$$
$$< 31 \quad ;0 \; 31 \le x \le 32 \quad ; \frac{x-31}{32-31} \; 32 \le x \le 33 \quad ; \frac{33-x}{33-32} \; x > 33 \quad ;0$$

The measured Temperature (℃) values are 32.3 from the interview, which is included in the warm parameters and the defining membership degree are.

$$\mu_{y\_warm}[32,3] = \frac{33-32,3}{33-32} = \frac{0,7}{1} = 0,7$$

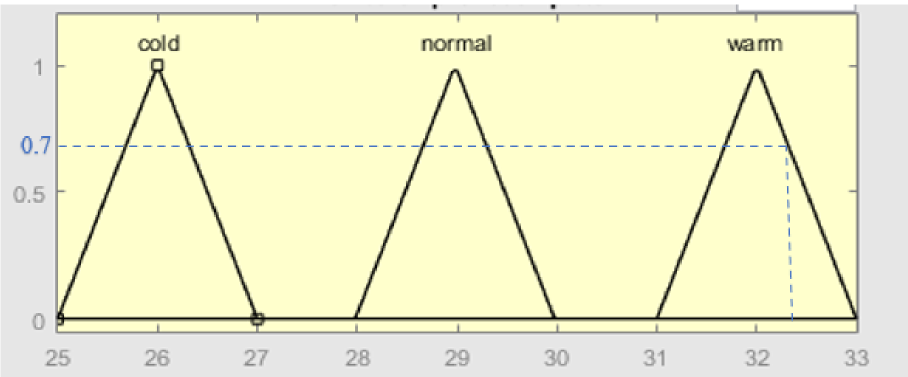

Figure 4. Membership degree of 32.3℃ Value

Fuzzy Rule Base

Table 3. Fuzzy Rule Base Set

IF	Water Quality(pH)	Temperature(℃)	Then	Maintanance
IF	Low	Cold	Then	High
IF	Good	Normal	Then	Low
IF	High	Warm	Then	High
IF	Low	Normal	Then	Medium
IF	Good	Warm	Then	Low
IF	High	Cold	Then	High

Based on the fuzzy rule base, it can be seen if the experiment meets rule number 5, which indicates that the treatment will have a Low value.

$$\alpha_5 = Min(\mu_{x\_good}[6,6] \cap \mu_{y\_warm}[32,3]) = Min(0,1\,;\,0,7)$$

