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Fuzzy Modeling Control Of Water Quality Parameters In Aquaculture

N.Sarala[1] and G.Bhuvana[2]
[1]Associate professor and [2]Research Scholar

Department of Mathematics, A.D.M. college for women (Autonomous),
AffilicatedtoBharathidasanUniversity,Nagapattinam,TamilNadu,India.

Abstract:

Aquaculture is a vital sector in global food production, yet its success is heavily dependent on optimal water quality management. This research investigates the application of fuzzy modeling to assess and predict key water quality parameters in aquaculture systems. Recognizing the inherent complexities and uncertainties in aquatic environments, fuzzy logic provides a robust framework for integrating diverse parameters such as temperature, dissolved oxygen, pH, ammonia levels, and turbidity. Through the development of a comprehensive fuzzy model, this study aims to analyze the interactions between various water quality factors and their impacts on aquatic species health, growth rates, and overall system productivity. By employing fuzzy inference systems, the research enables better decision-making for aquaculture management, allowing stakeholders to adapt to fluctuating environmental conditions and optimize aquaculture practices. The findings highlight the effectiveness of fuzzy modeling as a tool for improving water quality monitoring and management strategies, ultimately contributing to more sustainable aquaculture operations. This approach not only enhances the resilience of aquaculture systems but also supports the long-term viability of aquatic resources in the face of environmental challenges.

KeyWords: Aquaculture, Modeling, Fuzzy, Membership function, Analysis, Water quality.

I. Introduction

Aquaculture, the practice of cultivating aquatic organisms, is increasingly important in meeting global food demands. However, the sustainability and productivity of aquaculture systems are heavily influenced by water quality parameters. Factors such as temperature, dissolved oxygen, pH, ammonia levels, and turbidity can significantly impact the health of aquatic species and the overall success of aquaculture operations.

Traditional methods of assessing water quality often rely on linear models, which may not adequately capture the complexities and uncertainties inherent in aquatic environments. This is where fuzzy modeling comes into play. Fuzzy logic, inspired by human reasoning, allows for a more nuanced approach to modeling water quality parameters by accommodating imprecise data and uncertain conditions.

Fuzzy modeling can integrate various water quality parameters to predict outcomes related to fish growth, survival rates, and disease prevalence. This approach not only helps in optimizing the conditions for aquaculture but also aids in decision-making processes for managing aquaculture systems. By applying fuzzy logic, stakeholders can better understand the interactions between different water quality variables and their cumulative effects on aquatic life.

This research aims to explore the application of fuzzy modeling in assessing and managing water quality parameters in aquaculture. By developing a comprehensive fuzzy model, we can enhance the resilience and productivity of aquaculture systems, ensuring sustainable practices that benefit both the environment and the economy.

II BASIC DEFINITION OF FUZZY MODELING IN AQUACULTURE:

Fuzzy Modeling : In aquaculture involves using fuzzy logic to create models that can handle the inherent uncertainties and imprecise data in managing fish farms. Unlike traditional mathematical models that require precise input, fuzzy models use linguistic variables and fuzzy sets to represent and process vague, ambiguous, or incomplete information.

In aquaculture, fuzzy modeling can be used to model various aspects such as fish growth, water quality, and feeding rates. The advantage of fuzzy modeling is its ability to incorporate expert knowledge and handle uncertainties more effectively, which is crucial in complex and dynamic environments like fish farms.

Fuzzy Control: Fuzzy control is a method of controlling a system using fuzzy logic rather than traditional control strategies. In aquaculture, this means adjusting variables like feeding rates, aeration, or water temperature based on fuzzy rules derived from expert knowledge and observational data. The goal is to optimize the conditions for fish growth and health.

III SELECTING WATER QUALITY PARAMETERS:

Identify key parameters affecting aquaculture, such as pH, temperature, dissolved oxygen, ammonia, and nitrite. In aquaculture, maintaining optimal water quality is crucial for the health and growth of fish and other aquatic organisms. Key water quality parameters include:

1.pH

The pH scale determines how acidic or basic the water is. The majority of aquatic organisms have a preferred pH range. Deviations can stress fish, affect their growth, and impair their immune systems. For many freshwater species, the ideal pH range is typically between 6.5 and 8.5.

