RCTA
Revista Colombiana de Tecnologías de Avanzada
UNIPAMPLONA

Digital Object Identifier: 10.24054/rcta.v2i46.4140

Wifish: IoT and cloud computing-based aquaculture monitoring platform with AES-128 encryption

WiFish: Plataforma de monitoreo de acuicultura basada en IoT y cloud computing con cifrado AES-128

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Received: *april 24, 2025.* ***Accepted:*** *july 03, 2025.* ***Published:*** *august 08, 2025.*

How to cite: *A. J. Cuenca Luna, R. D. Quelal Villarreal, F. S. Donoso Martínez, F. G. Cuzme Rodríguez, and P. D. Muñoz Criollo, "Wifish: IoT and cloud computing-based aquaculture monitoring platform with AES-128 encryption", RCTA, vol. 2, no. 46, pp. 190–200, Aug. 2025.*
Recovered from https://ojs.unipamplona.edu.co/index.php/rcta/article/view/4140

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Abstract: The primary objective of this research is to enhance aquaculture management by developing an intelligent system that overcomes the inefficiencies of traditional water quality monitoring. This study introduces and validates WiFish, a comprehensive solution designed for real-time supervision of aquatic parameters across various scales of operation, from small test aquariums to large commercial fish farms. The methodology is founded on an Internet of Things framework, utilizing ESP32 microcontrollers integrated with high-precision sensors to continuously measure water pH, temperature, and salinity. All collected data is secured with AES-128 encryption and transmitted via Wi-Fi to a Huawei Cloud DataArts Studio infrastructure for advanced processing, storage, and analysis. Remote access for monitoring and alerts is provided through a custom mobile application and a Telegram bot. Empirical testing in operational aquaculture environments yielded significant results, demonstrating a 98 percent accuracy rate in measurements. The system's implementation led to a 75 percent reduction in the need for manual supervision and an optimization of resource consumption, including a 30 percent decrease in feed and chemical usage. The principal benefit is that WiFish represents a scalable, secure, and highly effective platform that boosts productivity and promotes sustainability. It successfully proves that integrating secure cloud computing and Internet of Things technology can profoundly transform water resource management in the modern aquaculture industry.

Keywords: Internet of Things, Environmental Monitoring, Cloud computing, Aquatic ecosystems, Aquaculture, Data Security, Wireless security.

Resumen: El objetivo principal de esta investigación es mejorar la gestión acuícola mediante el desarrollo de un sistema inteligente que supere las ineficiencias del monitoreo tradicional de la calidad del agua. Este estudio presenta y valida WiFish, una solución integral diseñada para la supervisión en tiempo real de parámetros acuáticos en varias escalas de operación, desde pequeños acuarios de prueba hasta grandes granjas comerciales de peces. La metodología se basa en un marco de Internet de las cosas, utilizando microcontroladores ESP32 integrados con sensores de alta precisión para medir continuamente el pH, la temperatura y la salinidad del agua. Todos los datos recopilados están protegidos con cifrado AES-128 y se transmiten a través de Wi-Fi a una infraestructura de Huawei Cloud DataArts Studio para su procesamiento, almacenamiento y análisis avanzados. El acceso remoto para el monitoreo y las alertas se proporciona a través de una aplicación móvil personalizada y un bot de Telegram. Las pruebas empíricas en entornos acuícolas operacionales arrojaron resultados significativos, demostrando una tasa de precisión del 98 por ciento en las mediciones. La implementación del sistema condujo a una reducción del 75 por ciento en la necesidad de supervisión manual y una optimización del consumo de recursos, incluida una disminución del 30 por ciento en el uso de alimentos y productos químicos. La principal ventaja de WiFish es que representa una plataforma escalable, segura y altamente efectiva que impulsa la productividad y promueve la sostenibilidad. Demuestra con éxito que la integración de la computación en la nube segura y la tecnología de Internet de las cosas puede transformar profundamente la gestión de los recursos hídricos en la industria acuícola moderna.

Palabras clave: Internet de las cosas, Monitoreo Ambiental, Computación en la Nube, Ecosistemas Acuáticos, Acuicultura, Seguridad de Datos, Seguridad Inalámbrica.

