Establishing a Telemetry-Based Management System for Distant Supervision of Water Quality Parameters in a Laboratory Dedicated to Shrimp Larvae Cultivation

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Abstracts: A management platform was developed for the monitoring, registration and alarm of the main water quality parameters: PH, dissolved oxygen, salinity and temperature, which are supervised in the cultivation of shrimp larvae (nauplius). With the platform, the person in charge of the laboratory will have a tool to analyze, determine and detect possible conditions that are dangerous to the animal's health.

Keywords: Aquaculture, Telemetry, Monitoring, Management, Larvae.

1. INTRODUCTION

Ecuador achieved the top position globally as a shrimp exporter, concluding the year 2021 with a production of 1,847,730,819 pounds, resulting in an estimated revenue of $5,055 million [1]. This accomplishment marked a significant milestone in the national aquaculture sector. Shrimp cultivation primarily occurs along the 2,859-kilometer coastline of Ecuador, boasting numerous farms [2]. The prevalent species in cultivation is Litopenaeus Vannamei. The larval stage of this shrimp is addressed by 149 registered shrimp larvae laboratories under the Subsecretary of Quality and Safety S.C.I of the Ministry of Aquaculture and Fisheries, with a majority situated in the province of Santa Elena, Ecuador [3]. In the laboratory where this project originated, conventional methods and portable tools were utilized for collecting and analyzing variables related to the water quality of the shrimp cultivation environment. This prompted an innovative approach to data acquisition, aiming to address the deficiency in monitoring and data recording systems. Effective monitoring and control of water quality parameters, including temperature, salinity, dissolved oxygen, and pH, are crucial for the well-being of this crustacean [4]. Dissolved oxygen is particularly sensitive to temperature variations [5]; as temperature increases, dissolved oxygen concentration decreases, as illustrated in Table 1. Insufficient oxygen levels render shrimp more susceptible to diseases, with a critical minimum oxygen value set at 4 to 5 ppm [6]. Temperature, as another significant variable, profoundly influences biological and chemical processes. A 10°C rise approximately doubles or triples the oxygen consumption of the animal, exacerbating the critical demand for oxygen in warmer conditions compared to colder waters [6].

Table 1. Salinity level according to water temperature

Temperature °C	Salinity 0 g/l	Salinity 0 g/l	Salinity 0 g/l	Salinity 0 g/l	Salinity 0 g/l
10	11.28	10.58	9.93	9.32	8.75
15	10.07	9.47	8.91	8.38	7.88
20	9.08	8.56	8.07	7.60	7.17
25	8.24	7.79	7.36	6.95	6.57
30	7.54	7.14	6.76	6.39	6.05
35	6.94	6.58	6.24	5.92	5.61

Salinity holds a crucial role, influencing the shrimp's maintenance of essential fluid levels and facilitating ionic balance, thereby impacting energy expenditure and growth rate [6]. Elevated salinity levels can lead to a reduction in dissolved oxygen within the culture water. Additionally, the pH level is contingent on the concentration of oxygen and other acidic elements in the pond. Algae-induced photosynthesis contributes to an increase in pH. Maintaining a pH within the optimal range of 6.5 to 9 is essential, reducing stress on shrimp during culture and promoting optimal growth, translating into increased profitability [6]. Ensuring proper levels of each of these parameters is of utmost importance for survival, particularly during the early stages of the shrimp life cycle. The life cycle spans from the naupliar stage to the zoea stage and mysis stage [7]. Subsequently, post-larval shrimp undergo metamorphosis in growth pools, as depicted in Figure 1.

Figure 1. Laboratory location determined through satellite mapping using Google Maps in 2020.

2. DEVELOPMENT OF THE SYSTEM

This section elaborates on the design of the proposed system and the components utilized, including the setup of the primary controller (Energy Manager Line-EDS) functioning as a communication gateway. It also covers the configuration of water quality sensors using the Modbus/RS485 communication protocol, the on-site assembly of the monitoring board and sensors, the creation of the management platform, and the interactivity among project components. In essence, the system involves the incorporation of three water quality sensors to gauge the variables: pH, dissolved oxygen, and salinity. It's noteworthy that the salinity sensor also provides the temperature variable, as illustrated in Figure 2.