2.Temperature

The water's temperature is what determines how hot or cold it is. Aquatic species' metabolic rates, oxygen solubility, and general health are all influenced by temperature. Each species has an optimal temperature range; for example, many freshwater fish thrive between 18°C and 24°C.

3. Dissolved Oxygen (DO)

Dissolved oxygen is the amount of oxygen available in the water for aquatic organisms to breathe. Essential for the respiration of fish and other aquatic organisms. Low levels can lead to hypoxia, stressing or killing fish. Adequate DO levels are typically above 5 mg/L for most species.

4. Ammonia (NH_3)

Ammonia is a compound of nitrogen and hydrogen and is a byproduct of fish metabolism and decomposition of organic matter. High levels of ammonia are toxic to fish and can lead to health problems or death. Ammonia is usually measured as Total Ammonia Nitrogen (TAN), which includes both ammonia (NH_3) and ammonium (NH_4^+). Safe levels are generally below 0.02 mg/L for ammonia.

5. Nitrite (NO_2^-)

Nitrite is a product of the nitrification process where ammonia is converted into nitrite by bacteria. Nitrite is toxic to fish and can interfere with their ability to transport oxygen. Safe levels are typically below 0.1 mg/L.

Additional Parameters to Consider

- **Nitrate (NO_3^-):** A byproduct of nitrite oxidation, nitrates are generally less toxic than nitrites but can still affect fish health and lead to eutrophication. Safe levels vary, but concentrations below 50 mg/L are typically recommended.
- **Hardness (GH - General Hardness, KH - Carbonate Hardness):** Measures the concentration of calcium and magnesium ions (GH) and carbonate/bicarbonate ions (KH). It affects fish health, particularly in species adapted to specific hardness levels.
- **Turbidity:** A fluid's haziness or cloudiness brought on by a high concentration of individual particles. High turbidity can hinder light penetration, which can have an impact on fish health and plant growth..
- **Salinity:** For marine and brackish water aquaculture, salinity is crucial as it affects osmoregulation and the overall health of aquatic species.

Monitoring and managing these parameters ensure a stable and healthy environment for aquatic life, promoting optimal growth and reducing the risk of diseases. Regular testing and adjustments based on the specific requirements of the species being cultured are essential for successful aquaculture operations.

IV FUZZIFY DATASENS :

Convert crisp data into fuzzy sets using membership functions, such as triangular or trapezoidal functions.

1. **pH:** 7.2
2. **Temperature:** 22°C
3. **Dissolved Oxygen (DO):** 6.5 mg/L
4. **Ammonia:** 0.01 mg/L
5. **Nitrite:** 0.02 mg/L

MEMEBERSHI FUNCTION:

1. **Triangular Membership Function**

The triangular membership function is defined by three points: (a,0),(b,1),(c,0)(a, 0), (b, 1), (c, 0)(a,0),(b,1),(c,0), where b is the peak of the triangle, and a and c define the base of the triangle.

$$\mu_A(x) = \begin{cases} \dfrac{x-a}{b-a}, & for \quad a \le x < b \\ \dfrac{c-x}{c-b}, & for\, b \le x \le c \end{cases}$$

0, otherwise

2. **Trapezoidal Membership Function**

The trapezoidal membership function is defined by four points: (a,0),(b,1),(c,1),(d,0)(a, 0), (b, 1), (c, 1), (d, 0)(a,0),(b,1),(c,1),(d,0), where bbb and ccc are the points where the function reaches its maximum value of 1, and aaa and ddd are the points where it returns to 0.

$$\mu_A(x) = \begin{cases} 0, & for \quad x < a \\ \dfrac{x-a}{b-a}, & for \quad a \le x < b \\ 1, & for \quad b \le x \le c \end{cases}$$

$$\begin{cases} \frac{d-x}{d-c}, & for \quad c < x \le d \\ 0, & for \quad x > d \end{cases}$$

V. RESULTS:

5.1 Membership Functions to Crisp Data:

In the context of aquaculture water quality parameters, fuzzification involves converting crisp data (specific measured values) into fuzzy sets using defined membership functions. This process allows for a more nuanced representation of water quality parameters, such as pH and ammonia levels.