1. INTRODUCTION

In a world marked by climate change and increasing pressure on natural resources, having reliable and low-cost environmental monitoring systems is essential [1]. In this context, the Internet of Things (IoT) has taken a leading role by enabling the collection and real-time transmission of data through interconnected sensors [2]. This technology has expanded into fields such as agriculture, transportation, healthcare, and environmental monitoring, especially for measuring variables like climate and water quality [2][3]. In aquaculture, for example, IoT sensors are used to measure critical water parameters, generating early warnings of potential risks [4]. LPWAN networks, such as LoRaWAN and WiFi, make it possible to transmit this data over long distances with low energy consumption, although they present security challenges that are being addressed through improvements in encryption methods like AES-128 [5][6].

The large amount of data generated requires scalable infrastructures, where cloud computing offers a flexible and cost-effective solution [7][8]. Moreover, modern architectures such as microservices and containers have gained ground, improving performance, scalability, and reducing costs in IoT platforms [9][10][11]. When immediate processing is required or there are connectivity limitations, the edge–cloud approach has proven effective, as in aquaculture farms where federated learning is applied without sharing sensitive data directly [12].

Artificial intelligence techniques complement IoT by enabling predictive analysis and automated responses. From fuzzy logic models for assessing water quality [4], to algorithms for filtering erroneous data in industrial networks [13], significant progress has been made. Furthermore, mobile and collaborative solutions with aquatic sensors have been proposed to expand the reach of monitoring [14].

Finally, the growth of IoT raises challenges such as security, interoperability, and reliability in networks with limited resources. Underwater IoT (IoUT) is being explored for extreme environments, where advanced strategies such as adaptive localization algorithms and digital twins are applied to maintain the accuracy and security of systems [15][16][17]. This landscape opens new possibilities for smarter, more sustainable, and accessible environmental monitoring systems.

The following sections of the article are organized as follows. Section two addresses the methodology used for the design of the monitoring system, detailing the types of sensors used, the data collection process, and the testing conditions. Section three presents the results obtained from temperature and pH measurements, with an emphasis on their sensitivity to slight variations in the aquatic environment. Subsequently, section four discusses the implications of these results in real-world contexts, and finally, section five presents the conclusions and recommendations for future technological improvements and system implementation.

2. METHODOLOGY

2.1 System Design

This section presents the system design, which integrates hardware and software components distributed across different nodes for data acquisition, actuator control, and remote supervision. The architecture includes wireless connectivity, cloud storage, and live streaming, enabling automated and real-time management of the aquatic environment.

2.1.1 System Architecture

The system is composed of four layers: data acquisition, connectivity, analysis/processing, and application "(see Fig. 1)". Distributed nodes based on ESP32 microcontrollers are used for reading temperature, pH, and controlling actuators, while the application layer allows real-time visualization and monitoring from end-user devices.

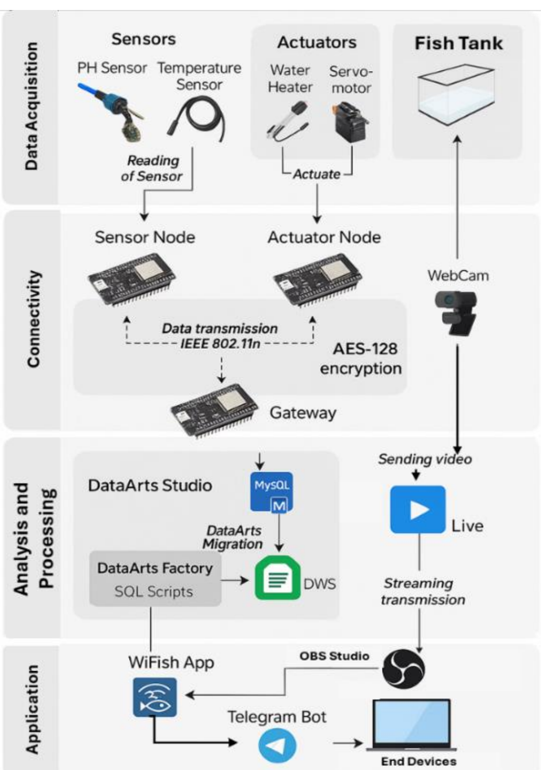

Fig. 1. *System architecture.*
Source: *Authors.*

- *Data Acquisition:* At this stage, a submersible DS18B20 sensor measures temperature and another sensor measures the water's pH in the fish tank. The data is sent from the Sensor Node to the Gateway. Meanwhile, the Actuator Node controls a water heater and a servo motor that dispenses food, receiving commands from the application.

