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Information Management Monitoring System for Fish Cage Farming

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Abstract
This study investigates the integration of Internet of Things (IoT) technologies within an Information Management Monitoring System (IMMS) to improve water quality monitoring, operational efficiency, and decision-making in fish cage farming on the Semantan River, Temerloh. Employing mixed methods, the research targets 117 fish cage farmers, sampling 30 to 50 participants. The IoT-powered IMMS enables real-time monitoring and data-driven management, enhancing aquaculture resilience against environmental challenges. This approach supports sustainable seafood production by optimizing water quality and farm operations, contributing to the aquaculture industry's adaptation and sustainability goals.

Keywords: Information management, Internet of Things (IoT), monitoring systems, decision-making

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1.0 Introduction

Fish cage farming has emerged as a significant method for aquaculture, allowing for efficient fish production while minimizing land use. In recent years, the aquaculture industry has become one of the fastest-growing food production practices for producing fresh seafood for markets around the globe without putting a strain on natural fish populations. Raising livestock in a controlled environment has existed for thousands of years and has now been made easier and more efficient with the rise of the Internet of Things (IoT). The application of IoT technology in aquaculture is increasingly being found, and it is being used to solve problems in fish cage farming. The advent of IoT technologies offers innovative solutions to these problems by enabling real-time data collection and analysis. The practical usage of IoT and Information Management has brought humanity far-reaching benefits and improved quality of life. However, the management of the systems often faces challenges such as water quality monitoring, disease control, and resource allocation. Hence, the Information Management Monitoring System (IMMS) is proposed to aid with water quality parameters, fish health management, and real-time monitoring caused by environmental issues. The IMMS is expected to continually track and monitor water quality, providing thorough data that can be collected on-site using conventional methods. Water testing and measurements are carried out in a way that restricts the data to the precise moment it was obtained. More advanced techniques include computer usage and sensors that can store data in memory for subsequent user retrieval and analysis. This study aims to develop an IMMS that integrates IoT technologies to optimize fish cage farming practices.

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2.0 Problem Statement

Despite the potential benefits of fish cage farming, many farmers struggle with traditional management practices that are often inefficient and reactive rather than proactive. Key issues have been addressed in this study:

2.1 Real-time monitoring capabilities

Traditional fish cage farming practices often rely on periodic checks rather than continuous monitoring of environmental conditions. This lack of real-time data can prevent timely interventions when issues arise, such as sudden changes in water quality or disease outbreaks (Loh et al., 2023). As a result, farmers may miss critical windows for corrective actions, leading to suboptimal outcomes in fish health management and productivity. The integration of IoT technologies has the potential to revolutionize monitoring practices by enabling continuous data collection and analysis. Many existing systems fail to provide timely alerts and real-time insights for effective farm management (Hemal et al., 2024 & Dayaday and Consorcio, 2021). They indicated that many current systems do not incorporate automated feedback mechanisms that can inform farmers about critical changes in water quality parameters.

2.2 Managing data related to fish growth and environmental issues

The traditional methods often lead to fragmented data collection processes, making it challenging for farmers to obtain a comprehensive view of their operations (Endut et al., 2019). The researcher also explains that this fragmentation can result in inaccurate assessments of water quality and fish health management, ultimately affecting growth rates and productivity. Implementing automated systems that utilize digital sensors for continuous monitoring can significantly alleviate these challenges. These systems streamline data collection and enhance the accuracy of readings by minimizing human error associated with manual testing (Hossain et al., 2021). They claim that many existing solutions still lack integration capabilities for effective data management across multiple parameters. The failure to consolidate the information into actionable takeaways or insights further complicates decision-making processes for farmers.

2.3 Decision-making support system

Many farmers lack access to sophisticated analytical tools to interpret collected data and provide actionable recommendations based on real-time information (Akerkar et al., 2021). The current systems often do not incorporate advanced algorithms or machine learning techniques that could facilitate intelligent decision-making regarding resource allocation, feeding schedules, and disease management (Dayaday & Namoco, 2021). The research has shown that integrating decision support features into water quality monitoring platforms could empower farmers to make informed choices faster (Hemal et al., 2024). Systems that analyze historical data alongside real-time inputs can predict potential issues before they escalate, allowing for proactive management strategies.