1. **pH**

- **Crisp Data:** 7.2
- **Triangular Membership Function (for "Optimal pH" with peak at 7.5 and base from 6.5 to 8.5**

$$\mu_{(Optimal)}\, pH(x) = \begin{cases} \dfrac{x-6.5}{7.5-6.5}, & for\ 6.5 \leq x < 7.5 \\ \dfrac{8.5-x}{8.5-7.5}, & for\ 7.5 \leq x < 6.5 \\ 0, & otherwise \end{cases}$$

$$\mu_{(Optimal)}\ pH(7.2) = \frac{7.2-6.5}{7.5-6.5}$$

$$= 0.7$$

Trapezoidal Membership Function (for "Acceptable pH" with range 6.0 to 8.0):

$$\mu_{acceptable}\ pH(x) = \begin{cases} 0 & for\quad x < 6.0 \\ \frac{x-0}{6.5-6.0} & for\ 6.0 \leq x < 6.5 \\ 1 & for\quad 6.5 \leq x \leq 7.5 \end{cases}$$

$$\begin{cases} \frac{8.0-x}{8.0-7.5} & for\ 7.5 < x \leq 8.0 \\ 0 & for\quad x > 8.0 \end{cases}$$

$$\mu_{Acceptable\ pH}\ (0.01) = 1 \qquad since\ (6.5 \leq 7.2 \leq 7.5)$$

The pH level of 7.2 indicates that it falls within the acceptable range for aquatic environments, with a strong membership in the "acceptable pH" category and a moderate membership in the "optimal pH" category. These fuzzy membership values can guide aquaculture management decisions, emphasizing the importance of maintaining pH levels that support the health and growth of aquatic species. Regular monitoring and adjustments based on fuzzy model outputs can enhance water quality management strategies in aquaculture systems.

2. **Temperature**

- **Crisp Data:** 22°C
- **Triangular Membership Function (for "Optimal Temperature" with peak at 22°C and base from 20°C to 24°C):**

$$\mu_{optimal\ Temperature}(x) = \begin{cases} \frac{x-20}{22-20}, & for\ \ 20 \le x < 22 \\ \frac{24-x}{24-22}, & for\ 22 \le x \le 24 \\ 0, & otherwise \end{cases}$$

$$\mu_{optimal\ Temperature}(22) = \frac{22-20}{22-20}$$

$$= 1$$

Trapezoidal membership function (for acceptable Temperature with range 18 °C to 26°C

$$\mu_{acceptable\ Temperature}(x) = \begin{cases} 0 & for \quad x < 18 \\ \frac{x-18}{20-18} & for\ 18 \le x < 20 \\ 1 & for \quad 20 \le x \le 24 \\ \frac{26-x}{26-24} & for\ 24 < x \le 26 \\ 0 & for \quad x > 26 \end{cases}$$

$$=1$$

The fuzzification process indicates that the temperature of 22°C is optimal for aquaculture, as evidenced by a membership value of 1 in both the "Optimal Temperature" and "Acceptable Temperature" categories. This suggests that the current temperature conditions are ideal for promoting the health and growth of aquatic organisms. Monitoring and maintaining this temperature range will be crucial for ensuring a productive aquaculture environment.

