INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IX September 2025

Aquaculture Sustainability through Iot, Real-Time Data Processing, and Blockchain Traceability

Niza Mohd Idris [1*], Ahmad Idil Abdul Rahman[1], Nur Izzatul Syazwani Mohd Radzi[2], Azari Abdolah[3]

[1]Centre for Telecommunication Research and Innovation (CETRI), Fakulti Technology dan Kejuruteraan Electronics dan Computer, University Technical Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka.

[2]Lumileds (M) Sdn Bhd (Plant 2), 11900 Bayan Lepas, Pulau Pinang.

[3]Department of Information Technology, Melaka International College of Science and Technology (MiCoST), Jalan Hang Tuah, 75300 Melaka, Malaysia

***Corresponding Author**

DOI: https://dx.doi.org/10.47772/IJRISS.2025.909000123

Received: 26 August 2025; Accepted: 05 September 2025; Published: 01 October 2025

ABSTRACT

The integration of Internet of Things (IoT) technologies in aquaculture enhances sustainability, efficiency, and farmer livelihoods. This study presents an IoT-based fish monitoring system using turbidity, temperature, and depth sensors connected to a cloud platform, with data accessible via mobile application. A 10-day deployment showed reliable monitoring of water quality and depth. Beyond technical benefits, the system empowers farmers, improves decision-making, and promotes sustainable aquaculture practices through digitalization. The system integrates three key sensors-DS18B20 for temperature, turbidity sensor for water clarity, and ultrasonic sensor for water depth-connected to the ESP8266 Wi-Fi module, which acts as the central controller. Data from the sensors are processed and displayed on an LCD screen, transmitted to a mobile application for remote access, and used to control a relay module. The relay operates a 12V fan, supporting water quality management. This integration ensures real-time monitoring, efficient resource use, and improved aquaculture sustainability. IoT-enabled fish monitoring strengthens aquaculture by improving resource management, reducing manual oversight, and empowering farmers with timely data, ultimately enhancing sustainability, resilience, and rural livelihoods in food production.

Keywords— Internet of things(IOT), Aquaculture monitoringWater quality management, Sustainable fish farming, Real-time data monitoring

INTRODUCTION

Aquaculture continues to expand as a vital contributor to global food security, yet its success hinges on the effective monitoring of key water quality parameters such as turbidity, temperature, and water level. Manual monitoring methods are often labor-intensive, reactive, and vulnerable to inaccuracies, highlighting a need for automated, real-time solutions.

The advent of the Internet of Things (IoT) offers a transformative pathway for aquaculture management. By integrating sensors, microcontrollers, wireless connectivity, and cloud platforms, IoT systems enable continuous data capture, remote monitoring, and instantaneous response to environmental deviations. Such capabilities enhance fish welfare, optimize operations, and reduce dependency on manual oversight.

This study introduces an IoT-based fish remote monitoring system combining a turbidity sensor, DS18B20 temperature sensor, and ultrasonic depth sensor. The system is powered by an ESP8266 microcontroller for data processing and Wi-Fi communication, with data streamed to a cloud-based platform. A complementary Android mobile application (developed in Android Studio) provides real-time data visualisation and alerts. To validate its functionality, the system was tested in a controlled aquarium over a 10-days period.

Related Works

The application of IoT in aquaculture has expanded considerably in recent years, with scholars highlighting its potential to improve water quality monitoring, resource efficiency, and farmer livelihoods [1], [2]. Bibliometric studies demonstrate the increasing academic and policy focus on IoT-driven aquaculture solutions, emphasizing global interest in sustainable fish production [3], [13]. Despite these advances, adoption remains uneven, especially in developing countries, where infrastructural limitations, cost concerns, and low levels of digital literacy hinder implementation [2], [14].

Researchers have developed low-cost monitoring systems using IoT and cloud technologies, allowing small-scale farmers to track turbidity, dissolved oxygen, and temperature more effectively [9], [14]. Studies also show that intelligent and automated IoT-based systems contribute to higher yields and more efficient feeding practices, but social acceptance depends heavily on affordability and usability [4], [8]. For example, participatory research in Nigeria revealed that farmers' willingness to adopt IoT monitoring depends not only on performance expectations but also on institutional support and trust in digital tools [4].