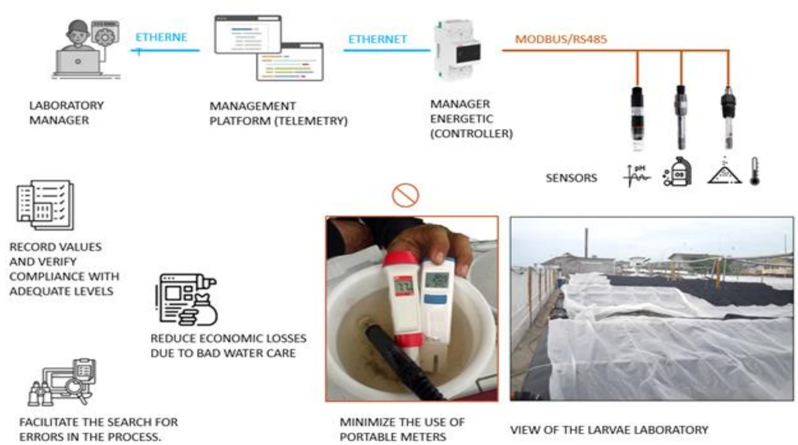

Figure 2. Outline of the management platform.

The system enables real-time monitoring, recording, and notification with both audible and visual alerts. Users can configure predefined maximum and minimum values for each variable, triggering alarms in case of conditions outside the established ranges [8]. Water quality sensors utilize the Modbus/RTU protocol and operate within a power supply range of 12 to 24 Vdc. Data from the water quality sensors is transmitted to the controller device (Line-EDS), which, through either wired (Ethernet) or wireless (Wi-Fi) communication ports, delivers the information for viewing on a management platform. This platform can be accessed via a computer within the laboratory's local network [9]. The primary aim is to provide the laboratory operator with a robust tool for monitoring compliance with optimal water quality levels in real time, preventing financial losses associated with inadequate water management. Additionally, it allows for identifying potential process failures by accessing the recorded data history. Following successful functional tests of the water quality sensors, an implementation trip to the larvae laboratory was scheduled, as depicted in Figure 3. Currently, laboratory managers manually record water quality variables, as shown in Figure 4.

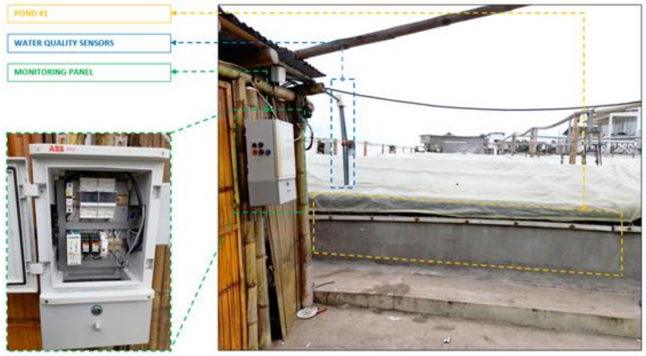

Figure 3. Implementation of sensors.

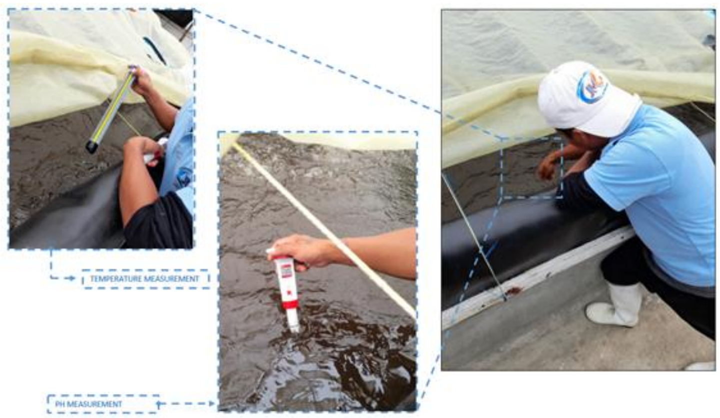

Figure 4. Assessment of parameters related to water quality.

The Power Studio Scada (PSS) software has been implemented for the development of the platform. This software allows the integration of the variables of the field equipment, whether they are from Circutor proprietary brand or from another manu-facturer [10]. The PSS is made up of three applications: PSS Editor, PSS Engine and PSS Client. In the PSS Editor application, it is where the lines of code that will condi-tion the operation of the program are programmed. The PSS Motor application is the core of the program and this is where the programmed lines of code will be executed. And in the PSS Client application, it is where the end user can view and interact with the programmed code lines. The most basic communications topology is shown in Figure 5.