$$\alpha_5 = 0,1$$

Table 4 Output Variable Maintenance

Maintenance (%)	**State**
[0 7 15]	Low
[15 25 40]	Medium
[40 65 100]	High

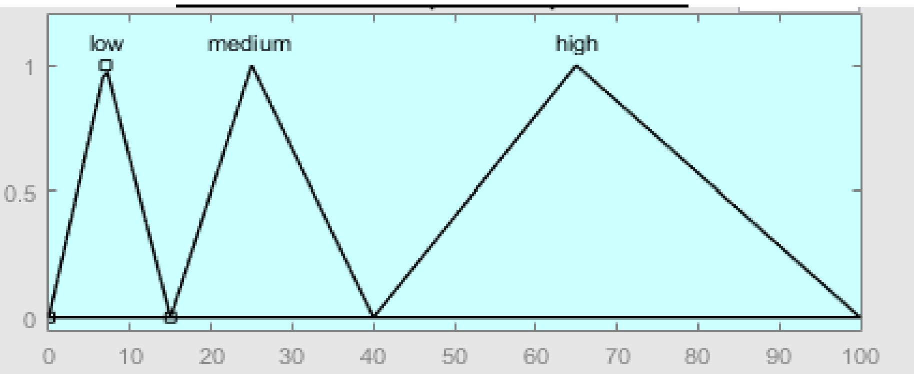

Figure 5. Membership Set of Maintanance

Low set value of 0,1 Membership degree

Set 1

$$\alpha_5 = \frac{x - 0}{7 - 0}$$

$$0{,}1 = \frac{x - 0}{7 - 0}$$

$$0{,}1 = \frac{x}{7}$$

$$x_1 = 0{,}7$$

Set 2

$$\alpha_5 = \frac{15 - x}{15 - 7}$$

$$0{,}1 = \frac{15 - x}{15 - 7}$$

$$0{,}1 = \frac{15 - x}{8}$$

$$0{,}8 = 15 - x$$

$$\alpha_2 = 14{,}2$$

The following membership function of the set are

$F(x,a,b,c)\{x < 0 \quad 0 \quad 0 \leq x \leq 0{,}7 \quad \frac{x-0}{7-0} \rightarrow \frac{x}{7} \quad 0{,}7 \leq x \leq 14{,}2 \quad 0{,}1 \quad 14{,}2 \leq x \leq 15 \quad \frac{15-x}{15-7} \rightarrow \frac{15-x}{8} \quad x > 15 \quad 0$

$$\rightarrow Momen\ set = \int_a^b f(x)x.dx$$

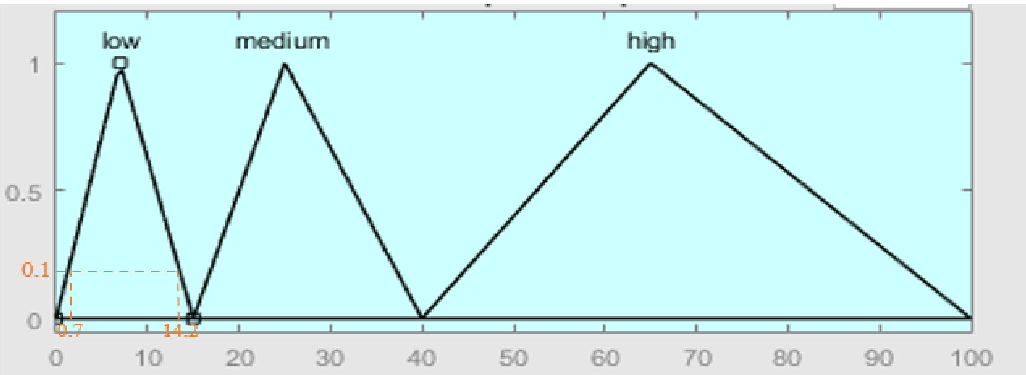

Figure 6. Implication function

Defuzzification

From the graph above, it can be seen that the value of membership degree 0.1 at a Low value divides it into three areas, respectively.

Calculating the Area

The area calculation will be related to the next calculation in this stage. This calculation is focused on the output variable that its implication value has previously determined.

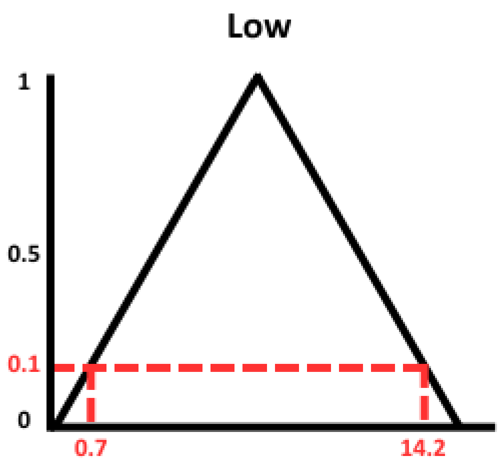

Figure 7 Area

Calculating this area uses the formula of the flat shapes formed. Areas 1 and 3 are formed as triangles where the formula is $a\ x\ t$ 2. And in area 2, it forms a rectangle with the formula $p\ x\ l$. Then the calculation below is obtained.

$$Area\ 1\ (Triangle) = \frac{(0{,}7-0)\ x\ 0{,}1}{2} = \frac{0{,}035}{2} = 0{,}035$$

$Area\ 2\ (Rectangle) = (14{,}2 - 0{,}7)x(0{,}1) = 1{,}35$

$Area\ 3\ (Triangle) = \frac{(15-14{,}2)\ x\ 0{,}1}{2} = \frac{0{,}08}{2} = 0{,}04$

After dividing the area, the area has its implication function for measuring the set moment.