Critical reviews of aquaculture digitization highlight governance and data-sharing challenges, particularly around fragmented standards and limited interoperability [6], [12]. Policy frameworks play an enabling role in adoption, with environmental monitoring mandates pushing the integration of IoT in certain aquaculture sectors [5], [6]. At the same time, sustainability scholars argue that digital aquaculture must integrate ecological and social dimensions to ensure long-term resilience [12], [6].

Emerging approaches such as blockchain and AIoT are also influencing aquaculture research. Blockchain combined with IoT can strengthen traceability and transparency in seafood supply chains [10], while AIoT solutions provide predictive analytics for feeding and disease management [7], [15]. Although these technologies hold promise, their complexity and higher operational costs may exclude small-scale farmers, reinforcing digital inequalities [7], [11]. Satellite remote sensing integrated with IoT is also being explored as a complementary approach for large-scale environmental monitoring in aquaculture ponds [11].

Overall, the literature suggests that IoT-based aquaculture has strong potential to transform fish farming through real-time monitoring, automation, and sustainable practices [1], [5], [9], [15]. However, challenges in cost, governance, training, and inclusivity remain, requiring interdisciplinary approaches that balance technological innovation with social and economic realities [2], [4], [6], [12].

Research Gap

Despite significant progress, three key research gaps remain. First, most IoT-based aquaculture systems prioritize real-time monitoring but lack predictive and decision-support features, which are critical for proactive disease prevention and resource management [7], [10], [15]. Second, there is a persistent trade-off between affordability and accuracy—low-cost solutions increase accessibility but compromise measurement precision, while high-performance systems remain unaffordable for small-scale farmers [4], [9]. Third, many studies are limited to short-term laboratory or pilot trials, leaving open questions about long-term reliability, scalability, and user acceptance in real farming environments [2], [3], [14]. Additionally, while mobile applications are increasingly adopted, usability and accessibility for farmers in resource-constrained settings remain underexplored [8], [13]. Addressing these gaps requires the development of IoT-based aquaculture systems that combine low-cost design, predictive analytics, and farmer-friendly interfaces, ensuring applicability across diverse aquaculture contexts.

METHODOLOGY

The IoT-based aquaculture monitoring system was developed to capture and process real-time water quality parameters. Three calibrated sensors formed the hardware core: a DS18B20 temperature sensor, a turbidity sensor, and an ultrasonic sensor for water depth. Calibration was critical to ensure accuracy, as even small deviations in temperature or turbidity readings could compromise fish welfare and lead to poor management decisions [16].

These sensors were connected to an ESP8266 Wi-Fi microcontroller, serving as the central processing and communication hub. Sensor data were processed locally and displayed on an LCD module, while simultaneously transmitted to a cloud platform for remote access via a mobile application. This hybrid architecture combined edge-based processing, which provided low-latency responses such as controlling a relay-operated 12V fan, with cloud-based analytics, which enabled long-term data storage, visualization, and predictive insights [17] shown in Figure 1.

The methodology also considered the broader environmental implications of IoT adoption in aquaculture. Real-time monitoring optimizes water and energy use, reducing unnecessary aerator operation and mitigating greenhouse gas emissions [18]. Moreover, by maintaining stable water quality, the system minimizes fish mortality and promotes sustainable resource management.

Finally, blockchain integration was conceptualized to enhance supply chain traceability. Sensor data on water quality, feeding, and farming practices can be securely recorded on blockchain ledgers. Smart contracts automate compliance, ensuring transparency, preventing fraud, and linking sustainable production practices with consumer trust[19].

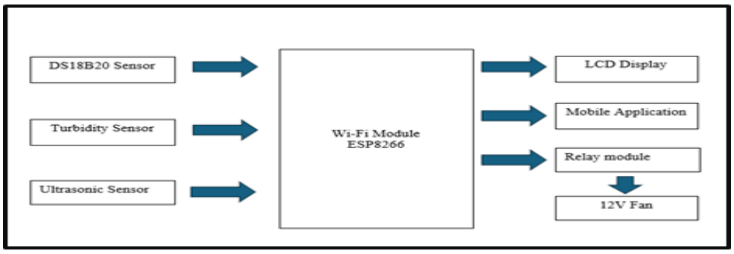


Figure 1 The block diagram of the project

RESULT AND ANALYSIS

This section describes the prototype of the fish farming box developed for the Fish Remote Monitoring System, together with the Android application that supports user interaction and data visualization. The prototype integrates essential sensors for monitoring key parameters such as temperature, turbidity, and water depth, which are transmitted to the mobile application in real time. The Android interface enables farmers to view current conditions, track historical trends, and receive alerts when parameters fall outside the optimal range. In addition, compulsory data analysis is incorporated to provide meaningful insights, ensuring effective decision-making and sustainable fish farming management.

