**IoT-Based and Solar-Powered Automated Water Temperature and pH**

**Control System for Black Tiger Shrimp (Penaeus monodon) Aquaculture**

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| **Cedrick John V. Cuico**  Bachelor of Science in Information Technology  Purok Malinawon 2 Magugpo East, Tagum City ,8100  c.cuico.141527.tc@umindanao.edu.ph | **Axle Paul Omalay**  Bachelor of Science in Information Technology  Purok Bautista, Mankilam, Tagum City, Davao del Norte, 8100  a.omalay.141548.tc@umindanao.edu.ph |
| **Thrishia May M Tutol**  Bachelor of Science in Information Technology Purok-4 Sagayen, Asuncion, Davao del Norte. 8102 t.tutol.141513.tc@umindanao.edu.ph |  |

**1. INTRODUCTION**

## **1.1 Project Context**

### Global seafood production is significantly influenced by the aquaculture industry, particularly the cultivation of Black Tiger Shrimp (Penaeus monodon). For these shrimps' growth and health, optimal water quality specifically temperature and pH level is essential. However, the labor-intensive and prone to human error of traditional methods of monitoring and adjusting water conditions frequently result in sub-optimal shrimp health and decreased production (Boyd, 2018) [1]. These difficulties can now be addressed in ways that are more effective and dependable acknowledgment to recent technological advancements.

### Shrimp aquaculture has gained prominence worldwide as a result of the increasing demand for seafood and the need for environmentally friendly food production methods. The joining of the Internet of Things (IoT) and environmentally friendly power sources, like solar based power, into aquaculture frameworks addresses a promising development. IoT innovation empowers constant checking and continuous information assortment, which can be utilized to automate water quality changes (Daigle and Theuvsen, 2020) [2].

### In the meantime, aquaculture operations can save money and lessen their impact on the environment thanks to solar power, a renewable energy source (Ebrahimi et al., 2021)[3]. The combination of these technologies meets the

### requirements for sustainable aquaculture practices and precise management of water quality.

### Broadly, in the Philippines, the aquaculture area has been a basic part of the country's food security and monetary turn of events. The production of aquaculture, including shrimp farming, makes a significant contribution to the country's total fishery production, as stated by the

### Philippine Statistics Authority (2020) [4]. The industry's expansion has been hampered, however, by issues like environmental sustainability and management of water quality. According to research (Froehlich et al., 2019) [5], the need for cutting-edge technologies to boost Philippine aquaculture's productivity and ensure its long-term viability has been emphasized.

### Shrimp farming is an important local business in Mindanao that helps many communities make ends meet. Shrimp aquaculture thrives in Mindanao due to its ideal climate and abundance of aquatic resources. However, neighborhood ranchers face determined issues connected with water quality and the significant expenses of conventional cultivationj techniques. Research led in Mindanao has stressed the possible advantages of coordinating current advancements into aquaculture practices to further develop proficiency and manageability (Quinitio et al., 2020) [6].

### The need for a long-term, cost-effective, and reliable approach to water quality management in Black Tiger Shrimp farming is at the heart of this study. The shared objective of increasing aquaculture productivity through technological innovation demonstrates the connection between the project context and the rationale. We can demonstrate the relevance and significance of developing an IoT-based, solar-powered automated water temperature and pH control system by connecting the broader challenges faced by the global, national, and local shrimp farming communities to the specific objectives of this study.

## **1.2 Purpose And Description**

### The reason for this study is to configure, carry out, and assess an IoT-based, solar oriented fueled mechanized water temperature and pH control framework explicitly for Black Tiger Shrimp aquaculture. The study aims to offer a solution that promotes sustainability and cost-effectiveness in shrimp farming operations in addition to ensuring optimal water conditions. To continuously monitor water temperatures and pH levels, the proposed system incorporates IoT controllers and sensors.

### These sensors transfer ongoing information to a focal handling unit, which utilizes predefined calculations to decide when intercessions are essential. According to Kumar et al. (2019) [7], the system automatically adjusts the water parameters when it detects deviations from optimal conditions, ensuring a stable and healthy environment for the shrimp.

### The use of solar panels as the primary power source is one of this project's most important innovations. The aquaculture operation's carbon footprint is reduced by this choice, as are its energy costs, making the system more financially viable for shrimp farmers. The combination of sunlight based power lines up with worldwide patterns towards environmentally friendly power and maintainability in horticulture and hydroponics (Chiaramonti and Maniatis, 2020) [8].