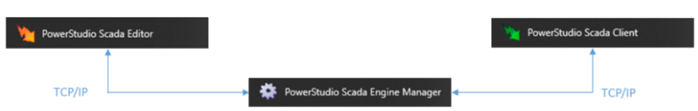

Figure 5. Communication topology.

For the execution of this project, Power Studio Scada Deluxe v4.17.9 has been employed. Three distinct screens were created: "Monitoring," "Parameters," and "Management." The "Monitoring" screen displays real-time data of water quality variables along with the overall alarm status, as depicted in Figure 6. The "Parameters" screen allows the configuration of maximum and minimum levels for each water quality variable to activate alarms, illustrated in Figure 7. On the "Management" screen, feeding schedules are initialized at specified hourly intervals, as shown in

Figure 8. The system exhibits and calculates the next alarm activation time. These feeding schedules are customizable, and the responsible biologist has the authority to assign values to each feeding interval. To document the feeding process, a button is integrated on the left side of the monitoring board. When the scheduled feeding time arrives, an alarm with audible and visual indicators activates. The operator must approach the board, press the button to silence the alarm, and concurrently leave a mark indicating the feeding event occurred, as presented in Figure 9.

Figure 6. Monitor system.

Figure 7. Settings system.

Figure 8. Management system.

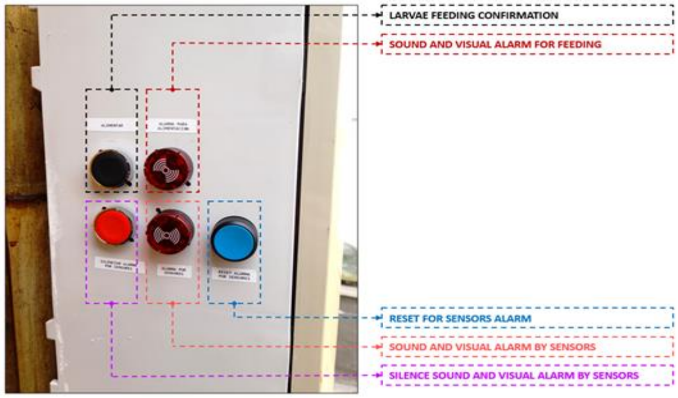

Figure 9. Functionality of the monitoring panel.

There also is an option to present these feeding records in a tabular format and export them to a (.csv) file for examination in a spreadsheet. In the event of sensor-triggered alarm activation due to levels beyond the standard ranges, a visible and audible alert will be initiated, requiring the operator's attention. For such instances, there are two buttons available, one for muting the alert sound and the other for resetting the alarm, prompting the system to reassess whether the levels have returned to normal. The sensor alarm will sound for a duration of 5 minutes, after which it deactivates, though the system remains in an alarmed state. Previously, water quality data in the laboratory was manually collected, and this information was documented in a notebook, as shown in Figure 10.

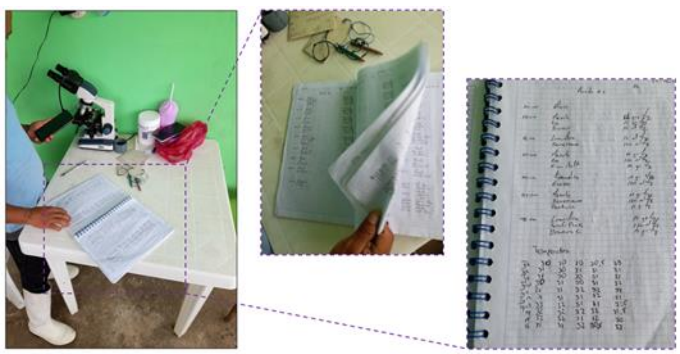

Figure 10. Manually documenting parameters related to water quality.

By utilizing the implemented platform, a comparison was conducted over a 2-day period from September 30, 2022, at 00:00 to October 02, 2022, at 11:00 p.m. The data was captured at three-hour intervals for each reading, resulting in the following outcomes. The graphs for the PH variable are illustrated in Figure 11. The measurements for the dissolved oxygen variable are depicted in the graphs found in Figure 12. In terms of salinity readings, the comparisons are displayed in Figure 13. Notably, the readings closely align, indicating to the responsible operator that their portable salinity meter provides accurate results. Lastly, the temperature results are presented in Figure 14.