Prototype Design

Figure 2 illustrates the prototype enclosure designed using Tinkercad software. The box is not only intended to house the sensors but also to ensure their protection and seamless integration. Each component is placed with careful consideration of spatial arrangement and connectivity. The enclosure provides shielding from environmental factors while maintaining accessibility for wiring and adjustments. The breadboard and wiring are systematically organized to reduce clutter and improve efficiency. Overall, the design offers a secure and well-structured environment for the components that continuously monitor aquaculture conditions.

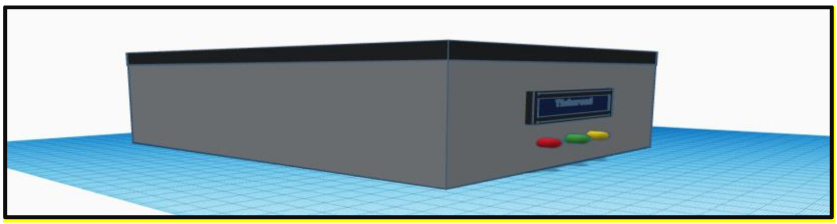
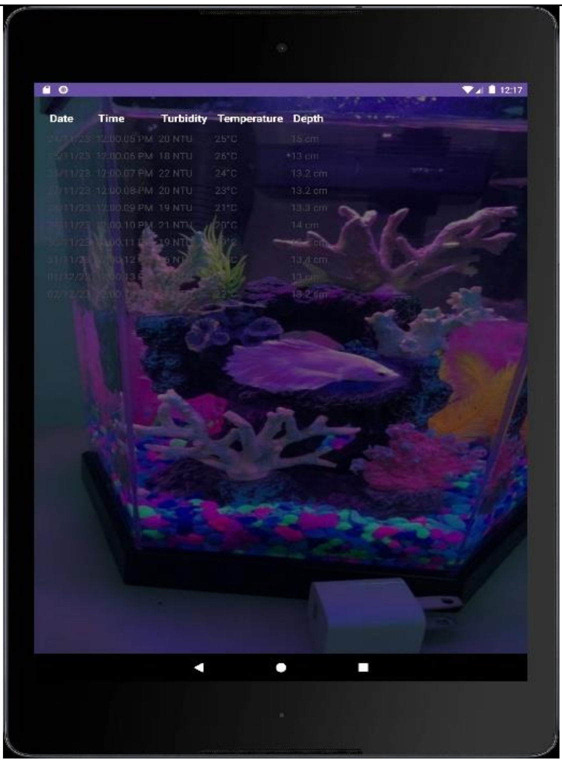


Figure 2 Prototype illustration box consists of sensors Android Application Development

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IX September 2025

Figure 3 Main Page GUI

As shown in Figure 3, the main page of the Android application functions as the central hub for monitoring and controlling the aquaculture environment. Real-time readings for turbidity, temperature, and water depth are displayed prominently. The interface is designed with usability in mind, offering intuitive navigation and responsive feedback. Actuator controls are also integrated, enabling users to toggle two water pumps and a fan, as well as adjust fan speed. This development stage emphasizes the synchronization between user commands, the Android interface, and the Arduino firmware, ensuring seamless communication and real-time responsiveness.



. **Figure 4** Data History GUI

Figure 4 presents the Data History page, accessible via the "Data History" button on the main page. This feature provides access to historical sensor data for up to 10 days, enabling trend analysis and informed decision-making. Implementation involved relational database design, efficient data retrieval mechanisms, and visualization tools. Each database entry stores timestamped sensor readings (turbidity, temperature, and water depth), ensuring accurate record-keeping and traceability. This feature enhances system functionality by supporting long-term monitoring and analysis of aquaculture conditions.