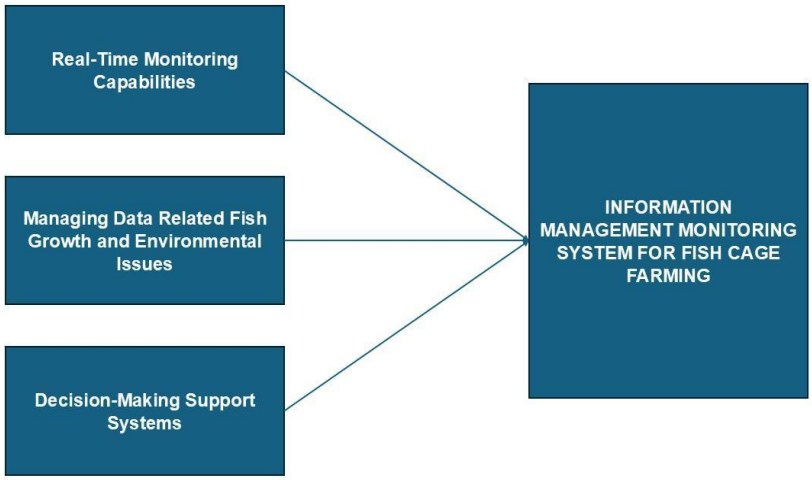

Figure 1 Conceptual Framework Information Management Monitoring System for Fish Cage Farming

3.0 Research Questions and Objectives

Based on the problem statement mentioned before, this study aims to seek the answer to three research questions that were created to guide the entire study: How can IoT technology be effectively integrated into fish cage farming to enhance monitoring and management? What are the key metrics for assessing water quality and overall fish health management, and how can an IMMS improve decision-making processes for fish cage farmers? To answer the stated research questions, three main objectives have been identified which are to develop an effective IoT-based monitoring system that enhances real-time monitoring and management capabilities in fish cage farming, to evaluate the key metrics for enhancing water quality and fish health management, and to improve decision-making processes with a guide from IMMS to fish cage farmers.

4.0 Literature Review

The integration of real-time monitoring systems in fish cage farming has become increasingly vital due to the growing demand for sustainable aquaculture practices. This literature review examines the challenges associated with traditional monitoring methods. It highlights the advancements by modern technology, mainly focusing on the lack of real-time monitoring capabilities, difficulties in managing data related to fish growth and environmental issues, and insufficient decision-making support systems.

4.1 Real-time monitoring capabilities

Traditional fish cage farming methods often rely on manual monitoring techniques, which are time-consuming and prone to human error. Modern real-time monitoring systems utilize IoT techniques for continuous data collection and analysis. Development of a comprehensive cage aquaculture monitoring system that employs environmental data loggers equipped with wireless communication capabilities. This system allows for the immediate transmission of water quality data, enabling fish cage farmers to respond swiftly to any anomalies detected in their aquatic environments (NexSens Technology, 2024). Real-time monitoring is essential for maintaining optimal conditions in aquaculture systems. The absence of real-time data can lead to severe consequences, including increased mortality rates among fish due to undetected fluctuations in water quality parameters such as pH, temperature, and dissolved oxygen levels. A study highlights that traditional water quality monitoring methods are often labor-intensive and reliant on periodic sampling, which can result in delayed responses to critical changes in the aquatic environment (Ramson et al., 2018). Recent advancements in IoT technologies have shown promise in addressing these challenges. A hybrid approach combining instrumentation with advanced deep learning algorithms has been proposed to monitor fish distributions in aquaculture environments. The study highlights that this method utilizes real-time behavioral data from fish models and integrates it with measurements from echosounders, allowing for immediate adjustments to farming practices based on observed conditions (Zhang & Su, 2024). The innovations highlight the potential for developing comprehensive monitoring systems that operate continuously, enhancing the ability to respond swiftly to environmental issues.