- *Secure Connectivity*: Communication between nodes is carried out via the IEEE 802.11n (Wi-Fi) protocol, ensuring transmission with AES-128 encryption. The Gateway acts as the central point for receiving data and sending commands.

- *Analysis and Processing:* The system leverages the Huawei Cloud platform, integrating DataArts Studio and DataArts Factory for storage, migration, and processing of data in MySQL "(see Fig. 2)". This infrastructure enables scalable and secure management of the collected information.

- Additionally, a real-time visual monitoring system was integrated using video streaming; a camera captures the fish tank environment. This feed is broadcast live via OBS Studio (as the encoder) and published to the Huawei Cloud Live service, used as the streaming server. End-users can access this live stream through the WiFish application, enabling continuous and secure remote visual supervision of the system.

- *Application Layer:* Visualization and control of the system are performed through the WiFish application, developed for mobile devices. A Telegram bot is also integrated for quick notifications, along with a live video server using OBS Studio, which streams the camera feed in real time to the application.

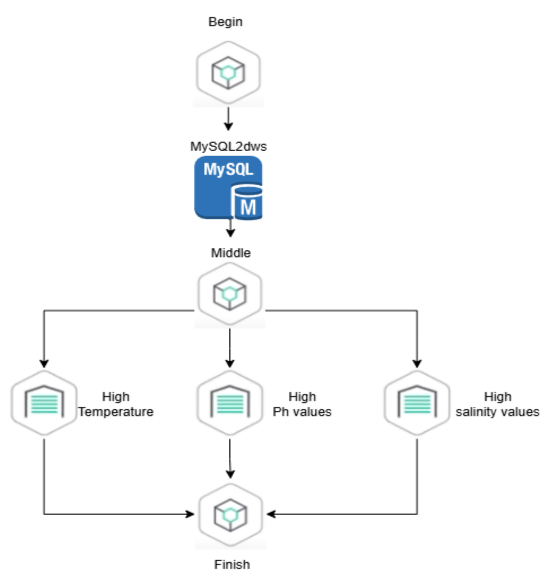

Fig. 2 *Huawei Cloud Architecture.*
Source: *Authors.*

2.2.2 Hardware

The system integrates various electronic elements distributed across its three nodes, enabling variable reading, automated control, and user interaction.

- *ESP32 Microcontroller:* Main processing unit in the Sensor Node, Gateway, and Actuator Node. Its Wi-Fi connectivity and dual-core processing make it ideal for real-time IoT systems.

- *DS18B20 Submersible Temperature Sensor:* Enables accurate water temperature measurement in the fish tank environment, facilitating automated thermal control.

- *pH Sensor:* Electrochemical device used to measure the level of acidity or alkalinity of the water. This sensor generates an analog signal proportional to the pH value, which is read by the microcontroller through an analog pin. It is fundamental for monitoring water quality, allowing for the detection of conditions that could affect the environment, and to activate alerts or corrective actions.

- *Water Heater:* Device responsible for adjusting the water temperature as required by the environment.

- *Relay Module:* Control interface that allows the microcontroller to activate or deactivate the water heater safely using a digital signal.

- *Camara:* Enables real-time video capture for remote visual supervision of the aquatic environment, connected to the streaming server.

- *Servo motor:* Actuator that executes programmed movements for food dispensing, remotely controlled from the mobile application.

2.1.3 Software

The system development utilized various software tools for programming physical devices, as well as for data management, remote visualization, and user application creation:

- *Arduino IDE:* Development environment used to program the ESP32 microcontrollers. It allows writing, compiling, and uploading the code needed for sensor reading, wireless communication, and actuator control.

- *MySQL:* Relational database management system used to store and organize the data collected by the system, facilitating later analysis and visualization.

- *DataArts Studio:* Huawei Cloud platform for comprehensive data management. It enables the design, modeling, and control of information flow in distributed environments.

- *DataArts Factory:* Data flow orchestration tool that automates ETL (extract, transform, and load) processes, facilitating the efficient preparation and transfer of data to storage or analysis systems.

- DataArts Migration: Specialized Huawei Cloud service that facilitates data migration from different sources to cloud databases, ensuring data integrity and continuity of information flow.