Hardware Development

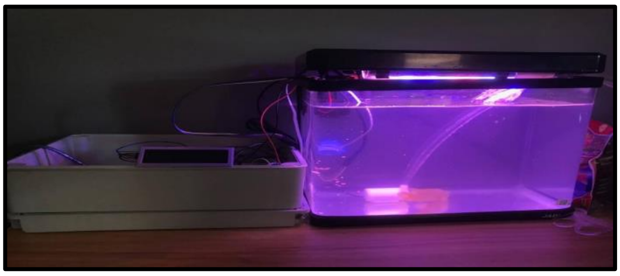


Figure 5 Prototype of Fish Remote Monitoring System

Figure 5 depicts the physical prototype setup within the aquarium environment. The aquarium serves as the testbed for the IoT-based Fish Monitoring System, replicating real aquaculture conditions. Within this environment, sensors are strategically positioned to capture critical parameters such as turbidity, temperature, and water depth. Actuators, including two water pumps and a fan, are integrated to regulate water circulation and maintain optimal environmental conditions. The Arduino microcontroller acts as the system's processing unit, handling sensor inputs, executing control algorithms, and ensuring communication with the Android application. This hardware-software integration validates the feasibility of the proposed system in providing real-time monitoring and control for aquaculture management.

Analysis of Fish Monitoring System

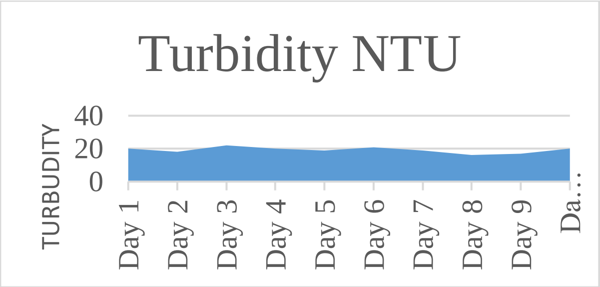


Figure 6 Graph of Turbidity data taken for 10 days.

The turbidity monitoring over a 10-day period showed relatively stable water quality with only moderate fluctuations. The average turbidity was 19.1 NTU, with most values between 18–21 NTU, and a modest standard deviation of 1.76 NTU. This indicates a well-regulated system with limited disturbance, providing a suitable environment for fish culture. In aquaculture, turbidity is a key parameter since excessive suspended particles can reduce light penetration, limit primary productivity, and cause stress or gill irritation in fish, while very low turbidity may indicate poor plankton availability, affecting the natural food chain [20]. The stable range observed here suggests a balanced aquatic environment that supports optimal fish growth and health. Moreover, the ability to detect short-term fluctuations, such as the sudden dip to 16 NTU, highlights the importance of continuous monitoring systems that enable timely interventions to sustain productivity and reduce risks [21].

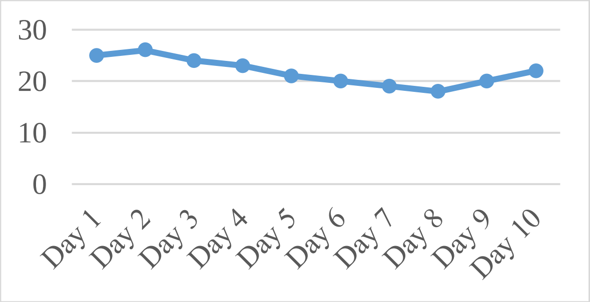


Figure 7 Graph temperature against date for 10 days

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IX September 2025

The temperature data recorded ranging from 25 °C down to 18 °C before rising to 22 °C, has important implications for fish aquaculture. Most tropical aquaculture species, such as tilapia and catfish, thrive at 25–30 °C, and the cooling trend observed in this dataset suggests a period of reduced metabolic activity, lower feed intake, and slower growth. Temperatures below 22 °C often trigger stress responses in warmwater fish, weakening their immune systems and increasing vulnerability to diseases such as Aeromonas infections. While cooler water holds more dissolved oxygen, which can be beneficial, sudden fluctuations over a short period may disrupt fish physiology and water quality management. Farmers may need to adjust feeding rates, strengthen aeration, and monitor water conditions closely to minimize losses. Overall, the dataset illustrates, refer to Figure 7, how even short-term changes in temperature can significantly influence fish health, behavior, and aquaculture productivity [22].