3. **Dissolved Oxygen (DO)**

- **Crisp Data:** 6.5 mg/L
- **Triangular Membership Function (for "Good DO" with peak at 6.5 mg/L and base from 5 mg/L to 8 mg/L):**

$$\mu_{Good\ DO}(x) = \begin{cases} \frac{x-5}{6.5-5}, & for\ \ 5 \le x < 6.5 \\ \frac{8-x}{8-6.5}, & for\ 6.5 \le x \le 8 \\ 0, & otherwise \end{cases}$$

$$\mu_{Good\ DO}(6.5) = \frac{6.5-5}{6.5-5}$$

$= 1$

Trapezoidal Membership Function (for acceptable DO" with from 4 mg/L to 8 mg/L):

$$\mu_{acceptable\ Temperature}(x) = \begin{cases} 0 & for \quad x < 4 \\ \frac{x-4}{5-4} & for\ 4 \le x < 5 \\ 1 & for \quad 5 \le x \le 7 \\ \frac{8-x}{8-7} & for\ 7 < x \le 8 \\ 0 & for \quad x > 8 \end{cases}$$

=1

The fuzzification process indicates that the dissolved oxygen level of 6.5 mg/L is classified as "Good DO," with a membership value of 1. It also falls within the acceptable range for dissolved oxygen, again with a membership value of 1. These findings suggest that the current DO conditions are optimal for supporting the health and growth

4. **Ammonia**

- **Crisp Data:** 0.01 mg/L
- **Triangular Membership Function (for "Low Ammonia" with peak at 0 mg/L and base from 0 to 0.1 mg/L):**

$$\mu_{Low\ Ammonia}(x) = \begin{cases} \frac{x-0}{0.05-0}, & for \quad 0 \le x < 0.05 \\ \frac{0.1-x}{0.1-0.05}, & for\ 0.05 \le x \le 0.1 \\ 0, & otherwise \end{cases}$$

$$\mu_{Low\ Ammonia}(0.01) = \frac{0.01-0}{0.05-0} = 0.2$$

Trapezoidal Membership Function (for acceptable Ammonia " with range 0 mg/L to 0.02 mg/L):

$$\mu_{Acceptable\ Ammonia}(x) = \begin{cases} 1, & for \quad 0 \le x < 0.02 \\ \frac{0.05-x}{0.05-0.02}, & for\ 0.02 \le x \le 0.05 \end{cases}$$

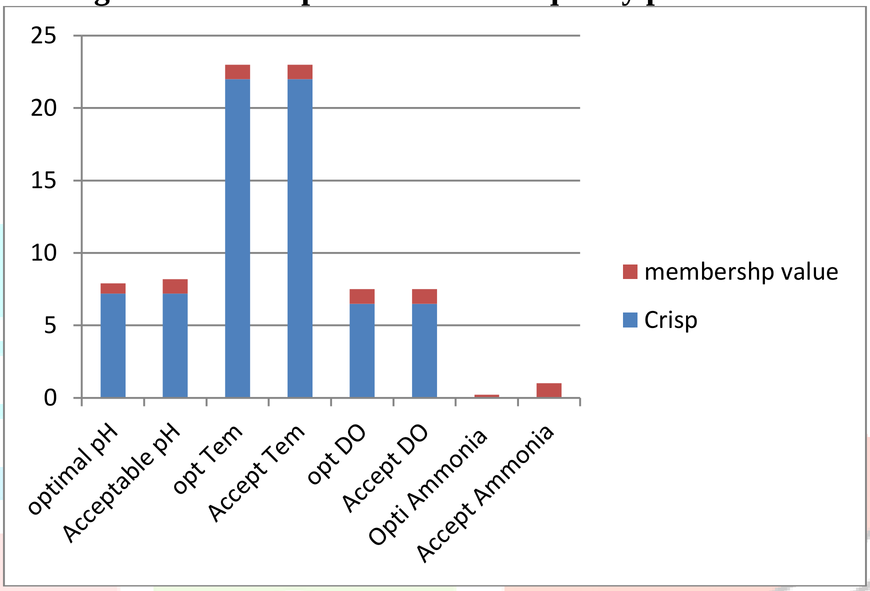
μ(Acceptable Ammonia) (0.01)=1 since (0.01<0.02)

The fuzzification results indicate that the ammonia level of 0.01 mg/L is classified as "Low Ammonia" with a membership value of 0.2, suggesting that it is on the lower end of the scale but still present. However, it is fully within the "Acceptable Ammonia" range, with a membership value of 1. This indicates that the current ammonia conditions are safe for aquatic organisms, supporting effective aquaculture management. Continuous monitoring of ammonia levels is essential to ensure water quality remains optimal.