- *DWS (Data Warehouse Service):* Cloud data warehouse that allows advanced analysis of large volumes of information using optimized SQL queries, supporting decision-making based on historical and real-time data.

- *OBS Studio:* Open-source software used to capture and encode video from the system-connected camera. It is responsible for live streaming to Huawei Cloud Live, enabling real-time remote visualization.

- *App Inventor:* Visual development platform used to build the system's mobile application. It allows connecting to the database, viewing readings, controlling the feeding actuator, and accessing live streaming.

2.1.4 Connection Diagram

This section presents the wiring diagram among the main system components, detailing the hardware distribution in the sensor and actuator nodes. This design allows for efficient integration, ensuring the proper functioning of the system in real time.

- *Sensor Node:* The sensor node is composed of an ESP32 microcontroller to which two sensors are connected: a DS18B20 temperature sensor and a pH sensor with adapter module "(see Fig. 3)". The DS18B20 sensor is connected using a 4.7 kΩ pull-up resistor, allowing for a stable digital reading. The sensor's power lines are connected to the VCC and GND pins of the microcontroller. On the other hand, the pH sensor provides an analog signal that connects to one of the ESP32's ADC pins, while its VCC and GND lines are also connected to the respective pins of the microcontroller. This configuration allows for real-time measurement of both temperature and pH levels in the water, sending the data to the Gateway node for processing and storage.

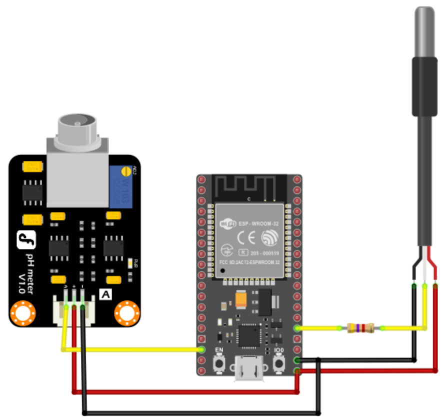

Fig. 3. *Sensor node wiring diagram.*
Source*: Own elaboration.*

- *Actuator Node:* The actuator node consists of an ESP32 microcontroller, a servo motor, and a relay module responsible for controlling a water heater "(see Fig. 4)". The servo motor is connected to the ESP32 through three lines: the control signal and the power lines (VCC and GND). The relay module receives a control signal from a digital pin of the ESP32 and is also powered from the VCC and GND pins. This relay allows activation or deactivation of the water heater connected to the 120 V AC power grid. The heater connection is made safely through the relay, interrupting one of the AC lines. This configuration allows the system, based on the temperature readings sent by the sensor node, to automatically activate the water heater, and for the servo motor to be remotely controlled to dispense food to the fish from the mobile application.

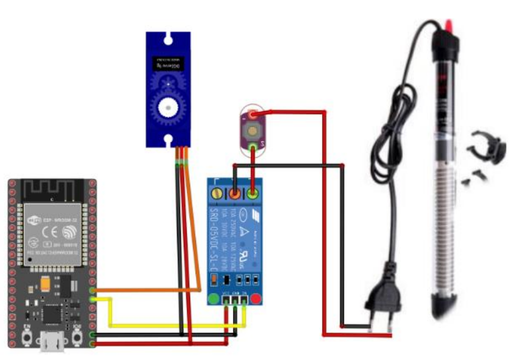

Fig. 4*. Actuator node wiring diagram.*
Source*: Own elaboration.*

2.1.5 Communication and Security

Communication between the different system nodes is carried out through the IEEE 802.11n (Wi-Fi) wireless protocol, allowing for efficient and long-range connectivity within the environment. The Sensor Node and the Actuator Node send and receive information from and to the Gateway Node, which acts as the central coordination and processing point.

To guarantee the integrity and confidentiality of the transmitted data, a symmetric AES-128 (Advanced Encryption Standard) encryption scheme is implemented. This mechanism protects both the data and the commands sent to the actuators, preventing unauthorized access or external manipulations. Thus, secure communication between devices is ensured, and the reliability of the system is reinforced against possible vulnerabilities in wireless networks.