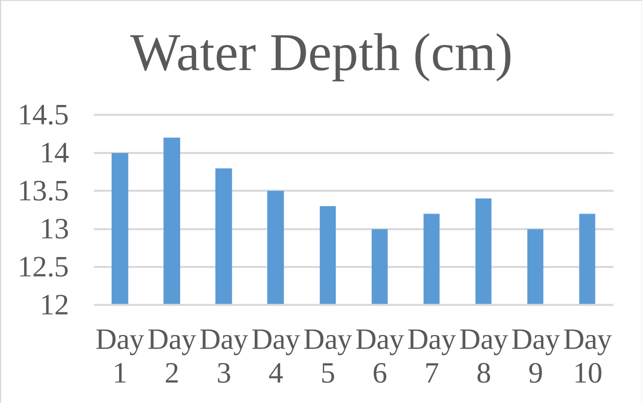


Figure 8 Graph of Depth vs Date Taken in 10 days

The depth data recorded shows that the aquarium water level remained relatively stable, with only minor variations between 13.8 cm and 14.2 cm, as depicted in Figure 8. This stability is vital in fish aquaculture because consistent water depth helps maintain uniform water quality, including balanced dissolved oxygen and temperature distribution, while also reducing stress on fish. Rapid fluctuations in water level can disrupt these parameters and negatively impact fish health and growth. The minimal variability in depth suggests effective monitoring and sound water management practices. Stable water depth also enhances the efficiency of aeration and feeding systems, providing fish with a reliable and healthy environment. Maintaining such control over water conditions is therefore essential to reducing disease risk, promoting steady growth, and improving overall productivity in aquaculture systems [23].

CONCLUSION

This study demonstrates that IoT-based aquaculture systems, equipped with calibrated sensors and integrated with mobile applications, can improve water quality monitoring, fish welfare, and operational efficiency. Calibration of temperature, turbidity, and ultrasonic sensors ensures accuracy, reducing the risk of errors in monitoring and supporting sustainable fish farming practices [16,17]. The comparison between cloud and edge processing revealed complementary strengths: cloud systems facilitate large-scale data storage and analysis, while edge computing supports real-time, low-latency decision-making [18].

From a broader perspective, IoT adoption offers significant environmental benefits by optimizing resource use, reducing waste, and preventing overfeeding or poor water management [17]. Furthermore, integrating blockchain with IoT enhances transparency, prevents fraud, and strengthens trust in the seafood supply chain by enabling end-to-end traceability [19]. Overall, this approach not only advances technical efficiency but also fosters sustainability, inclusivity, and resilience in aquaculture practices.

ACKNOWLEDGEMENT

The authors would like to thank the Centre for Research and Innovation Management (CRIM) and Universiti Teknikal Malaysia Melaka (UTeM) for financing this work.