4.2 Managing data related to fish growth and environmental issues

Managing data collection concerning fish growth and environmental issues is crucial for optimizing production in aquaculture. However, traditional methods often result in fragmented data collection processes that hinder practical analysis and decision-making. A study emphasizes the need for integrated systems to consolidate parameters such as water temperature, pH levels, and turbidity into a single platform for easier management and analysis (Fakhrurroja et al., 2019 & Bachri, 2023). The implementation of IoT-based systems has shown promise in addressing these challenges. A study highlighted that it elaborates on a freshwater monitoring system designed using IoT technology that allows fish cage farmers to monitor critical parameters accurately while minimizing physical involvement in data collection (Affan, 2023). Such systems streamline data management and enhance the accuracy of readings, thereby supporting better fish growth management strategies. Effectively managing data related to fish growth and environmental issues is vital for informed decision-making in aquaculture. Many farms struggle with inadequate data collection practices, often resulting in poor-quality information (Eldor, 2023). A lack of reliable data can lead to misguided operational decisions, adversely affecting fish health and farm productivity. The farms operating without structured data management systems are at a significant disadvantage. Assessing the impact of various management practices on fish performance is difficult. For instance, when water quality deteriorates without proper monitoring, fish expend energy to adapt, stunting growth and increasing disease susceptibility. Therefore, implementing robust data management frameworks encompassing real-time monitoring and historical data analysis is crucial for optimizing key water quality parameters. A study found that an IoT-based aquaculture monitoring system allows farmers to track pH levels, dissolved oxygen content, and turbidity in real time via cloud platforms (Bachtiar et al., 2022). This technology streamlines data collection and enhances the accuracy of readings by reducing human error associated with manual testing. Moreover, applying big data analytics and AI in aquaculture monitoring systems, such as innovative aquaculture, presents an opportunity for improved data management. A study emphasized that by leveraging large datasets, which are big data-driven and collected from various sources, such as sensors measuring environmental issues, farmers can gain insights into trends and patterns that affect production outcomes and maintain a fish cage farming sustainability environment (Benjelloun et al., 2021). This capability enables more informed, data-driven decision-making regarding feeding allocation strategies and resource management.

4.3 Decision-making support systems

Effective decision-making in aquaculture relies heavily on accurate and timely data. However, many fish cage farmers lack access to sophisticated decision-making support systems to analyze collected data and provide actionable insights. A study highlighted that it is important to develop monitoring systems that collect data and integrate analytical tools capable of offering recommendations based on real-time data (Nuankaew et al., 2023). Integrating vague logic into water quality monitoring systems allows for more nuanced interpretations of data, enabling fish cage farmers to make informed decisions regarding water treatment and fish feeding schedules and practices (Bachri, 2023). By providing alerts and suggestions for corrective actions when parameters fall outside acceptable ranges, the systems empower farmers to manage their operations proactively rather than reactively. The complexity of aquaculture operations necessitates a comprehensive approach to the decision support system that incorporates tactical and strategic elements. A study highlighted that integrating a decision support system into aquaculture management can significantly enhance the ability of farmers to make informed choices regarding production practices (Panudju et al., 2023). The researcher also developed a framework presented in their studies that emphasizes the importance of combining qualitative and quantitative analytical approaches to support decision-making processes in aquaculture. The framework aids in understanding the factors influencing aquaculture development but facilitates scenario

analysis for evaluating alternative production technologies. Farmers can better navigate aquaculture operations' complexities while addressing sustainability and economic viability challenges. Insufficient decision-making support systems further exacerbate the challenges faced by fish cage farmers. Many existing systems do not incorporate advanced analytical tools to interpret collected data effectively. However, a group of researchers conducted research that indicates that integrating a decision-making support system, which is called a Decision Support System (DSS), has been developed into aquaculture management that significantly enhances fish cage farmers' ability to make informed decisions based on real-time information (Climate-ADAPT, 2020). The group project has developed a DSS that simulates various climate change scenarios affecting aquaculture operations. The system allows users to input specific farm characteristics and retrieve biological outputs that inform economic simulations. Such frameworks assist in understanding the impacts of environmental issues and provide risk assessments that can guide strategic planning.