2.2. Implementation

Once the functional modules of the system were defined, implementation proceeded in a controlled environment. The hardware was assembled and strategically distributed to guarantee precise measurement and efficient automatic response. In parallel, the ESP32 nodes were programmed with embedded logic that enables sensor reading, actuator activation, and secure communication via encrypted Wi-Fi. Finally, connectivity with cloud services and visualization tools was established, allowing for remote supervision and system automation under real conditions.

2.2.1 Physical System Assembly

The physical system implementation began with the connection of the DS18B20 digital temperature sensor, using a 4.7 kΩ pull-up resistor between the data line and the power supply to ensure stable reading, and the pH sensor to the ESP32 microcontroller. Simultaneously, a relay module was integrated to enable the automatic activation of a submersible heater based on the monitored temperature values. For mechanical actuation, SG90 servo motors were connected to one of the digital outputs of the ESP32, which is responsible for operating an auxiliary mechanism within the controlled environment. This assembly was set up in an experimental fish tank "(see Fig. 5)", simulating a small-scale aquatic ecosystem.

Fig. 5. *Physical prototype.* ***Source****: Own elaboration.*

Additionally, a webcam was mounted on a fixed tripod, directly facing the fish tank, with the aim of providing a continuous view of the monitored environment. The camera was connected to a computer that acts as the local processing center and live streaming hub, allowing for real-time remote supervision.

2.3 Testing

To validate the integral functioning of the system, tests were carried out in environments of different scales, with the aim of evaluating sensor accuracy, wireless network stability, cloud interoperability, and interaction with the visualization and control modules. This phase made it possible to detect necessary adjustments to guarantee the reliability of the system under real conditions.

2.3.1 Testing in Fish Tanks (Small Scale)

Initially, the system was implemented in test fish tanks, where the continuous reading of the temperature (DS18B20) and pH sensors was verified, analyzing their accuracy under controlled conditions. The servo motor's response time for food dispensing and the operation of the relay connected to a heater were also evaluated. Data transmission through Wi-Fi with AES-128 encryption was also verified, validating its integrity from the microcontroller to the cloud database. During this stage, calibration adjustments were made, especially to the pH sensor, to improve the reliability of the measurements.

Fig. 6*. Initial implementation of the system in experimental fish tanks.* ***Source****: Own elaboration*

2.3.2 Testing in Shrimp Ponds (Medium Scale)

Subsequently, the system implementation was extended to larger shrimp ponds, where environmental conditions are more variable. In this environment, the stability of the wireless network, Wi-Fi coverage in open fields, and the system's resilience to factors such as humidity and salinity were tested. Stable sensor behavior was observed, and the continuous transmission of data to Huawei Cloud was validated. Likewise, the integration of the camera with OBS Studio was tested, achieving live video transmission from the pond and combining it with remote variable reading via the mobile application.

Fig. 7. *System deployment in shrimp ponds.*
Source*: Own elaboration*

2.3.3. Testing in Industrial Aquaculture Farms (Large Scale)

At this stage, the system was implemented in an industrial aquaculture farm to validate its scalability and performance under real operating conditions. Critical variables such as temperature and pH were continuously monitored, and supervision was automated by means of actuators and a live camera. Huawei Cloud was key in this implementation, as it enabled centralized storage, structuring, and analysis of data through DataArts Studio and DWS. This facilitated real-time alert generation and remote access from the mobile application, ensuring efficient, secure, and continuous management of the system.

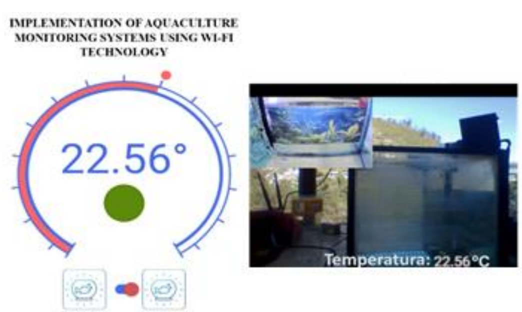

Fig. 8*. System implementation in experimental fish tanks.*
Source*: Own elaboration.*

3. RESULTS

3.1. Improvement in Operational Efficiency of Aquaculture Monitoring

Through real-time monitoring and streaming visualization, it has been observed that pet sellers, pool managers, and those working with aquaculture species have managed to optimize their tasks. This system has enabled the reduction of operating costs, minimized the time spent by personnel on direct supervision, and facilitated the efficient management of species feeding.