### Additionally, the IoT-based framework of the system enables remote monitoring and control, allowing farmers to manage their operations from any location with internet access. This component is especially significant in areas where admittance to talented work is restricted, as it decreases the requirement for steady nearby oversight (Jain and Singh, 2020) [9]. This study plans to make a framework that is remarkable, creative, and exceptionally pertinent to current difficulties in the hydroponics business. This project is one of a kind because it combines cutting-edge IoT technology with renewable energy sources to provide a comprehensive approach to managing water quality. Its development is clear in the automation and continuous checking abilities, which altogether improve the productivity and viability of shrimp cultivating tasks. The importance of this task is highlighted by the developing worldwide accentuation on maintainability and the dire requirement for more proficient aquaculture rehearses. In conclusion, this study develops a sophisticated, long-lasting, and cost-effective method for managing water quality in Black Tiger Shrimp farming, filling a pressing need in the aquaculture sector. The proposed system aims to improve shrimp health, boost production, and promote environmentally friendly practices by utilizing IoT technology and solar power, ultimately advancing sustainable aquaculture.

## **1.3 Objectives**

### *1.3.1 General Objectives*

To develop an automated system utilizing IoT and solar energy for enhanced control of water temperature and pH in Black Tiger Shrimp (Penaeus monodon) aquaculture, aiming to promote optimal health and growth conditions.

### *1.3.2 Specific Objectives*

*1.3.2.1* To integrate a high-precision temperature sensor and a heating rod to ensure precise water temperature regulation for tiger shrimp cultivation based on real-time data.

*1.3.2.2* To integrate a pH sensor and a submersible pump connected to a water filter to maintain optimal pH levels and water quality for tiger shrimp cultivation based on real-time data.

1.3.2.3 To integrate a dissolved oxygen sensor and an aerator to ensure optimal oxygen levels for tiger shrimp cultivation based on real-time data.

1.3.2.4 To integrate solar panels to provide a sustainable and energy-efficient power source for the automated systems used in tiger shrimp cultivation.

*1.3.2.5* To automate all operations, including temperature regulation, pH level maintenance, water filtration, dissolved oxygen monitoring, and energy management, to achieve minimal human intervention and ensure optimal conditions for tiger shrimp cultivation based on real-time data.

1.3.2.6 To integrate solar panels to provide all necessary power and achieve self-sufficiency for the system.

*1.3.2.7* . To develop our own mobile application for monitoring and human intervention as necessary.

## **1.4 Scope And Limitation**

**Scope:**

This research focuses on developing and implementing an automated aquaculture system powered exclusively by solar energy. The system targets black tiger shrimp producers in Tagum City and the BFAR XI Provincial Fishery Office, Davao del Norte. Key aspects of the research include:

* **Solar-Powered Automation:** The system will be designed to operate entirely on solar energy, ensuring sustainability and reducing operational costs associated with conventional energy sources.
* **Stationary Design:** The system will be stationary, designed to optimize space and efficiency within aquaculture environments.
* **Minimized Human Intervention:** Automation will be prioritized to minimize the need for human intervention throughout the aquaculture cycle, from setup to harvest. This aims to enhance efficiency and reduce labor costs.
* **ESP32 Integration:** Monitoring and control functionalities will be facilitated through an ESP32 processor, enabling real-time data collection and remote management via a dedicated mobile application.

**Limitations:**

* **Geographical Focus:** The research is limited to black tiger shrimp producers in Tagum City and the BFAR XI Provincial Fishery Office, Davao del Norte, Philippines. Results may not be directly applicable to other geographic locations without further adaptation.
* **Technology Dependency:** The effectiveness of the system is dependent on the reliability and efficiency of solar energy and the ESP32 processor. Variations in solar exposure and technological limitations may impact system performance.
* **Operational Constraints:** While the system aims to minimize human intervention, certain operational tasks such as maintenance and occasional manual adjustments may still be required, especially in unforeseen circumstances.

By addressing these scope and limitations, this research aims to contribute to the advancement of sustainable and efficient aquaculture practices through innovative automation and renewable energy integration.

**2. Methodology**

This chapter discusses the methodology utilized for this investigation. It includes the research methods and procedures that will be used to develop the system.

**2.1 Planning**

The researchers will interview the BFAR XI Provincial Fishery Office Davao del Norte personnel to understand the specific requirements and objectives of the aquaculture, including the exact measurements of the growth factor of Black tiger prawn(Penaeus monodon).