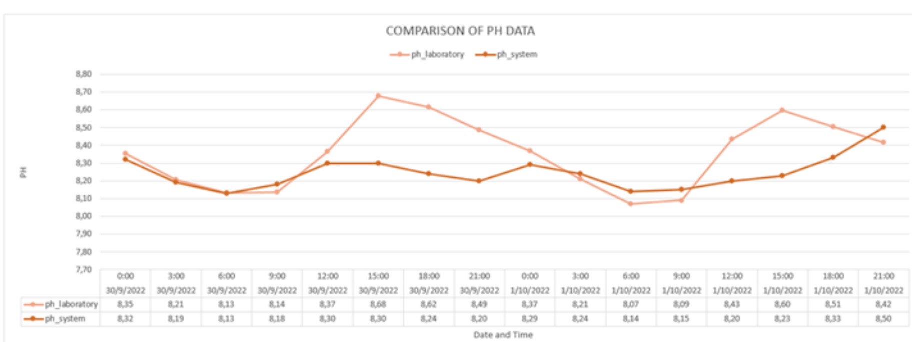

Figure 11. Comparison of pH data.

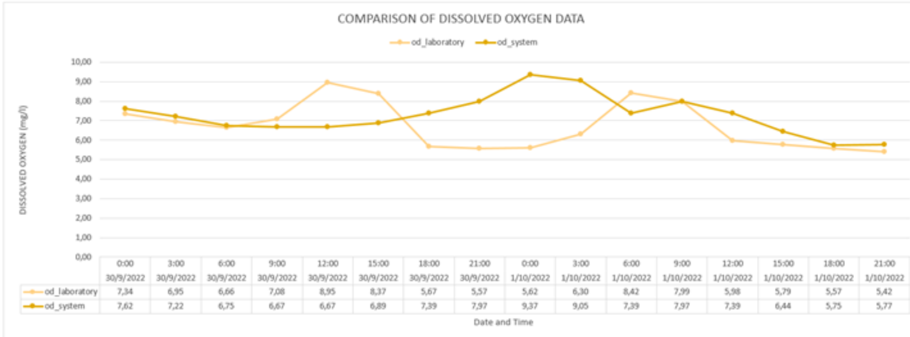

Figure 12. Comparison of data related to dissolved oxygen.

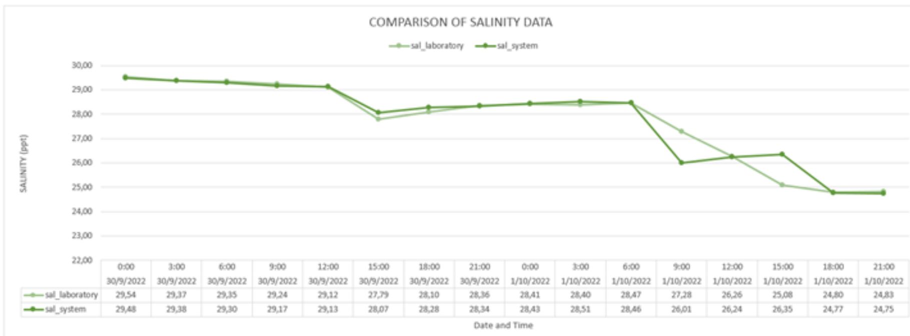

Figure 13. Comparison of data concerning salinity.

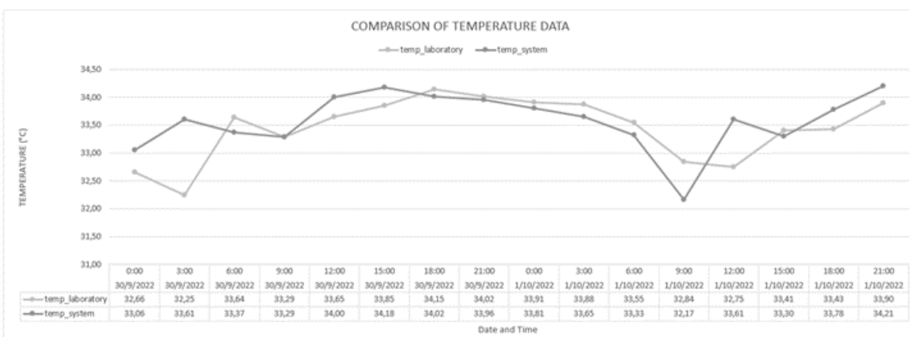

Figure 14. Temperature data comparison.