3.1.1. Comparison of Time and Effort Required With and Without WiFish

Previously, the fish feeding process required a significant investment of time, as it had to be done manually and on-site. In cases where the person responsible was not present, it was necessary to travel from their workplace or home to the farming or sales area, resulting in wasted time and additional effort. With the implementation of the WiFish system, this process has been automated and optimized: from any location, the user can monitor in real time the status of the aquaculture species via streaming, and by pressing the feeding button in the interface, a servo motor is activated to dispense a controlled amount of food. This process takes less than a minute, representing a significant improvement in efficiency and remote control.

3.1.2. Reduction of Manual Tasks

The WiFish project design covers multiple aspects of aquaculture management, including water climate monitoring, automatic feeding, and real-time data collection from sensors. This integration allows for significant optimization of daily tasks, resulting in considerable time savings for the user.

Regarding climate control, the system allows the configuration of an appropriate temperature range for each species directly from the microcontroller. When the environmental temperature drops, especially at night, the system automatically activates a water heater to maintain optimal conditions within the pond or tank.

For feeding, the system offers two modes of operation: an automated mode, where the servo motor dispenses food at a scheduled time; and a manual mode, via the mobile application, where the user can activate feeding by pressing a button. This automation covers approximately 80% of the tasks that were previously performed manually. The remaining 20% correspond to maintenance tasks, such as cleaning the tank.

The application also collects and displays sensor data, such as pH value, which generally remains between 6.0 and 8.0. If a prolonged deviation outside this range is detected, the system generates a notification alerting the user to the need for physical maintenance, thus contributing to the well-being of aquatic species.

3.2. Reduction of Input Consumption in Production

It is essential to know the species of fish to which the WiFish system will be applied, since each type has specific feeding requirements. Based on this, the servo motor must be configured to dispense the appropriate amount of food per cycle. Another key factor is the number of fish in the tank, which allows for a more precise calculation of the total amount of food needed.

For example, if a single fish consumes approximately 25 grams of balanced food per day, and there is a population of between 8 and 10 fish in the same environment, a direct multiplication is performed to estimate the total daily consumption. Based on this calculation, the number of servo motor turns is configured so that the amount of dispensed food is sufficient, avoiding both waste and overfeeding. This customization ensures efficient feeding tailored to the real conditions of the system.

In the manual feeding method, since there is no exact measure based on the actual number of fish, a cup or generic container is often used to dispense food. This practice frequently leads to inaccuracies: in many cases, overfeeding occurs, increasing food waste and deteriorating water quality; while in other cases, if a smaller amount is taken, insufficient feeding may occur, affecting the health of the species.

In Fig. 9, a comparative graph is shown that relates the number of fish to the estimated daily food consumption, for both the automated method (WiFish), which maintains a constant ratio of 25 grams per fish, and the manual method, which presents random variations due to the lack of dosage control. This difference highlights the need to automate the process to ensure precise, efficient, and healthy feeding for aquatic species (see Fig. 9).

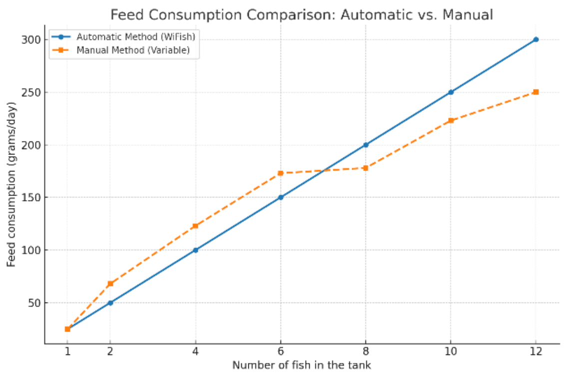

Fig. 9 *Comparative graph of food consumption.*
Source*: Own elaboration*

3.2.1. Economic and Environmental Impact of Using WiFish

By maintaining adequate and dosed feeding through the WiFish system, significant savings in food consumption are achieved. In practice, when feeding was done manually, a bag of food was depleted in approximately a month and a half due to overfeeding and waste. In contrast, with the implementation of the automated system, that same amount of food can last between 3 and 3.5 months, thanks to precise dosing adjusted to the actual number of fish. This optimization not only reduces operating costs but also improves the sustainability of aquaculture management.