**2.2 System Requirements Specification**

The system is a prototype of a solar-powered automated system for aquatic environments capable of monitoring and adjusting pH level, temperature, humidity, and dissolved oxygen. The solar-powered aquatic environment system automatically adjusts the various environmental elements to maintain the necessary requirements to maximize the growth potential of the Black tiger shrimp (Penaeus monodon). This is achieved by integrating various components, sensors, solar panels, and control units to ultimately make an environment that works seamlessly and efficiently while being self-sustainable in terms of power.

**2.3 System Analysis**

The automation system is equipped with temperature and humidity sensor, making it possible for the system to detect and display the temperature and humidity of the water for monitoring and control. With the help of heating rod, we can attune the temperature of water to maintain it to optimal level for black tiger shrimp(Penaeus monodon) aquaculture.

The automation system is further enhanced with the inclusion of a pH sensor and a dissolved oxygen sensor, which enable the detection and display of water quality parameters, including pH and dissolved oxygen levels, in our monitoring application. This comprehensive monitoring capability ensures that we are well-informed about the state of the water in the tank, allowing for proactive adjustments to maintain optimal conditions for black tiger shrimp (Penaeus monodon) aquaculture. By closely monitoring and controlling the critical water parameters, the system can help to create an environment that is conducive to the health and growth of the shrimp. Moreover, the system's reliance on solar power ensures a sustainable and environmentally-friendly approach to aquaculture operations.

**2.4 System Design**

he system design will be consistent with the system design and the system's process. In this instance, researchers will utilize prototyping design. It will greatly assist in developing and enhancing the system's capabilities and resolving issues.

In this phase, the proposed system will be developed using the following software, hardware, user, and network requirements:

**2.4.1 Hardware Requirements**

2.4.1.1 **Heating Rod and Temperature Sensor:** Work in unison to maintain optimal water temperature. The temperature sensor continuously monitors the water, while the heating rod automatically adjusts the heat to ensure a stable and ideal environment for the health and growth of black tiger shrimp (Penaeus monodon).

2.4.1.2 **pH Sensor:** Continuously monitor water pH levels to ensure optimal conditions for the health and growth of black tiger shrimp (Penaeus monodon).

2.4.1.3 **Submersible Pump and Water Filter:** Work in tandem to maintain clean and clear water by circulating and filtering impurities, ensuring optimal conditions.

2.4.1.4 **Dissolved Oxygen Sensor and Aerator:** Collaboratively maintain optimal oxygen levels in the water. The dissolved oxygen sensor continuously monitors oxygen concentration, while the aerator activates as needed to infuse the water with oxygen, ensuring a healthy environment for black tiger shrimp (Penaeus monodon).

2.4.1.5 **ESP32 as Main Processing Unit:** Acts as the central hub for managing all system components. It processes data from sensors, including temperature, pH, and dissolved oxygen sensors, and controls the heating rod, aerator, submersible pump, and water filter. The ESP32 ensures real-time monitoring, efficient data processing, and seamless communication between components, maintaining optimal conditions for the health and growth of black tiger shrimp (Penaeus monodon).

2.4.1.6 **TP4056 with Solar Panels:** The TP4056 is a battery charging IC commonly used with solar panels in renewable energy applications. When paired with solar panels, the TP4056 efficiently charges batteries by regulating the charging process based on the solar panel's output voltage. This setup ensures that batteries, such as lithium-ion or lithium-polymer cells, are charged safely and optimally, even under varying sunlight conditions. The TP4056 IC includes features like overcharge protection and thermal regulation, enhancing battery lifespan and safety. This integration allows the aquaculture system to operate continuously, utilizing stored solar energy to power critical components, such as sensors and actuators, ensuring uninterrupted monitoring and maintenance of optimal conditions for black tiger shrimps.

#### 2.4.1.7 **Windows 10 Devices for Development:** The development of the mobile application will be carried out on Windows 10 devices with the following minimum specifications: AMD 10 PRO processor and 12GB RAM. These devices are essential for developing and testing the mobile application, ensuring that it operates smoothly and efficiently to handle real-time data processing and monitoring tasks effectively.

**2.4.2 Software Requirements:**

***2.4.2.1*** C++ serves as the programming language of choice for the ESP32. It's employed for object-oriented programming, providing a structured approach and enabling code reuse, which lowers development costs. C++ is also portable, allowing for the creation of applications that work across different platforms.