Fuzzified data: Table 1

	Membership function	Crisp value	Membership vale
pH	Optimal pH	7.2	0.7
	Acceptable pH	7.2	1
Temperature	Optimal temperature	22°C	1
	Acceptable temperature	22°C	1
Dissolved Oxygen (DO)	Good DO	6.5 mg/L	1
	Acceptable DO	6.5 mg/L	1
Ammonia	Low Ammonia	0.01 mg/L	0.2
	Acceptable Ammonia	0.01 mg/L	1

Fig 1:Membership values of water quality parameters



- The pH, temperature, and dissolved oxygen levels are optimal or acceptable, indicating favorable conditions.
- Ammonia levels are considered acceptable, but the membership value suggests potential concerns regarding low ammonia levels.

This summary highlights the conditions being monitored and their respective fuzzified assessments.

5.2 Sensitivity Analysis of Fuzzy Model Outputs:

Sensitivity analysis in the context of fuzzy modeling for aquaculture water quality parameters involves examining how changes in input values (such as temperature, dissolved oxygen, pH, and ammonia levels) impact the outputs of the fuzzy model. This helps identify which parameters have the most significant influence on the overall assessment of water quality.

1. **Temperature**
2. **Dissolved Oxygen (DO)**
3. **pH**
4. **Ammonia**

Methodology

1. **Define Baseline Values**: Use the crisp data from previous analyses as baseline values.
2. **Incremental Changes**: Introduce systematic variations (e.g., ±10%, ±20%) to each parameter.
3. **Recalculate Membership Values**: For each variation, recalculate the membership values using the corresponding fuzzy membership functions.
4. **Analyze Outputs**: Observe how the outputs (membership values) change with respect to the variations in inputs.

1. Temperature

- **Baseline Value**: 22°C
- **Variations**: 20°C, 24°C (±10% and ±20%)

Temperature (°C)	**μ (Optimal Temperature)**	**μ(Acceptable Temperature)**	
20	0.5	1	
22	1	1	
24	1	1	

A decrease to 20°C reduces the membership value for optimal temperature significantly, while values of 22°C and 24°C maintain optimal and acceptable ratings.

2. Dissolved Oxygen (DO)

- **Baseline Value**: 6.5 mg/L

  Variations: 5.5 mg/L, 7.5 mg/L

DO (mg/L)	**μ (Good DO)**	**μ(Acceptable DO)**
5.5	0.5	1
6.5	1	1
7.5	1	0.5

Analysis:

- A decrease in DO to 5.5 mg/L lowers the "Good DO" membership value, while an increase to 7.5 mg/L maintains the acceptable level but diminishes the "Good DO" classification.

3. pHS

- **Baseline Value**: 7.2
- **Variations**: 6.5, 8.0

pH	**μ(Optimal pH)**	**μ(Acceptable pH)**
6.5	0	1
7.2	0.7	1
8.0	0	0.5

A drop to 6.5 results in a complete loss of optimal classification. A rise to 8.0 shows a significant decline in both optimal and acceptable ratings.

4. Ammonia

- **Baseline Value**: 0.01 mg/L
- **Variations**: 0.005 mg/L, 0.03 mg/L

Ammonia (mg/L)	µ(Low Ammonia)	µ(Acceptable Ammonia)
0.005	0.4	1
0.01	0.2	1
0.03	0	0.6

Lowering ammonia to 0.005 mg/L increases the membership for "Low Ammonia," while raising it to 0.03 mg/L results in a loss of "Low Ammonia" status but maintains an acceptable classification.

- **Temperature** and **DO** have a pronounced effect on optimality classifications, crucial for maintaining aquaculture health.
- **pH** shows a strong influence on both optimal and acceptable classifications, requiring close monitoring.
- **Ammonia** levels are critical; lower values ensure low toxicity, while higher levels risk pushing the water quality into unacceptable ranges.