3.3. Accuracy in Detecting Environmental Conditions

One of the main objectives of WiFish is to accurately and continuously capture changes in water conditions. Figures 10 and 11 separately present the variations recorded by the sensors in real time for pH and temperature parameters. The system showed a consistent ability to identify relevant micro fluctuations, allowing the detection of patterns that would go unnoticed in conventional manual methods (see Fig. 10 and Fig. 11).

This behavior is critical for carrying out timely interventions in sensitive processes such as oxygenation, food dosing, or the application of chemicals. For example, abrupt drops in pH or gradual increases in temperature can affect oxygen solubility or induce physiological stress in cultured species. Thanks to its real-time readings, WiFish stands out as a reliable system for anticipating critical changes in the aquatic environment.

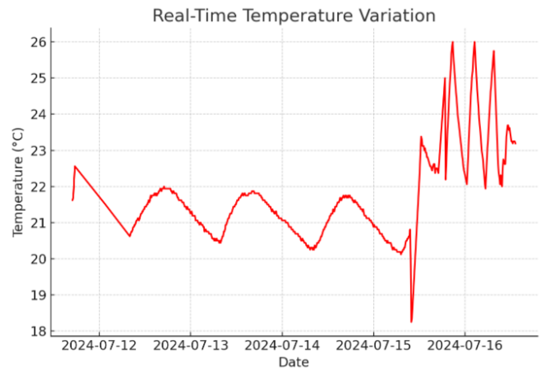

Fig. 10 *Real-time temperature variations detected by WiFish.*
Source: *Own elaboration.*

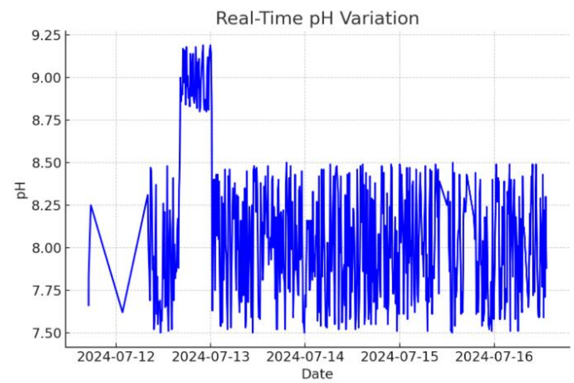

Fig. 11 *Real-time pH variations detected by WiFish.*
Source*: Own elaboration.*

The system's sensitivity to slight changes in environmental parameters was evaluated to validate its ability to react to minimal variations. Figure 12 shows an amplification of the signal recorded in a limited time window, where micro fluctuations in temperature and pH with high fidelity are evident (see Fig. 12).

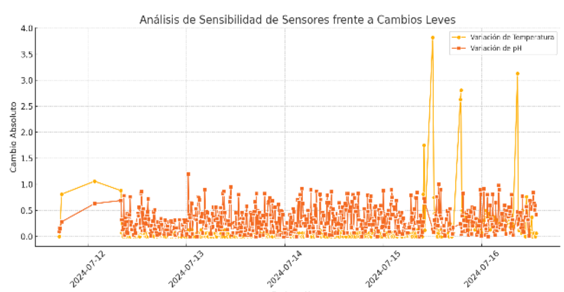

Fig. 12 *Sensitivity analysis of WiFish sensors to slight changes in temperature and pH.*
Source*: Own elaboration*

In particular, it was observed that the temperature sensor reacts more frequently to environmental alterations, such as thermal changes caused by partial sun exposure or water movements, while the pH sensor maintains a more stable response, although equally sensitive to abrupt transitions. This result suggests that the system can discriminate significant changes from environmental noise, ensuring data reliability for subsequent predictive analysis and alert generation.

3.4 Validation of Secure and Continuous Data Transmission

The validation of secure and continuous data transmission in the WiFish system focused on evaluating the performance of AES-128 encryption implemented on resource-constrained microcontrollers. The tests showed that encryption does not generate a significant load on the node's processing, maintaining stable and protected transmission. Regarding link quality, parameters such as packet loss and latency were monitored, obtaining acceptable results for real-time applications. An average latency of less than 200 ms and a loss rate below 1% were observed, confirming that the system can operate securely and efficiently in aquatic environments with variable connectivity.

