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DIGITALISATION OF WATER pH MONITORING IN AQUACULTURE

Fittrie Meyllianawaty Pratiwy[1]
[1]Department of Fisheries, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Indonesia.
Corresponding author email: vthreemeyllia@gmail.com

Abstract

Digitalisation in aquaculture has emerged as a strategic necessity in response to increasing production demands and environmental challenges affecting water quality. Among critical water quality parameters, pH plays a fundamental role in regulating fish physiology, metabolic balance, and survival. Fluctuations beyond optimal ranges can lead to physiological stress, disease susceptibility, and reduced production performance. Recent technological advances, particularly Internet of Things (IoT)-based systems, enable real-time monitoring and digital management of pH conditions, improving decision making and operational efficiency.

This review article synthesises published studies concerning digital pH monitoring applications in aquaculture and evaluates their impacts on aquaculture productivity in Indonesia. Literature analysis indicates that digital monitoring systems may reduce fish mortality risks by up to 30% while increasing production yields by approximately 20–25%. However, challenges including infrastructure limitations, high initial investment, and limited technological literacy among farmers still hinder widespread adoption. Support from government and institutions are therefore essential to optimise digital technology implementation and improve aquaculture sustainability.

Keywords:

Hybrid Intelligence, Smart Cities, AI, Real-Time Systems, Deep Learning.

1. Introduction

The aquaculture sector continues to expand in response to increasing global demand for animal protein. Maintaining optimal environmental conditions is therefore essential to ensure stable production and reduce economic risks. One of the most influential parameters in aquaculture systems is water pH, which directly affects physiological processes, nutrient availability, and toxicity levels in culture environments. Improper pH conditions may reduce growth rates and increase mortality, making continuous monitoring crucial.

Indonesia's aquaculture sector contributes significantly to national economic development, with fisheries contributing approximately 3.2% to national GDP (KKP, 2022). However, climate variability and pollution increasingly challenge water quality management. Consequently, digitalisation of monitoring tools has emerged as a practical solution to reduce risks caused by environmental fluctuations.

IoT-based monitoring systems implemented in various aquaculture facilities have shown considerable effectiveness. Supriyadi et al. (2023) reported that digital monitoring systems can reduce response time to water quality changes by approximately 50%. Moreover, integration of digital sensors with data management platforms enables analytical evaluation of historical data, improving feeding efficiency and operational profitability (Lestari et al., 2023).

2. Materials and Methods

This study applies a literature review methodology by analysing published articles, conference proceedings, and technical reports related to digital pH monitoring technologies in aquaculture. Data synthesis focuses on technological developments, implementation outcomes, productivity impacts, and adoption challenges reported in previous studies.

Comparative analysis between conventional and digital monitoring approaches is used to evaluate performance improvements in aquaculture production systems.

3. Results and Discussion

3.1 Digital Technologies in pH Monitoring

Digital monitoring technologies enable continuous observation of water quality parameters. IoT-based systems allow farmers to receive real-time notifications when pH levels deviate from acceptable ranges, thereby reducing mortality risks (Susanto et al., 2021). Arduino and ESP-based sensors integrated with mobile applications further simplify monitoring procedures, reducing manual measurement requirements (Musthofa, 2021).

Implementation studies demonstrate productivity increases of up to 20% and mortality reductions reaching 30% when digital monitoring is applied (Hendra et al., 2022). Furthermore, data logging supports long-term environmental analysis that correlates water quality stability with fish growth performance (Rachmadi et al., 2023).

3.2 Productivity Impact of Digitalisation

Digital monitoring enhances operational efficiency by enabling immediate corrective actions when environmental conditions change. Studies indicate mortality reductions reaching 30% in farms using IoT monitoring systems (Sari et al., 2021). Yield improvements of approximately 25% have also been reported due to improved environmental stability (Utama et al., 2022).

Shrimp farming operations applying digital monitoring technologies have demonstrated production increases up to 40% per production cycle due to rapid response capabilities (Rahman et al., 2023).

3.3 Case Study Implementations

Case studies show successful integration of pH monitoring with temperature and turbidity measurements, combined with machine learning algorithms for environmental recommendations (Sari, 2022). Survival rates in grouper farming increased to 95% under continuous monitoring conditions compared with conventional systems (Prabowo et al., 2023).

Digital monitoring adoption in shrimp farming operations has also demonstrated productivity improvements due to improved data accuracy and rapid decision-making support.

3.4 Implementation Challenges

Infrastructure limitations remain a significant constraint. Approximately 60% of aquaculture areas lack stable internet connectivity required for IoT systems (KKP, 2022). Limited technological literacy also restricts adoption, with only around 30% of farmers possessing adequate knowledge regarding digital tools (Rachman et al., 2021).

Initial investments ranging from IDR 5–10 million further hinder small-scale adoption (Junaidi, 2023). Inadequate calibration practices also lead to inaccurate readings in many field instruments (Sari & Pramono, 2022). Training programs and financial incentives are therefore essential.

3.5 Future Potential

Future developments may integrate AI-based predictive systems and automated feeding technologies, increasing production efficiency by up to 25% (Yulianto et al., 2023). Advancements in communication technology and digital infrastructure will further support sustainable aquaculture digitalisation (Yulianti, 2023).

4. Conclusion

Digitalisation of pH monitoring represents a significant advancement in aquaculture management. Real-time monitoring systems improve productivity and reduce mortality risks. However, adoption challenges including infrastructure gaps, limited knowledge, and investment costs must be addressed through coordinated policy and institutional support. Successful implementation will strengthen sustainability and competitiveness of Indonesian aquaculture.

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