5.0 Methodology

The current study's approach is **mixed method**s. Researchers typically do not see specific questions or hypotheses, especially tailored to mixed methods research(Creswell & Creswell, 2009). The configuration is necessary because mixed methods rely not exclusively on qualitative or quantitative research but on both forms of inquiry. Both qualitative and quantitative methods need to be advanced in a mixed methods study to narrow and focus the purpose statement.

5.1 Research design

This study employs a mixed-methods approach, both quantitative and qualitative, to achieve comprehensive insights into the effectiveness of the information management monitoring system for fish cage farming in the Semantan River, Temerloh. The mixed-methods approach is ideal for this research as it allows for the quantitative measurements of key parameters while capturing qualitative insights into the experience and perceptions of stakeholders. The quantitative data is a component that focuses on measurable aspects such as productivity optimization, stakeholder communication patterns, and environmental parameters. Meanwhile, the qualitative data is the aspect that explores farmers' perceptions, the challenges faced, and the dynamics of stakeholders' interactions to provide deeper context and understanding.

5.2 Population and Sampling

The target population for this study consists of 117 fish cage farmers operating in the Semantan River, Temerloh. A stratified random sampling technique is employed to ensure the diversity and representativeness of the sample. Farmers are divided into subgroups based on specific criteria such as **experience level** (e.g., novice, intermediate, experienced), **geographic location within the Semantan River**, and **usage of monitoring technologies**. A representative sample of **30 to 50 farmers** is selected, balancing diversity with the practicality of data collection and analysis.

5.3 Data collection methods

The study employs quantitative and qualitative tools to gather robust data. The quantitative tools that will be used are **surveys or questionnaires** and **productivity metrics** (fish growth rates, mortality rates, overall production efficiency) to **assess the monitoring systems' adoption levels and usage patterns**. The qualitative tools that will be used are **interviews** (conduct semi-structured interviews with fish farmers and key stakeholders to explore challenges in communication, barriers to technology adoption, and perceptions of the monitoring system's utility) and **focus group**s (facilitate group discussions among stakeholders to identify common challenges, explore collaborative solutions, and gather insights into collective experiences and perceptions).

5.4 Data analysis

The study explains the data analysis tools, usage, and methods that can be used for quantitative and qualitative analysis. The quantitative analysis will use **statistical tools** like SPSS (analyzing survey data and performing regression analysis to identify correlations between the monitoring system use and productivity improvements). The qualitative analysis will apply thematic analysis to data from **interviews** and **focus groups** (identifying recurring themes such as barriers to effective communication, perceptions of sustainability, and challenges in technology adoption).

5.5 Validation and Triangulation

A triangulation

method is employed to ensure the reliability and validity of the findings. This involves cross-verifying data from multiple sources, such as quantitative data (surveys and environmental measurements) and qualitative insights (interviews and focus groups). This approach enhances the credibility of the results and provides a comprehensive understanding of the issues under study. This methodology ensures a well-rounded and in-depth exploration of the research objectives, integrating diverse perspectives and robust data analysis techniques.

6.0 Conclusion

The transition from traditional monitoring practices to advanced IoT-enabled systems represents a significant leap forward in aquaculture management. Real-time monitoring capabilities address critical gaps in operational efficiency by providing timely insights into environmental issues. Improved data management practices enhance the ability of fish cage farmers to track growth metrics effectively.

The development of decision-making support systems equipped with analytical tools to foster proactive management strategies that can lead to better outcomes in fish cage farming operations. As the aquaculture industry continues to evolve, ongoing research and continuous development will be essential in refining these technologies and ensuring they meet the diverse needs of fish cage farmers worldwide.

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Paper Contribution to Related Field of Study

This research paper contributes to the field of Information Systems Management.

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