3.4.1. Performance of AES-128 Encryption on Resource-Constrained Nodes

The impact of the AES-128 encryption algorithm on resource-constrained microcontrollers such as the ESP32 was evaluated under real operating conditions. The results showed that although CPU and RAM usage increases compared to unencrypted transmission, the system continues to operate within acceptable margins. The processing load increased on average by 14% in CPU and 13% in RAM when encryption was added, which does not significantly affect the overall performance of the node. Figure 13 illustrates this comparison between resource usage with and without encryption (see Fig. 13).

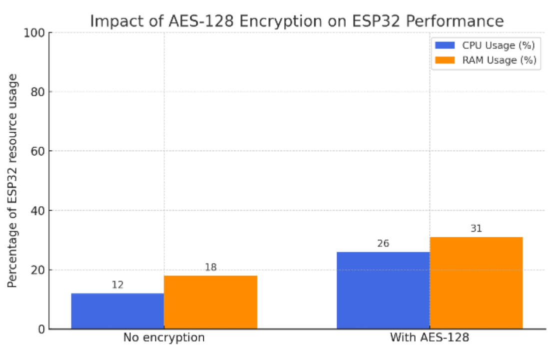

Fig. 13 *Impact of AES-128 encryption*
Source*: Own elaboration*

3.4.2. Packet Loss and Latency

During field tests, the stability of the communication channel between sensor nodes and the cloud platform was measured. A monitoring system for transmitted and received packets was used to calculate the loss rate, which remained below 1% under normal conditions. In addition, the average observed latency was 170 ms, which is adequate for applications requiring near real-time monitoring, such as feeding control or notifications for critical pH or temperature thresholds. These results validate the system's viability for operation in environments with variable connectivity without compromising the continuity or integrity of transmitted data.

3.6 Scalability and Adaptability of the System

The WiFish system has proven to be scalable and adaptable to different farming sizes, allowing its implementation in both domestic tanks and larger ponds. The tests carried out in different scale scenarios validate its stable and efficient operation. Furthermore, the modular design of the system facilitates its replication in other aquatic ecosystems, such as shrimp farms or reservoirs, adapting the monitoring and control parameters according to the specific conditions of each environment.

4. DISCUSSION

The results obtained validate the effectiveness of WiFish as a real-time aquaculture monitoring solution based on IoT and cloud computing technologies. The deployed architecture, supported by ESP32 microcontrollers and temperature and pH sensors, demonstrated reliable performance in all three evaluated environments. However, there are critical aspects that must be considered for its scalability and robustness.

First, although Wi-Fi connectivity under the IEEE 802.11n protocol worked acceptably well in controlled environments, its coverage and stability could be compromised in rural areas. In such scenarios, technologies such as LoRa or NB-IoT offer greater range and energy efficiency [5][6]. Additionally, while AES-128 encryption is effective and secure, it introduces a moderate processing load on the ESP32; for systems with lower computational capacity, lighter cryptographic schemes could be considered [6].

On the other hand, the Huawei Cloud infrastructure was essential for data processing and visualization. Integration with DataArts Studio and DWS enabled automated workflows, real-time alerts, and remote access, demonstrating that the system's intelligence lies in distributed cloud analysis [12]. However, reliance on constant connectivity limits its operation in environments with intermittent access; therefore, it is recommended to incorporate local backup logic and temporary storage.

Finally, although the automation of tasks such as feeding and thermal control represents significant progress, the system still requires manual configurations. The incorporation of adaptive algorithms or fuzzy logic could enable a more dynamic response to environmental variations [4].

5. CONCLUSIONS

The WiFish platform was successfully developed and implemented as an integrated IoT system for monitoring temperature and pH in aquaculture environments. It demonstrated efficient real-time data transmission, high measurement accuracy, and the ability to generate immediate alerts, validating its operability under controlled conditions.

The system architecture, based on the ESP32 microcontroller and AES-128 encryption protocol, was technically validated through a comparative analysis with current scientific literature, showing that the design decisions are aligned with international best practices in intelligent and secure aquaculture.

WiFish stands out as a scalable, cost-effective, and easy-to-implement solution capable of operating in rural areas with limited infrastructure. Its ability to reduce human intervention, anticipate critical conditions, and generate accessible visual reports represents a significant contribution to the autonomous and sustainable monitoring of aquaculture systems.

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