The proximity in the obtained values is evident, and through this analysis, the overseeing operator can assess the variance between their portable meters. The system enables the creation of pre-designed reports as needed, as depicted in Figure 15, thereby replacing manual notes with an automated reporting process.

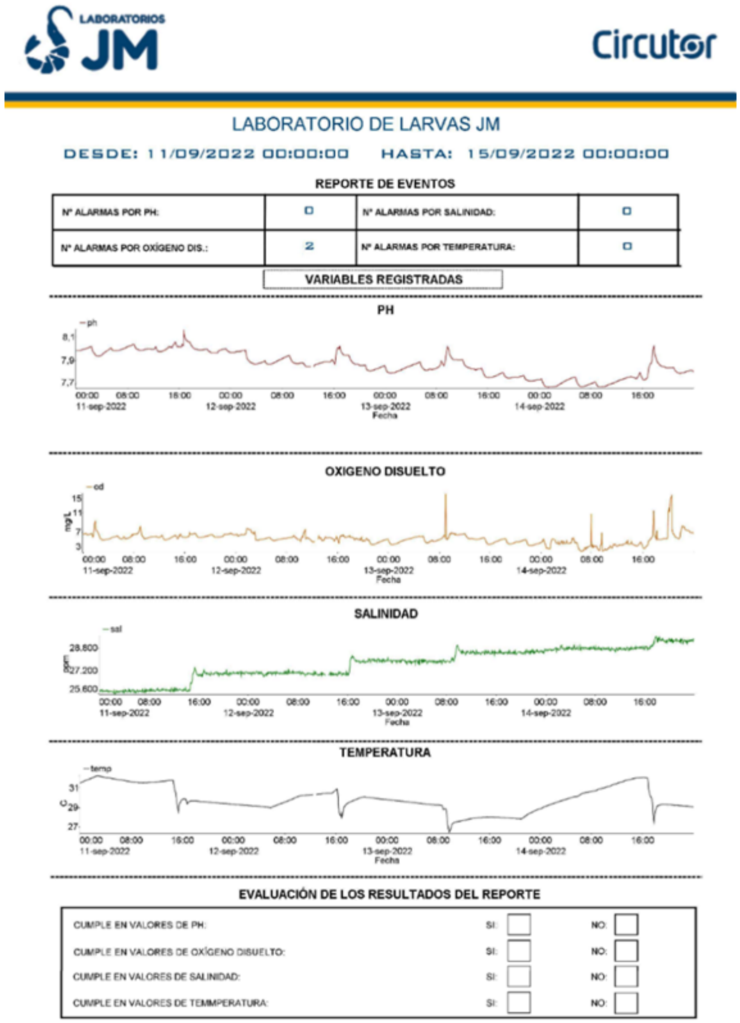

Figure 15. Format for automated reports.

CONCLUSIONS

Ultimately, a telemetry-based management platform was developed for remotely monitoring water quality variables in the shrimp larvae breeding laboratory. This tool enables the operator to generate a report in (.pdf) format for potential printing and further evaluation of the acquired data. After reviewing other research papers, it was observed that there are limited technological advancements specifically tailored for shrimp larvae laboratories; most projects have been focused on shrimp growth pools. The water quality variables assessed include pH, dissolved oxygen, salinity, and temperature, seamlessly integrated into the platform through the appropriate sensors. This integration empowers operators to qualitatively and quantitatively verify if water quality levels are within the approved ranges. The system permits the laboratory operator to set up alarms, triggering immediate corrective actions when any parameter surpasses the appropriate limits. For instance, in the case of low dissolved oxygen, the operator can increase oxygen levels by utilizing electric aerators or pressurized oxygen tanks. In addressing pH imbalances, chemicals can be added to regulate pH levels in the water. Regarding salinity, a change in freshwater can be implemented to reduce salinity levels in seawater ponds, facilitating the sale of larvae with lower salinity levels. Subsequently, the larva can be nurtured in its juvenile stage in a breeding pool with river water containing lower salinity. With the implementation of this project, the issue of a faulty monitoring and registration system was effectively resolved.

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