Overall, this analysis highlights the need for careful management of water quality parameters to ensure optimal conditions for aquaculture. Understanding these sensitivities can guide interventions to maintain water quality within safe and productive ranges.

Conclusion:

The overall water quality parameters indicate a favorable environment for aquaculture, particularly in terms of pH, temperature, and dissolved oxygen. However, the concerns regarding ammonia levels warrant further monitoring and potential management strategies to ensure the long-term health and sustainability of the aquatic ecosystem. Addressing these issues proactively will enhance water quality and support successful aquaculture practices. The use of fuzzy modeling in assessing water quality parameters provides a nuanced understanding of environmental conditions in aquaculture. This approach allows for better management practices by highlighting not just the current state but also areas of concern that may affect aquatic life. Future research should focus on continuous monitoring and adjustments based on fuzzy assessments to ensure optimal conditions in aquaculture systems.

Reference:

[1]. H. Rubel *et al.*, "A strategic approach to sustainable shrimp production in India: The case for improved economics and sustainability," in "A strategic approach to sustainable shrimp production," Boston, Jan 2, 2020 2020. [Online]. Available: 〈https://media-publications.bcg.com/BCG-A-Strategic-Approach-to-Sustainable-Shrimp-Production-in-India-Jan-2020.pdf〉.

[2]. VASEP, "Ban tin thuong mai thuy san: Pho Thu tuong Chinh phu chi dao xem xet, xu ly kien nghi cua VASEP ve go kho cho doanh nghiep thuy san [Seafood Trade Newsletter: Deputy Prime Minister Directs Review and Resolution of VASEP's Recommendations to Ease Challenge," VASEP, 2023, vol. 26.

[3]. Q.T.K. Ngoc, B.B. Xuan, E.D. Sandorf, T.N. Phong, L.C. Trung, T.T. Hien Willingness to adopt improved shrimp aquaculture practices in Vietnam Aquac Econ Manag, 25 (4) (2021), pp. 430-449

[4]. J. Carvalho Pereira, A. Lemoine, P. Neubauer, S. Junne Perspectives for improving circular economy in brackish shrimp aquaculture Aquac Res, 53 (4) (2022), pp. 1169-1180

[5]. C. Huang, *et al.* Effect of adding microalgae to whiteleg shrimp culture on water quality, shrimp development and yield Aquac Rep, 22 (2022), Article 100916

[6]. C.E. Boyd "General relationship between water quality and aquaculture performance in ponds Fish diseases, Elsevier (2017), pp. 147-166

[7]. Canadian water quality guidelines for the protection of aquatic life, CCME, 2001

[8]. R.A. Bórquez-Lopez, R. Casillas-Hernandez, J.A. Lopez-Elias, R.H. Barraza-Guardado, L.R. Martinez-Cordova Improving feeding strategies for shrimp farming using fuzzy logic, based on water quality parameters Aquac Eng, 81 (2018), pp. 38-45, 10.1016/j.aquaeng.2018.01.002

[9].Nagothu, S. K., Bindu Sri, P., Anitha, G., Vincent, S., & Kumar, O. P. (2025). Advancing aquaculture: fuzzy logic-based water quality monitoring and maintenance system for precision aquaculture. *Aquaculture International*, *33*(1), 32.

[10].Kale, S.fuzzy logic approaches to water quality assessment aquaxulture science,53.

[11].Heinemann, A.B.; Hoogenboom, G.; De Faria, R.T. Determination of Spatial Water Requirements at County and Regional Levels Using Crop Models and GIS: An Example for the State of Paraná, Brazil. *Agric. Water Manag.* **2002**, *52*, 177–196.

[12].Liang, Y.; Cai, Y.; Wang, X.; Li, C.; Liu, Q. Water Security Assessment with the Improvement of Modifying the Boundary Consistency Between Footprint and Provision. *Sci. Total Environ.* **2021**, *801*, 149639.

[13].Jennings, G. *Water-Based Tourism, Sport, Leisure, and Recreation Experiences*; Routledge: London, UK, 2007; pp. 1–20.