Moment Calculation 1

This first moment uses the x-value 0 as the lower limit and 0.7 as the upper limit. Calculate it using the itegral formula of the upper limit minus the lower limit.

$$\int_0^{0{,}7} \left(\frac{x-0}{7-0}\right)x\ dx = \int_0^{0{,}7} \left(\frac{x^2}{7}\right)dx = \frac{x^3}{21} |0{,}7\ \ 0 = \frac{49}{3000} = 0{,}0163$$

After integral calculation, it is found that the first moment value is **0,0163**.

Moment Calculation 2

The second moment calculation also uses an integral calculation. The lower limit is 0.7 with an upper limit of 14.2.

$$\int_{0{,}7}^{14{,}2} (0{,}1)x\ dx = \int_{0{,}7}^{14{,}2} (0{,}1x)dx = \frac{x^2}{20} |14{,}2\ \ 0{,}7 = \frac{4023}{400} = 10{,}0575$$

After integral calculation, it is found that the second moment value is **10,0575**.

Moment Calculation 3

This last moment calculation uses a lower limit value of 14.2 and an upper limit value of 15. The calculation is as below.

$$\int_{14{,}2}^{15} \left(\frac{15-x}{15-7}\right)x\ dx = \int_{14{,}2}^{15} \left(\frac{15x-x^2}{8}\right)dx = \frac{15x^2}{16} - \frac{x^3}{24} |15\ \ 14{,}2 = 0{,}578667$$

After integral calculation, it is found that the last moment value is **0,578667**.

$$Z^* = \frac{\sum\ Moment}{\sum\ Area} = \frac{0.0163+10{,}0575+0{,}578667}{0{,}035+1{,}35+0{,}04} = 7{,}47$$

The manual calculation above gets a lift of 7.47.

2. **Possible Challenges and Obstacles:**
   In using fuzzy interference in this study, we cannot avoid potential biological constraints, such as changes in temperature and water quality, differences in catfish species, and biological must maintained in the biofloc pond. Successfully addressing this challenge will be key to the success of non-invasive interventions in fish management.
3. **Practical Application:**
   In applying fuzzy interference in biofloc ponds, practical research is needed on how the system that has been created can bring about changes in this field and see how effective it is in providing the recommended treatment by temperature and water quality so that its success can be ensured. This needs to be done routinely every day so that you can get a clearer picture of its use and application.
4. **The Importance of Research on the Fisheries Industry:**

This research focuses on technology development and its impact on the fishing industry. Supports several previously existing discoveries and improves better research results as a contribution to sustainability in increasing the success of raising catfish using biofloc ponds

5. **Limitation of Field Reasearch**
   The scope of this research is restricted to the biofloc pond system, there are limitations to the data gained. in-depth research on the conditions is required because different fish species, pond designs, and treatment methods could yield different outcomes

CONCLUSION

This research highlights the use of Fuzzy Inference Systems (FIS) in improving the rearing of catfish (Clarias gariepinus) in Biofloc ponds, focusing on essential factors such as temperature and water quality. In facing the challenges of environmental dynamics, especially in the efficiency of biofloc systems for water quality management, this research identifies the need for a more integrated and adaptive approach. A thorough analysis of current research gaps indicates the need for FIS integration for adaptive decision-making. This is important considering previous studies' limitations in dealing with temperature and water quality fluctuations. By introducing a new application of FIS, this research significantly contributes to developing sustainable and adaptive aquaculture practices. Integrating Fuzzy Logic into biofloc management decision-making is an innovative step in this research, supported by the latest literature from leading journals. Overall, this study highlights the importance of this new approach in improving and supporting previous findings and confirms its relevance in modern aquaculture practice.

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