REFERENCES

1. Ahmed, N., Thompson, S., & Glaser, M. (2019). Global aquaculture productivity, environmental sustainability, and climate change adaptability. Environmental Management, 63(2), 159–172. https://doi.org/10.1007/s00267-018-1117-3
2. Béné, C., Barange, M., Subasinghe, R., Pinstrup-Andersen, P., Merino, G., Hemre, G. I., & Williams, M. (2015). Feeding 9 billion by 2050 – Putting fish back on the menu. Food Security, 7(2), 261–274. https://doi.org/10.1007/s12571-015-0427-z
3. Diana, J. S. (2012). Aquaculture production and biodiversity conservation. Bioscience, 62(6), 503–513. https://doi.org/10.1525/bio.2012.62.6.9
4. Food and Agriculture Organization of the United Nations. (2022). The state of world fisheries and aquaculture 2022. FAO. https://doi.org/10.4060/cc0461en
5. Gokulnath, K., & Rajini, V. (2018). IoT-based smart monitoring of water quality parameters for aquaculture using fuzzy logic. International Journal of Pure and Applied Mathematics, 119(15), 1985–1992. https://acadpubl.eu/jsi/2018-119-15/articles/15a/41.pdf
6. Hossain, M. S., & Rahman, M. M. (2021). Smart aquaculture system for water quality monitoring and fish health management using IoT. Aquaculture Engineering, 95, 102196. https://doi.org/10.1016/j.aquaeng.2021.102196
7. Islam, M. S., & Phillips, M. J. (2020). Economic and social dimensions of aquaculture and fisheries: Sustainability and trade-offs. Aquaculture, 518, 734872. https://doi.org/10.1016/j.aquaculture.2019.734872
8. Khan, S., & Lorenz, E. (2021). Socioeconomic impacts of digital technologies in aquaculture: Evidence from Asia. Marine Policy, 127, 104441. https://doi.org/10.1016/j.marpol.2021.104441
9. Kumar, R., Singh, M., & Sinha, A. (2019). IoT-based real-time monitoring system for aquaculture. Procedia Computer Science, 165, 845–851. https://doi.org/10.1016/j.procs.2020.01.121
10. Li, X., & Li, J. (2020). Digitalization in aquaculture: A global perspective. Journal of Aquaculture Research & Development, 11(2), 1–7. https://doi.org/10.35248/2155-9546.20.11.599
11. Mohd, S., Ahmad, F., & Abdullah, M. (2021). IoT-based aquaculture monitoring for sustainable fish farming. Journal of Environmental Management, 287, 112304. https://doi.org/10.1016/j.jenvman.2021.112304
12. Lin, J.-Y., Tsai, H.-L., & Lyu, W.-H. (2021). An Integrated Wireless Multi-Sensor System for Monitoring the Water Quality of Aquaculture. Sensors, 21(24), Article 8179. https://doi.org/10.3390/s21248179
13. Virapat, C. (2022). The current challenges of sustainable aquaculture in the Asia-Pacific region and the measures recommended. Asia Pacific Journal of Rural Development, 32(2), 207–216. https://doi.org/10.1177/10185291231193516
14. Johnson, T. R., Beard, K., Brady, D. C., Byron, C. J., Cleaver, C., Duffy, K., Keeney, N., Kimble, M., Miller, M., Moeykens, S., Teisl, M., van Walsum, G. P., & Yuan, J. (2019). A social-ecological system framework for marine aquaculture research. Sustainability, 11(9), 2522. https://doi.org/10.3390/su11092522
15. Sung, W., Tofik Isa, I. G., & Hsiao, S. (2023). An IoT-based aquaculture monitoring system using Firebase. Computers, Materials & Continua, 76(2), 2179–2200. https://doi.org/10.32604/cmc.2023.041022
16. Bakar, A. A. A., Bakar, Z. A., Yusof, Z. M., Ibrahim, M. J. M., Mokhtar, N. A., & Zaiton, S. N. (2025). IoT-based real-time water quality monitoring and sensor calibration for enhanced accuracy and reliability. International Journal of Interactive Mobile Technologies (iJIM), 19(1), 155–170. https://doi.org/10.3991/ijim.v19i01.51101
17. Olanubi, O. O., Akano, T. T., & Asaolu, O. S. (2024). Design and development of an IoT-based intelligent water quality management system for aquaculture. Journal of Electrical Systems and Information Technology, 11, 15. https://doi.org/10.1186/s43067-024-00139-z
18. Alghamdi, M., & Haraz, Y. G. (2025). Smart Biofloc systems: Leveraging Artificial Intelligence (AI) and Internet of Things (IoT) for sustainable aquaculture practices. Processes, 13(7), 2204. https://doi.org/10.3390/pr13072204

19. Ismail, S., Reza, H., Salameh, K., Kashani Zadeh, H., & Vasefi, F. (2023). Toward an intelligent Blockchain IoT-enabled fish supply chain: A review and conceptual framework. Sensors, 23(11), 5136. https://doi.org/10.3390/s23115136
20. Boyd, C. E. (2015). Water quality: An introduction. Springer. https://doi.org/10.1007/978-3-319-17446-4
21. Jais, N. A. M., Abdullah, A. F., Kassim, M. S. M., Karim, M. M. A., & Muhadi, N. 'A. (2024). Improved accuracy in IoT-based water quality monitoring for aquaculture tanks using low-cost sensors: Asian seabass fish farming. Heliyon, 10(8), e29022. https://doi.org/10.1016/j.heliyon.2024.e29022
22. Mangi, S. C. (2024). Water level fluctuation effect on fish reproduction success. International Journal of Ecology, 2024, Article ID 4876582. https://doi.org/10.1155/2024/4876582
23. Reverter, M., Tapissier-Bontemps, N., Sarter, S., & Sasal, P. (2020). Aquaculture at the crossroads of global warming and antimicrobial resistance. Nature Communications, 11(1), 1870. https://doi.org/10.1038/s41467-020-15735-6