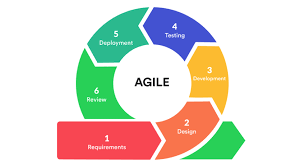
***2.4.2.2*** Firebase as the database used for ESP32. Firebase is a cloud-based database that, unlike other databases, does not need to be hosted on a physical server. Firebase is perfect for Arduino Uno because it doesn't rely on local server infrastructure.

***2.4.2.3*** Kotlin will be used to create and build our application in Android Studio IDE. It is a language that is familiar and comfortable to use. The flexibility that this programming language offer is very helpful for the project and make it easier for developers to adapt different needs.

**2.5 System Development**

Researchers will utilize Agile Software Development Methodology. This allows researchers to maintain control over the system's development through an iterative process. This continuous testing and quality assurance throughout the project life cycle helps researchers produce a high-quality product that meets the specified requirements and expectations. By breaking down the project into smaller, manageable tasks and allocating resources accordingly, the researchers will be able to plan effectively, employ accurate prediction techniques, and mitigate risks by addressing issues early in the development process.

***Figure 2.* Agile Software Development**



Agile systems and processes are focused on delivering value to the end-user of the product. That means a strong interest in their needs and wishes, putting users at the center of project planning. This is done by means of engaging with users’ needs, including developing [user stories](https://www.boldare.com/blog/build-digital-products-with-user-story-mapping/) that clearly identify key types of user, what they want and what value the product should deliver to them. These stories are then mapped or laid out to show the users’ various journeys when using the planned product to various degrees of detail. This mapping process results in clear priorities for development which determines which aspects and features are worked on in each sprint or iteration (Pawel Kanski, 2022). [10].

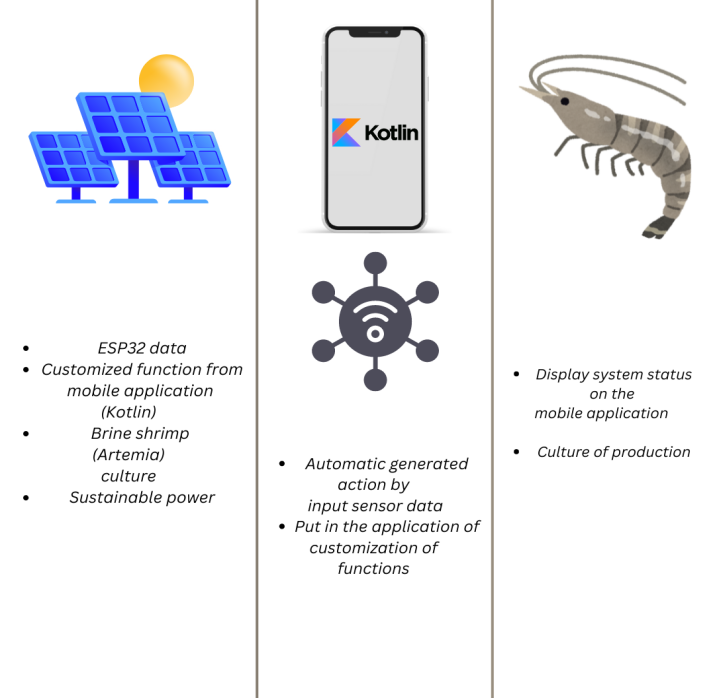
**2.6 Testing and Implementation**

In this phase, researchers will use Exploratory Testing to more effectively adapt to changes. User testing will be conducted to evaluate the proposed system. They will assess the system's compatibility and overall quality using a prototype version. Through this investigation, evaluators will determine the system's efficiency. Based on their findings, testers will create and implement test plans to gain a comprehensive understanding of the system.

**3. Technical Background**

The cultivation of black tiger shrimp (Penaeus monodon) is a significant sector within the aquaculture industry, contributing substantially to the global seafood market. The proposed a smart aquaculture system will be useful for the Tagum City black tiger shrimp farmers and the BFAR XI Provincial Fishery Office, Davao del Norte, Philippines. The way we optimize the growth and health of black tiger shrimp and it’s several key environmental parameters while meticulously monitoring and controlling its environment, including water temperature, pH levels, dissolved oxygen, and water cleanliness will certainly benefits them. The advances in technology, particularly the integration of Internet of Things (IoT) devices and automated systems, will offer innovative solutions to maintain these important parameters within optimal ranges. This project aims to leverage such technologies to create a sustainable and efficient aquaculture system.

***Figure 1.* Conceptual Framework**



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